

Effects of oral creatine supplementation on muscular strength and body composition

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ABSTRACT

BECCUE, M. D., J. D. LOCHMANN, and D. R. MELROSE. Effects of oral creatine supplementation on muscular strength and body composition. *Med. Sci. Sports Exerc.*, Vol. 32, No. 3, pp. 654–658, 2000. **Purpose:** The purpose of this investigation was to examine the effects of 6 wk of oral creatine supplementation during a periodized program of arm flexor strength training on arm flexor 1RM, upper arm muscle area, and body composition. **Methods:** Twenty-three male volunteers with at least 1 yr of weight training experience were assigned in a double blind fashion to two groups (Cr, $N = 10$; Placebo, $N = 13$) with no significant mean pretest one repetition maximum (1RM) differences in arm flexor strength. Cr ingested 5 g of creatine monohydrate in a flavored, sucrose drink four times per day for 5 d. After 5 d, supplementation was reduced to 2 g·d⁻¹. Placebo ingested a flavored, sucrose drink. Both drinks were 500 mL and made with 32 g of sucrose. 1RM strength of the arm flexors, body composition, and anthropometric upper arm muscle area (UAMA) were measured before and after a 6-wk resistance training program. Subjects trained twice per week with training loads that began at 6RM and progressed to 2RM. **Results:** 1RM for Cr increased ($P < 0.01$) from (mean \pm SD) 42.8 \pm 17.7 kg to 54.7 \pm 14.1 kg, while 1RM for Placebo increased ($P < 0.01$) from 42.5 \pm 15.9 kg to 49.3 \pm 15.7 kg. At post-test 1RM was significantly ($P < 0.01$) greater for Cr than for Placebo. Body mass for Cr increased ($P < 0.01$) from 86.7 \pm 14.7 kg to 88.7 \pm 13.8 kg. Fat-free mass for Cr increased ($P < 0.01$) from 71.2 \pm 10.0 kg to 72.8 \pm 10.1 kg. No changes in body mass or fat-free mass were found for Placebo. There were no changes in fat mass and percent body fat for either group. UAMA increased ($P < 0.01$) 7.9 cm² for Cr and did not change for Placebo. **Conclusion:** Creatine supplementation during arm flexor strength training lead to greater increases in arm flexor muscular strength, upper arm muscle area, and fat-free mass than strength training alone. **Key Words:** TRAINING, EXERCISE, EXERTION, FAT-FREE MASS, ERGOGENIC AIDS, WEIGHT TRAINING

Nutritional and biochemical supplements are continually introduced into sport and physical fitness. As the use of these nutritional supplements continues to increase, so does the need to investigate their effects on human performance.

Oral creatine supplementation increases the creatine and PCr content of human skeletal muscle (6,10,11,14,17,29,30). Creatine supplementation increases maximum intermittent bicycle and treadmill exercise performance during repeated bouts of exercise (1,4,6,8,15,21,27,28) but not in single maximum bouts (7,24,26) or endurance exercise (2).

A few studies have examined the effects of creatine supplementation during resistance exercise. The short-term (1 wk) effects of creatine supplementation without training include an increase in one repetition maximum (1RM) muscular strength (9), increased number of repetitions com-

pleted per set (9,31), and increased peak power during each set (31). Also, short-term supplementation increases isokinetic knee torques during repeated sets of knee extensions (12,13,29).

The effects of creatine supplementation and resistance training have been examined by four studies. Experienced male weight lifters (19,21) supplemented for 28 d. Noonan et al. (25) had experienced male weight lifters supplement for 8 wk. These studies showed increases in 3RM muscular strength (19), 1RM bench press (25), the amount of weight lifted in one set (21), and the number of repetitions completed in five sets (19). Neither maximum isometric strength (21) nor vertical jump height (25) increased. Vanderberghe et al. (30) resistance trained inexperienced females for 10 wk with creatine supplementation. 1RM muscular strength increased 20–25% for the leg press, leg extension, and squat exercise but not for the bench press and leg curl. Also, arm flexion torques during five sets of 30 repetitions were 11–25% greater after supplementation and training.

