

# The Effects of 6 Weeks of Creatine Monohydrate Supplementation on Performance Measures and Body Composition in Collegiate Track and Field Athletes

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## ABSTRACT

Thirty-six (16 men, 20 women) collegiate track and field athletes (sprinter, jumpers, and throwers) were randomly divided into a placebo (P,  $n = 21$ ) group and a creatine supplemented (C,  $n = 15$ ) group. Six weeks of supplementation consisted of  $0.30 \text{ g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$  of creatine monohydrate ( $\text{Cr}_m$ ) or a placebo. Subjects were involved in a preseason conditioning program that consisted of interval sprinting and multijoint, large-muscle-group weight-training movements programmed in a periodized manner. Pretesting (PRE) and posttesting (POS) consisted of a 7-site skinfold analysis, hydrostatic weighing, countermovement vertical jump, static vertical jump, and  $5 \times 10$ -second maximum cycle ergometer rides. Data were analyzed using  $G \times T$  analysis of variance. Significant interactions occurred for several variables. Creatine effected superior gains (percent change creatine vs. placebo) in countermovement vertical jump height (7.0 vs. 2.3%), countermovement vertical jump power index (6.8 vs. 3.1%), average cycle peak power (12.8 vs. 4.8%), cycle average power (10.8 vs. 3.1%), cycle total work (10.8 vs. 3.5%), cycle initial rate of power production (30.0 vs. 11.2%), and lean body mass. These results suggest that 6 weeks of  $\text{Cr}_m$  intake can favorably enhance vertical jump, power output, work capacity, and lean body mass in men and women collegiate track and field athletes following a periodized training program.

**Key Words:** vertical jump, power, periodization, maximum cycle ergometry

**Reference Data:** Kirksey, B., M.H. Stone, B.J. Warren, R.L. Johnson, M. Stone, G.G. Haff, F.E. Williams, and C. Proulx. The effects of 6 weeks of creatine monohydrate supplementation on performance measures and body composition in collegiate track and field athletes. *J. Strength Cond. Res.* 13(2):148-156. 1999.

## Introduction

It has been established that supplementation of creatine monohydrate ( $\text{Cr}_m$ ) can increase the total creatine, free creatine, and phosphocreatine (PCr) stores of muscle tissue (7, 15, 18, 19, 39).  $\text{Cr}_m$  supplementation has also been shown to increase the rate of PCr resynthesis after repeated muscular contractions or bouts of high-intensity exercise (7, 16, 17). Numerous studies have reported enhanced high-intensity exercise performance on a cycle ergometer following supplementation with  $\text{Cr}_m$  (4, 7, 10, 11, 18, 26, 34). With the exception of Earnest et al. (11), all these cycle ergometer investigations used supplementation protocols of a short duration ( $\leq 7$  days). Although several studies have measured the effects of  $\text{Cr}_m$  supplementation on anaerobic capacity and the performance of certain events (such as running and swimming) possessing a large anaerobic component, to our knowledge no study to date has measured the effect of  $\text{Cr}_m$  supplementation on a single, short-duration ( $\leq 2$ -second), high-power movement like the vertical jump.

Along with an increased creatine content of the muscle, one of the most commonly reported effects of creatine ingestion is an increase in body mass (2, 3, 8, 11, 17, 27, 34). Investigations in this area found significant body mass increases of 0.9-3.8 kg, while creatine supplementation lasted 5-44 days. Earnest et al. (11) and Kreider et al. (27) both found significant increases in lean body mass after 28 days of creatine supplementation using hydrodensitometry and dual-energy x-ray absorptiometry, respectively. While these investigations used trained subjects, they were not collegiate-level athletes involved in rigorous competition-oriented training.

**Table 1.** Biometric data for creatine and placebo groups.

Parameter	Creatine ( <i>n</i> = 15)	Placebo ( <i>n</i> = 21)
Age (y)	19.9 ± 0.4	19.9 ± 0.4
Height (cm)	69.6 ± 1.0	68.5 ± 0.9
Weight (kg)	74.7 ± 5.2	67.4 ± 3.1

Research that used athletes as subjects for Cr<sub>m</sub> supplementation have used supplementation periods of ≤ 7 days and have obtained mixed results (5, 6, 20, 29). Thompson et al. (38) supplemented athletes for 6 weeks; however, only 2 g·d<sup>-1</sup> Cr<sub>m</sub> was administered. This was insufficient to increase PCr stores or elicit an ergogenic effect. The purpose of this study was to determine the effects of long-term (6-week) Cr<sub>m</sub> supplementation on performance measures and body composition of track and field athletes.