The physiological mechanisms linking creatine supplementation and increased exercise performance are largely unexplained. One possibility is an increase in body mass and

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fat-free mass. Several investigations found body mass increases after short-term creatine supplementation (1,2,9,31), and others found no change in body mass (8,29). Three resistance training studies (19,21,30) found increases in body mass and fat-free mass and one (25) found no change.

Despite an abundance of studies, only four studies (19,21,25,30) have examined the effects of creatine supplementation while strength training. Only two of these studies (25,30) reported changes in 1RM, a criterion measure of muscular strength. Moreover, one of the latter studies employed novice weight lifters (30) and the other football athletes (25). The purpose of this investigation was to examine the effects of 6 wk of oral creatine supplementation during a periodized program of arm flexor strength training on arm flexor 1RM, upper arm muscle area, and body composition.

METHODS

Subjects. Twenty-three healthy male volunteers (mean age \pm SD, 21.5 \pm 2.7 yr) participated in the research project. The subjects were experienced recreational weight lifters. All subjects had at least 1 yr of continuous weight training before the study but were not competitive powerlifters or bodybuilders. On the average, the subjects lifted 2–3 times a week, attempting to work all the major muscle groups. During the study subjects continued their regular workouts without any upper arm exercises. None of the subjects were vegetarians, nor were they using anabolic steroids or creatine monohydrate. All subjects provided informed consent after receiving a description of the study. The study was approved by the Carbondale Human Subjects Committee, Southern Illinois University at Carbondale.

Strength testing. Strength testing was 1 wk before the start of the 6 wk resistance training program. The testing sessions were approximately 60 min in length and completed by each subject alone. All subjects abstained from biceps and back training for at least 48 h before testing. The one repetition maximum (1RM) test was administered after each subject performed two warm-up sets with the arm flexors. The warm-up sets were a pyramid system of increasing weight and decreasing repetitions. After all warm-up sets were completed, the subject attempted a 1RM of the arm flexors. The strength tests were performed with a standard wide-grip cambered lifting bar on a preacher curl bench. With the assistance of a spotter, the bar was lifted from the weight rack to the flexed arm position. The bar was lowered and raised in a controlled movement. Weight increments of at least 1.0 kg were added to the bar after each trial until the subject could not lift the bar through a full range of motion. Generally, a 1RM was found after three or four trials.

Training sessions. Subjects trained the arm flexors for 6 wk with a standard wide-grip cambered lifting bar on a preacher curl bench. This exercise was chosen because it is a single joint movement that is easily isolated for testing and training. All training was lead by one of the investigators. The training sessions were completed in small groups.

Training was periodized by alternating heavy and light training sessions on two nonconsecutive days per week. The heavy training loads were the normal loads prescribed by the protocol. The light training loads were 80% of the heavy training loads. Subjects performed two or three warm-up sets before the first training set. Subjects completed four training sets. They worked maximally during each set and received verbal encouragement while exercising. Two minutes separated each training set. The training sessions required the subjects to lift with repetition maximum (RM) loads. An RM load is the maximum amount the subject could lift for a predetermined number of repetitions. Training sessions 1 through 4 required the subject to perform four working sets at 6RM. Training volume decreased while exercise intensity increased as the program continued. 4RM loads were used for sessions 5 through 8, and 2RM loads were used for sessions 9 through 12.