## Methods

Subjects were 36 collegiate track and field athletes (sprinters, jumpers, and throwers). All subjects signed informed consents in accordance with university guidelines. Thirty-six men (*n* = 16) and women (*n* = 20) were randomly assigned to a group supplemented with creatine monohydrate (C) (*n* = 15) or a group ingesting a nonnutritive placebo supplement (P) (*n* = 21). The groups C and P were found to not be significantly different based on body mass, sex, and event (Table 1).

Subjects were supplemented at a dose of 0.3 g·kg<sup>-1</sup>·d<sup>-1</sup> for either C or P. The supplement was provided in capsule form and the C and P were indistinguishable. All subjects were required to report to the Human Performance Laboratory 3 times per day, between 07:00 and 10:00 hours, at 15:00 hours before practice, and at 17:00 hours following practice, to be observed taking their supplement. The supplement was supplied to the subject in a plastic bag labeled with their subject number. A double-blind protocol was used. Capsules were taken with water ad libitum. On weekends, the subjects were given enough supplement for their required dosages. They returned the empty bags with a supplement form, which had their signature, a witness' signature, and the time each dose was taken.

Subjects were tested on 2 occasions: immediately before beginning the supplementation protocol (PRE) and after 6 weeks of supplementation (POS). All variables were measured at the PRE and POS times. Subjects were given a dietary record booklet for the end of weeks 2 and 5. They were instructed to record everything they ate for 2 weekdays and 1 weekend day. The quantity of food was also recorded. The diets were analyzed for total calories, carbohydrates, protein, and

fat using the Food Processor II software (ESHA Research, Salem, OR).

Subjects reported to the laboratory following an overnight fast for body composition assessment by hydrodensitometry. Body mass was measured on a medical scale to the nearest 0.1 kg. Body composition was also determined by the 7-site skinfold method using Lange skinfold calipers (Cambridge Scientific Industries, Cambridge, MD) in addition to hydrodensitometry. All skinfolds were measured by the same researcher for all subjects at PRE and POS. Percent fat was determined using the Siri equation (33). Test-retest reliability has been consistently >0.9 in our laboratory.

Static and countermovement vertical jumps were measured with the Vertec (Sports Performance, Columbus, OH). Subjects were required to perform a warm-up consisting of 1 minute of side straddle hops and 2 minutes of light stretching. They were then given the opportunity for 1 practice jump. Reach height was determined with the subjects' feet flat on the ground and arms maximally extended over their heads. The last bar of the Vertec, which they could move with their fingertips, was recorded as the reach height. Subjects then performed 2 countermovement vertical jumps and 2 static vertical jumps. They were given a countdown from 3 to 1 and were instructed to jump on the command "jump" by the researcher operating the force platform software. A 1-minute rest was given between each jump. Following the 2 countermovement vertical jumps, subjects were instructed on proper technique for the static vertical jumps. They were required to lower to a point at which their upper leg was parallel with the ground. They held this position until the countdown was complete and the "jump" command was given. Two static vertical jumps were performed.

The best value of the two respective jumps was used as the jump height. Vertical jump score was determined by subtracting the reach height from the jump height. This vertical jump score was then used to determine power index by the Lewis formula:

$$2.21 \cdot \text{body mass (kg)} \cdot \sqrt{\text{vertical jump (m)}} (12)$$

Vertical jumps were measured PRE and POS. Test-retest reliability for vertical jump height has been consistently >0.9 in our laboratory.

Measurements of work and power were determined by use of 5 × 10-second maximum cycle ergometer rides. All rides were performed on a Monark cycle ergometer model 868 (Monark-Crescent AB, Barberg, Sweden). Subjects were required to warm up by pedaling with no resistance for 1 minute. The resistance of the ergometer was then set to 0.1 kg/kg of body mass. Subjects' feet were then taped to the pedals and each performed a 2-second burst of pedaling to become familiar with the resistance of the ergometer. The Monark was interfaced with an Apple IIGs

(Apple, Cupertino, CA) microcomputer equipped with a Nalandata A2A data acquisition unit and fitted with specifically designed software (Nalan Computer Specialties, Boone, NC) to analyze work and power data. The computer operator gave the "go" command and the subject performed a 10-second ride with maximal effort. During the ride, verbal encouragement was given by the researchers. The subject's hips were kept on the seat of the bike with assistance from a researcher. One minute of recovery was given between rides in which the subject was instructed to slowly pedal backward with no resistance. A total of 5 rides were accomplished. Values determined by use of the ergometer software include peak power, average power, total work, average work, initial rate, and fatigue rate. Maximum cycle ergometry was performed PRE and POS. Test-retest reliability for power and work variables has been consistently  $>0.9$  for this system in our laboratory.

Training for all athletes consisted of a preseason periodized track and field training program. Weight training was performed Monday, Wednesday, and Friday and consisted primarily of large-muscle mass movements. All athletes also performed a sprint training program on Tuesday and Thursday. Tuesday's workout consisted of  $6 \times 100$ -m sprints with recoveries of 90–120 seconds between runs. Thursday's workout consisted of  $6 \times 150$ -m sprints with recoveries of 90–120 seconds between runs.

### Statistical Analysis

All data were analyzed using group-by-trials analysis of variance with an alpha level of 0.05. Where appropriate, interactions were tested using a *t*-test ( $p \leq 0.05$ ). Data were analyzed with SAS (Cary, NC) and BMDP (Berkeley, CA) software.

### Results

Table 2 displays the dietary analysis data for the C and P groups. There were no significant differences in total kilocalories, carbohydrates, protein, or fat between the PRE and POS measurements within each group, and there were no significant differences between the C and P groups.

Body mass showed a significant time effect for both groups, with POS values being higher than PRE, while lean body mass showed a significant ( $p < 0.05$ ) group-by-time interaction, with C improving at a greater rate than P (Table 3). There was not a significant group-by-time interaction for any of the other body composition variables.

Countermovement vertical jump height (Figure 1) and static vertical jump height (Figure 2) both had a significant ( $p < 0.05$ ) time effect for C and P, with POS exhibiting higher jump heights than PRE. Countermovement vertical jump height and countermovement

**Table 2.** Dietary analysis for creatine and placebo groups before and after supplementation.\*

Parameter	Creatine	Placebo
Kcal·d <sup>-1</sup>		
Before	2,838 ± 260	2,699 ± 206
After	2,682 ± 233	2,737 ± 238
Carbohydrates (g·d <sup>-1</sup> )		
Before	414.2 ± 43.6	383.2 ± 25.4
After	376.0 ± 30.6	412.9 ± 37.4
Protein (g·d <sup>-1</sup> )		
Before	119.6 ± 13.7	120.2 ± 13.2
After	118.4 ± 14.1	107.2 ± 9.4
Fat (g·d <sup>-1</sup> )		
Before	77.5 ± 7.2	74.6 ± 7.6
After	79.1 ± 8.5	74.7 ± 8.6

\* All values are expressed as mean ± standard error of the mean.

**Table 3.** Body composition as measured by hydrodensitometry for creatine and placebo groups before and after supplementation.†

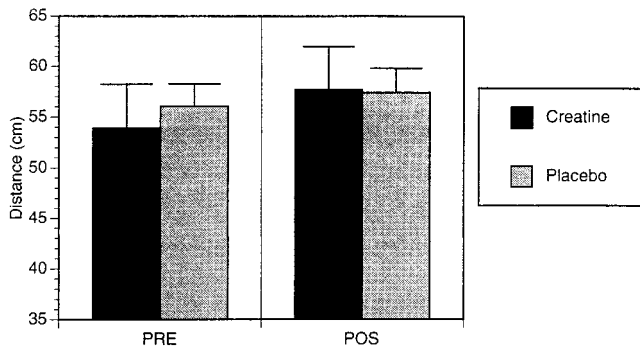
Parameter	Creatine	Placebo
Body Mass (kg)		
Before	74.4 ± 5.2	67.1 ± 3.1
After	76.5 ± 5.2	68.4 ± 3.2
Body fat (%)		
Before	14.0 ± 2.9	11.9 ± 2.0
After	13.2 ± 2.6	12.0 ± 2.0
Lean body mass (kg)		
Before	62.9 ± 3.7	59.0 ± 3.0
After	65.5 ± 3.8*	60.0 ± 3.0
Fat mass (kg)		
Before	11.4 ± 3.4	8.1 ± 1.8
After	11.0 ± 3.0	8.3 ± 1.8

† All values are expressed as mean ± standard error of the mean.

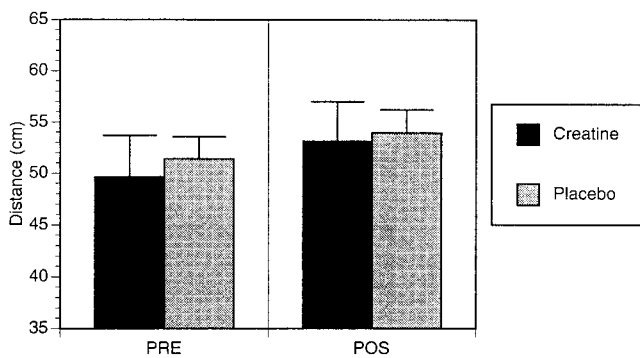
\* Significant group-by-time interaction at the  $p < 0.05$  level.

vertical jump power index (Figure 3) also showed a significant ( $p < 0.05$ ) group-by-time interaction, with C improving at a greater rate than P. Differences in C and P static vertical jump power index (Figure 4) approached significance ( $p = 0.07$ ), with C improving by 7.1% and P improving by only 4.4%.