Supplementation. Creatine supplementation began during week 1 of the training sessions and continued through the post-test. A double blind design was employed to create two groups (Placebo and Cr) with no significant mean pretest 1RM differences in arm flexor strength (Placebo, 42.6 \pm 15.9 kg, Cr, 42.8 \pm 17.7 kg). Subjects in the Cr group ($N = 10$) ingested 5 g of creatine monohydrate dissolved in a flavored sucrose drink, four times daily (20 g \cdot d $^{-1}$) for 5 d. The Placebo group ($N = 13$) ingested a flavored sucrose drink without creatine monohydrate four times daily. After 5 d, creatine supplementation was reduced to 2 g \cdot d $^{-1}$. All subjects consumed their drink immediately after the training session. Both drinks were 500 mL and made with 32 g of sucrose. The presence of creatine monohydrate was undetectable by taste in the flavored sucrose-sweetened drink. To maintain the double blind design, an individual not involved in training or testing the subjects prepared the supplement. This individual had no influence or knowledge of the recording or interpretation of the data. After all subjects completed the post-test, group membership (Cr, Placebo) was revealed to the investigators and the subjects. There were no side effects of the supplementation protocol reported by the subjects at any time.

Body composition. Body composition was assessed before and after 6 wk of resistance training using hydrostatic weighing. To determine body volume, subjects were underwater weighed in a tank filled with warm water (\sim 30°C). Body mass was determined to the nearest 0.1 kg (Detecto Scales, Webb City, MO) before entering the water. The subject was underwater weighed at residual lung volume in a bent-forward seated position. Residual lung volume was estimated from forced vital capacity (FVC) (32). The subjects practiced the technique and then a minimum of four trials were conducted to determine underwater weight. The average of the four trials was used to calculate the subject's body volume. The accuracy of individual estimates of body density by this technique has been shown to be less than when residual lung volume is measured (23). On the other hand, Morrow et al. (23) stated that "accurate estimates of group means is possible." Our body composition data on the Placebo group have a reliability of $R = 0.96$ with no

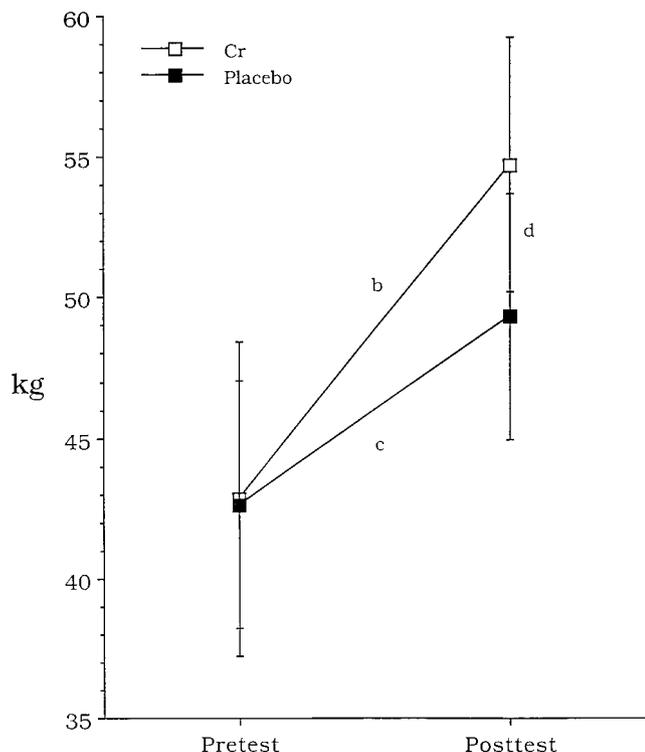


Figure 1—Muscular strength (1RM) is presented for Cr and Placebo. There were no significant ($P > 0.01$) differences between the groups at pretest. There was a significant ($P < 0.01$) increase in muscular strength for both groups (b and c) from pretest to post-test. At post-test, Cr muscular strength was significantly ($P < 0.01$) greater than Placebo muscular strength (d).

significant mean differences. Percent body fat was calculated from body density (5).

Upper arm circumferences were measured at three locations on the right arm of the subject. The distance from the acromion to the olecranon was measured to determine the total upper arm length. Circumference measurements were made at 1/3, 1/2, and 2/3 of total upper arm length. Upper arm skinfolds were measured at 1/3 and 2/3 of the upper arm length as a longitudinal fold on the posterior aspect of the right upper arm. Skinfolds were also taken at the triceps and biceps skinfold sites (22). The skinfold measurements were made with a Lange skinfold caliper. Upper arm muscle area was calculated with the circumference taken at 1/2 of total upper arm length and the triceps skinfold (16).

Data analysis. These data were analyzed with a 2×2 repeated measures ANOVA (Group: Placebo and Cr; Time: pre- and post-test) and 4 *a priori* contrasts with SuperANOVA (Abacus Concepts, Inc., Berkeley, CA). An alpha level of 0.05 was used to test all differences. The alpha level of the individual contrasts was adjusted to 0.01 with the Bonferroni technique. All data are presented as mean \pm SD.

RESULTS

Muscular strength (1RM) for each group is shown in Figure 1. Mean arm flexor 1RM strength for Placebo significantly ($P < 0.01$) increased from 42.5 ± 15.9 to 49.3 ± 15.7 kg, while 1RM for Cr significantly ($P < 0.01$) in-

TABLE 1. Pretest and post-test body composition is presented for Cr and Placebo (means \pm SD).

	Cr		Placebo	
	Pretest	Post-test	Pretest	Post-test
Body mass (kg)	86.7 ^{a, b} (14.7)	88.7 ^{b, d} (13.8)	81.6 ^a (6.6)	82.0 ^d (6.8)
Fat mass (kg)	15.6 ^a (9.0)	15.7 (6.7)	13.1 ^a (5.0)	13.6 (4.8)
Fat free mass (kg)	71.2 ^{a, b} (10)	72.8 ^{b, d} (10.1)	68.6 ^a (5.8)	68.5 ^d (5.9)
Body fat (%)	17.8 (6.9)	17.7 (5.6)	16 (5.5)	16.5 (5.2)

The superscripts note where significant mean differences ($P < 0.01$) were found as a result of the four contrasts:

^a Cr pretest vs Placebo pretest.

^b Cr pretest vs Cr post-test.

^c Placebo pretest vs Placebo post-test.

^d Cr post-test vs Placebo post-test. Means without superscripts are not significantly different.

creased from 42.8 ± 17.7 to 54.7 ± 14.1 kg from pretest to post-test. Moreover, at post-test 1RM for Cr was significantly ($P < 0.01$) greater than Placebo. This was a $29.9 \pm 16.77\%$ increase in 1RM for Cr and a $16.5 \pm 6.25\%$ increase for Placebo. The percentage increase for Cr was significantly greater ($P < 0.01$) than Placebo.

Body mass and body composition are shown in Table 1. Body mass was significantly ($P < 0.01$) greater for Cr than Placebo at pretest and post-test. There was a significant ($P < 0.01$) 2.0 kg increase in body mass from pretest to post-test for Cr. Body mass was unchanged for Placebo. Fat-free mass was significantly ($P < 0.01$) greater for Cr than Placebo at pretest and post-test. Fat-free mass for Cr increased significantly ($P < 0.01$) 1.6 kg from pretest to post-test. No significant change in fat-free mass was observed for Placebo. Fat mass and percent body fat were unchanged for both Cr and Placebo.

Anthropometric measurements are shown in Table 2. The triceps skinfold for Cr decreased significantly ($P < 0.01$) 1.2 mm (15.0%) from pretest to post-test. None of the other

TABLE 2. Pretest and post-test upper arm anthropometric measurements are presented for Cr and Placebo (means \pm SD).