All cycle ergometry variables (peak power, average power, total work, and initial rate) measured showed a significant ( $p < 0.05$ ) time effect (Figures 5–8). A significant ( $p < 0.05$ ) group-by-time interaction was also noted for all cycle ergometry variables. Peak power in ride 1 for C improved by 17.8% between PRE and



**Figure 1.** For counter movement vertical jump height, there was a significant time effect ( $p < 0.05$ ) and a significant interaction ( $p < 0.05$ ), with the creatine group greater than the placebo group.



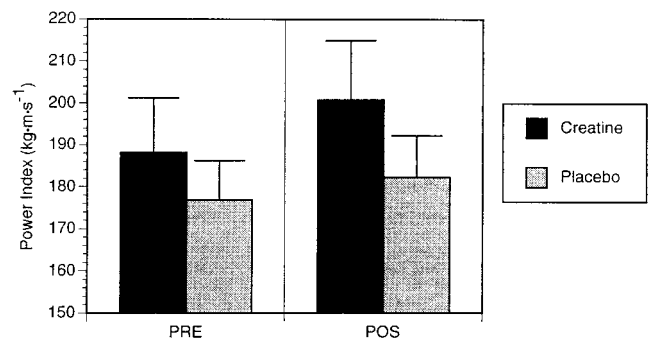
**Figure 2.** For static vertical jump height, there was a significant time effect ( $p < 0.05$ ).

POS, with P improving by 7.9%. Peak power in ride 5 for C increased 8.0% between PRE and POS, while P increased peak power by just 0.3%. Similar trends in the first and fifth rides were noted for average power, total work, and initial rate as well.

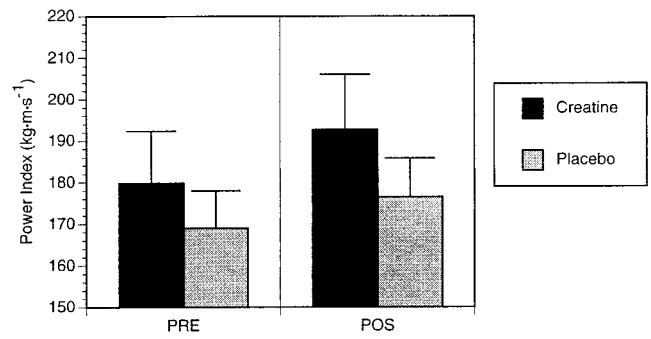
## Discussion

The results of this study indicate that  $Cr_m$  supplementation can exert an ergogenic effect. Based on both skinfolds and hydrostatic weighing, creatine appears to promote increases in lean body mass; logically this effect could produce alterations in performance. The ergogenic effect was particularly evident in power-related measures, both on the cycle ergometer and in the vertical jump measures. Exactly how creatine supplementation affects these beneficial alterations is not completely clear.

The vertical jump typically takes less than 1 second to complete; therefore, it would not be likely for PCr to be a limiting factor as an energy substrate for this activity. As previously stated, PCr is not significantly reduced until high-intensity effort has been sustained for 5–7 seconds (23). Enhanced PCr stores from creatine supplementation would not directly benefit the performance of the vertical jump as an energy supplier.



**Figure 3.** For counter movement vertical jump power index, there was a significant time effect ( $p < 0.05$ ) and a significant interaction ( $p < 0.05$ ), with the creatine group greater than the placebo group.

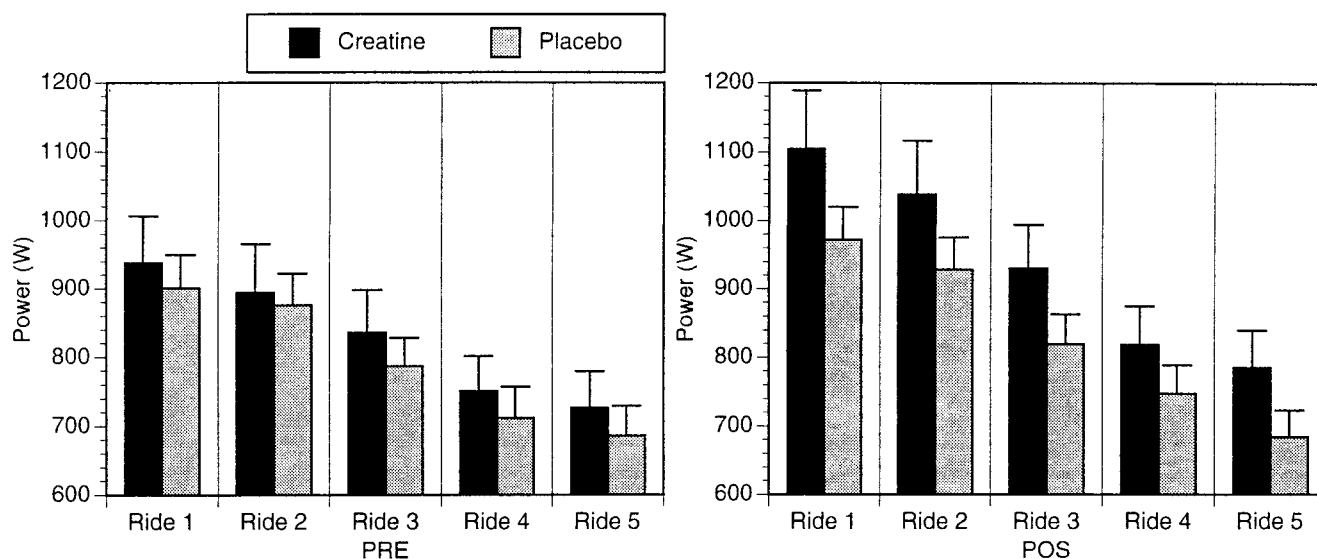


**Figure 4.** For static vertical jump power index, there was a significant time effect ( $p < 0.05$ ).

Greater neural activation of the muscle-maximizing force production could enhance vertical jump (30). There is no evidence that creatine supplementation or enhanced creatine stores have any neurological effects. Furthermore, there is no theoretical mechanism by which creatine could have any direct influence on neural factors or muscle activation.

Earnest et al. (11) and Volek et al. (42) found that creatine supplementation allowed subjects to perform more work during a weight-training program. It has also been determined that weight training can enhance vertical jumping ability (35). The weightlifting movements performed during the weight-training sessions closely reproduce the movement and propulsive forces of the vertical jump (1, 13, 30, 35, 36, 44). Although these data were not analyzed for this investigation, C may have allowed the accomplishment of a higher intensity and volume load during the weight-training sessions than P and therefore had a greater training effect on the vertical jump (see "Practical Applications"). This would be the same means by which static vertical jump power index approached significance ( $p = 0.07$ ), with C improving more than P.

Cycle peak power, average power, total work, and initial rate demonstrated a significant ( $p < 0.05$ ) time effect as well as a significant ( $p < 0.05$ ) group-by-time interaction. Peak power in ride 1 for C improved by



**Figure 5** For cycle peak power, there was a significant time effect ( $p < 0.05$ ) and a significant interaction ( $p < 0.05$ ), with the creatine group greater than the placebo group.

17.8% between PRE and POS, with P improving by 7.9%. Peak power in ride 5 for C increased 8.0% between PRE and POS, while P increased peak power by just 0.3%. Average power, total work, and initial rate showed similar trends in the first and fifth rides.

These data agree with the consensus of findings by other researchers. Earnest et al. (11) noted an increase in work and power during three 30-second Wingate cycle tests following creatine supplementation. Söderlund et al. (34) and Dawson et al. (10) used 5 and 6, respectively, maximal 6-second rides with 30 seconds of recovery between rides. Both found increases in work and power following creatine supplementation. Söderlund et al. (34) also noted that even though total work was increased, lactate had been reduced.

It is well known that during the first seconds of high-intensity exercise, the ATP-PC system is the predominant energy supplier for muscular work. Serresse et al. (31) determined that 55–60% of the energy expenditure during a 10-second maximal cycle ergometer ride was supplied by the ATP-PC system. The ability to recover ATP and PCr for subsequent maximal exertions would therefore be of utmost importance in maintaining high work and power levels.

Greenhaff et al. (17) found that following  $Cr_m$  treatment ATP levels were 50% higher after two 30-second bouts of maximal isokinetic cycling. Following Cr supplementation, the loss of ATP was approximately 30% less after maximal cycling (7). Söderlund et al. (34) and Greenhaff et al. (18) both found decreased lactate levels after creatine-supplemented maximal cycle ergometer rides with higher work measurements and power outputs.

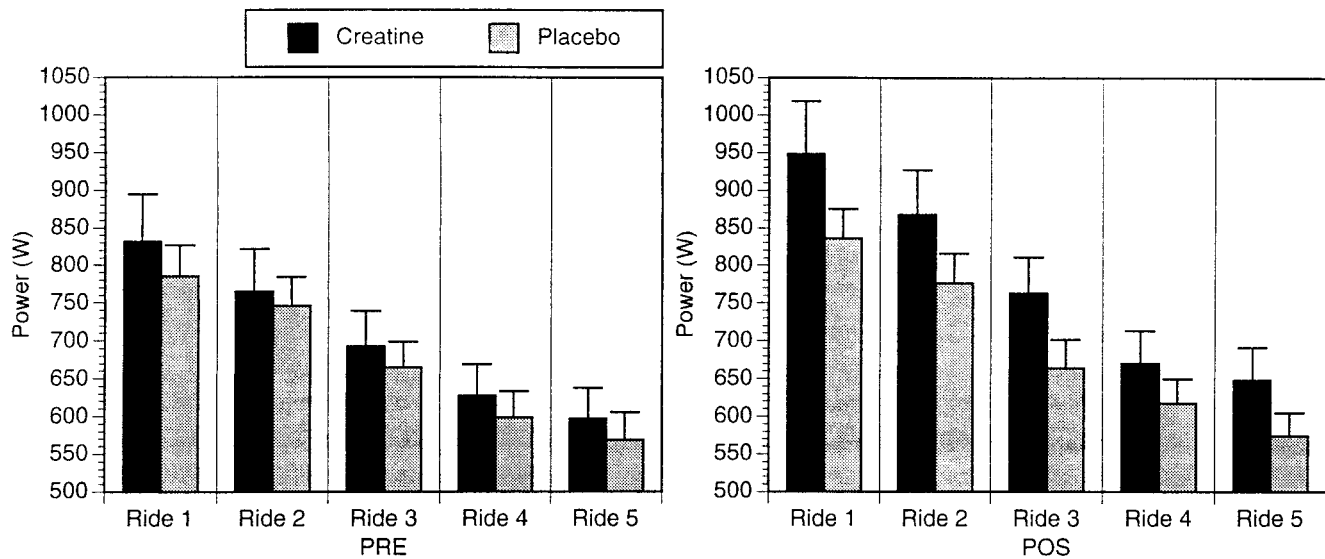
The mechanism for these changes is likely related to resynthesis of PCr at an elevated rate following creatine supplementation. Greenhaff et al. (16) deter-

mined that after creatine supplementation PCr levels were 20% higher 2 minutes after multiple muscular contractions. An enhanced rate of PCr resynthesis could explain why there is more ATP available and lower lactate levels. Higher PCr levels allow the creatine kinase reaction to produce ATP at a faster rate, and this optimization of the ATP-PC system reduces the demand for ATP from the glycolytic system, thereby decreasing the lactate by-product (43). With these benefits an individual could produce more work and power than a non-creatine-supplemented individual.

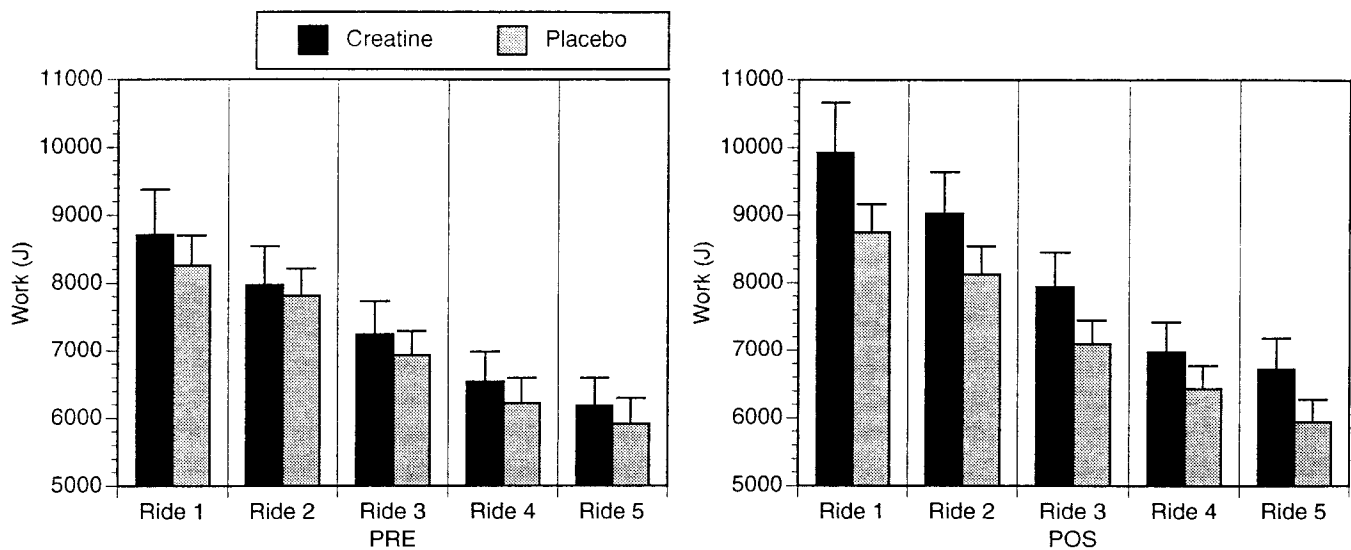
The source of this rapid replenishment of PCr during recovery may be primarily oxidative in nature. Increases in free creatine appear to stimulate oxidative phosphorylation by mitochondrial creatine kinase. The resulting adenosine diphosphate enters the mitochondrial matrix and stimulates ATP production, which in turn is available for PCr replenishment. Thus, creatine stimulates mitochondrial PCr production by producing one ATP for every PCr formed (9).

While increased PCr stores from creatine supplementation could explain the more improved performance of the C group, the training could also play a role. As previously stated, Earnest et al. (11) and Volek et al. (42) found that creatine supplementation allowed subjects to perform more work during a weight-training protocol. Although these data were not analyzed for this investigation, C may have accomplished a higher workload during the weight-training sessions than P and therefore had a greater training effect (see "Practical Applications").

There was a significant ( $p < 0.05$ ) time effect for body mass in C and P. A significant ( $p < 0.05$ ) group-by-time interaction was found for lean body mass. While lean body mass significantly ( $p < 0.05$ ) increased for the C group, body fat percentage showed



**Figure 6.** For cycle average power, there was a significant time effect ( $p < 0.05$ ) and a significant interaction ( $p < 0.05$ ), with the creatine group greater than the placebo group.



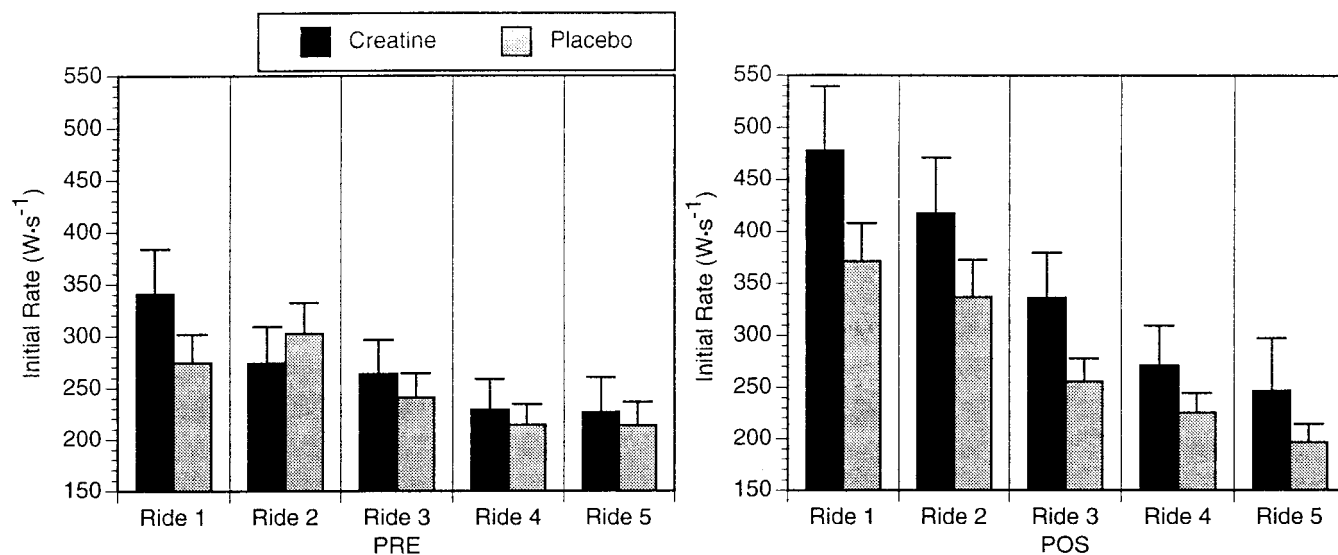
**Figure 7.** For cycle total work, there was a significant time effect ( $p < 0.05$ ) and a significant interaction ( $p < 0.05$ ), with the creatine group greater than the placebo group.

a  $-6.0\%$  change from PRE to POS in C and a  $+0.09\%$  change from PRE to POS in P.

Many researchers have observed increases in body mass associated with creatine supplementation in both trained and untrained men and women (3, 8, 11, 17, 34, 40, 42). Other investigations have attempted to determine the composition of the increased body mass. Earnest et al. (11) found a significant ( $p < 0.05$ ) increase in body mass for C that was not found in P after 28 days of supplementation. The change in lean body mass for C of that investigation approached significance ( $p = 0.054$ ), while the lean body mass for P was virtually unchanged. Kreider et al. (27) also observed significant increases in body mass and lean

body mass associated with 28 days of ingestion of a creatine-containing supplement.

It has been suggested that the change in body mass associated with creatine supplementation could be attributed to an increase in water retention (9). This may be true for the studies that have taken place during a short period ( $<7$  days). However, research that used longer-term ( $\geq 28$  days) creatine supplementation and measured body composition strongly suggests that the increase in body mass could be attributed to increases in lean body mass, i.e., skeletal muscle hypertrophy. This investigation's findings using hydrodensitometry are supported by the findings of Earnest et al. (11), who also used hydrodensitometry. Kreider et al. (27)



**Figure 8.** For cycle initial rate of power production, there was a significant time effect ( $p < 0.05$ ) and a significant interaction ( $p < 0.05$ ), with the creatine group greater than the placebo group.

came to similar results with the use of dual-energy x-ray absorptiometry used to assess body composition.

The mechanism for the increases in lean body mass related to creatine supplementation could be in the stimulatory effect that creatine may have on protein synthesis (22, 24, 25, 32, 41). However, since all the studies that have taken into consideration the composition of the weight gain lasted  $\geq 28$  days and involved resistance training, the effect of creatine on training load could play a role. Earnest et al. (11) found that not only did C have significant increases in lean body mass, but it also had significant increases in resistance training load. If creatine could increase the load an individual was capable of handling on a given training day (see "Practical Applications"), then the increase in lean body mass could be seen as a natural response to an increase in total work (14).

It has been established that some amino acids stimulate protein synthesis (43). It is possible that creatine may have the same effect. With increases in dietary creatine consumption, endogenous production is decreased. The growth-limiting amino acids, which are necessary for the production of creatine, are conserved and available for protein synthesis (43).

## Summary

Compared with P, C had significant improvements in countermovement vertical jump, countermovement vertical jump power index, lean body mass, maximum cycle ergometer peak power, average power, initial rate, and total work. Based on the results of this investigation, long-term (i.e., 6-week) supplementation of  $Cr_m$  can favorably improve vertical jump, power output, work capacity, and body composition in high-level athletes.

When  $Cr_m$  is used in conjunction with a proper sport-specific training program, athletes could have a higher training capacity and therefore show greater improvements in performance of those tasks specific to their event. Although all the mechanisms and ergogenic effects of creatine are not yet completely understood, there is enough evidence available to advocate the use of this supplement by strength/power athletes during training and competition.

## Practical Applications

It has been well established that resistance training improves muscle force and power production through enhanced neural activation and hypertrophy of the trained muscle (21, 28). Creatine supplementation appears to augment the effects of resistance training. Elevated creatine stores associated with creatine supplementation have been shown to significantly improve the total work accomplished during repeated muscular contractions and, specifically, increase the total workload accomplished during a given weight-training workout (4, 11, 42). As reported by Greenhaff et al. (17), these improvements could be attributed to an enhanced PCr resynthesis following muscular contractions.

Volume load, which is proportional to workload, can be defined as weight-repetitions, (37). Earnest et al. (11) and Volek et al. (42) specifically determined that the increase in workload occurred with the C groups performing more repetitions at a predetermined weight. If the weight were increased and the repetitions remained constant, then volume load (workload) would also be increased. Although these data were not analyzed for this investigation, this may be the mechanism by which C improved vertical jump,

maximum cycle ergometer total work and power, and lean body mass greater than P. At the given repetition range for the weight-training sessions, C subjects were able to use more weight than P and accomplished a higher workload. This would allow for greater force production capability of the muscle. Therefore, C could have shown a greater improvement in the measured variables over P because of an enhanced training effect brought about by the ability to accomplish more work during the weight-training sessions.

Recently, concern has been expressed that creatine may be associated with muscle cramps and tears. In the present study, one muscle cramp during one sprint session was noted in a woman sprinter in C and one muscle tear occurred in a man sprinter in P. The woman sprinter had a history of muscle cramping and the male sprinter reinjured a previously injured hamstring. These data suggest no untoward side effects occurred as a result of creatine ingestion during a short period.

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