	Cr		Placebo	
	Pretest	Post-test	Pretest	Post-test
1/3 skinfold (mm)	7.6 (3.3)	7.8 (2.9)	8.5 (3.6)	9.1 (3.0)
2/3 skinfold (mm)	15.2 ^a (5.4)	15.1 ^d (5.5)	17.1 ^a (4.8)	16.7 ^d (5.1)
Biceps skinfold (mm)	4.1 (1.7)	3.7 (2.0)	4.3 (1.3)	4.1 (1.2)
Triceps skinfold (mm)	8.0 ^b (2.8)	6.8 ^b (2.2)	8.7 (3.5)	8.6 (3.5)
1/3 circumference (cm)	33.5 ^b (1.8)	34.8 ^b (2.0)	33.4 ^c (2.5)	34.4 ^c (2.4)
1/2 circumference (cm)	35.7 ^b (3.5)	36.8 ^b (3.3)	35.8 (2.5)	36.3 (2.7)
2/3 circumference (cm)	35.6 ^b (3.4)	37.4 ^{b, d} (3.5)	35.6 (1.8)	35.7 ^d (2.2)
Upper arm muscle area (cm ²)	88.4 (17.15)	96.3 ^{b, d} (18.32)	87.6 (13.21)	90.1 ^d (14.24)

The superscripts note where significant mean differences ($P < 0.01$) were found as a result of the four contrasts:

^a Cr pretest vs Placebo pretest.

^b Cr pretest vs Cr post-test.

^c Placebo pretest vs Placebo post-test.

^d Cr post-test vs Placebo post-test. Means without superscripts are not significantly different.

skinfolts for either group changed from pretest to post-test. All three upper arm circumference measurements for Cr increased significantly ($P < 0.01$). The 1/3 upper arm circumference increased 1.3 cm (3.9%), the 1/2 upper arm circumference increased 1.1 cm (3.1%), and the 2/3 upper arm circumference increased 1.8 cm (5.1%). For Placebo, only the 1/3 upper arm circumference significantly ($P < 0.01$) increased 1.0 cm (3.0%) from pretest to post-test.

Upper arm muscle area (UAMA) for each group was calculated from anthropometric measurements. UAMA at pretest was not significantly different between Cr ($88.4 \pm 17.15 \text{ cm}^2$) and Placebo ($87.6 \pm 13.21 \text{ cm}^2$). Cr UAMA increased ($P < 0.01$) 7.9 cm^2 (9.1%) from pretest to post-test. No change in UAMA was found for Placebo. At post-test, Cr UAMA ($96.3 \pm 18.32 \text{ cm}^2$) was significantly ($P < 0.01$) greater than Placebo ($90.1 \pm 14.24 \text{ cm}^2$).

DISCUSSION

The major finding of this study was that oral creatine supplementation in conjunction with resistance strength training of the arm flexors results in greater arm flexor muscular strength and increases in UAMA and fat-free mass than resistance strength training alone.

A progressive resistance training program for the arm flexors resulted in increased arm flexor strength in all subjects. The training program was very demanding and pushed the subjects well beyond their normal training routine. However, in a comparison of the magnitude of the strength gains, the Cr increase was 11.8% greater than Placebo. These data agree with the two studies (9,31) that showed increased muscular strength with short-term creatine supplementation and the four studies (19,21,25,30) that showed greater increases in muscular strength with creatine supplementation while resistance training. In particular, our data extend the work of Vanderberghe et al. (30) with novice females and Kreider et al. (21) and Noonan et al. (25) with experienced football players to experienced male weight lifters. None of the other studies tested or trained the arm flexors, but the strength increases were similar.

It is possible that one of the ergogenic effects of creatine supplementation is to improve muscular performance during the workouts. The subjects may have been able to perform more muscular work during the training sessions. This increased work would provide a stimulus for greater increases in 1RM strength. Our workout data do not support this

increased work hypothesis. When the weight lifted was multiplied times the number of repetitions completed and summed across the number of sets, Cr averaged $2840 \pm 773.3 \text{ lb}$ lifted per week and Placebo averaged $2688 \pm 811.2 \text{ lb}$ lifted per week for 6 wk. Furthermore, there were no significant differences in the trend of pounds lifted across the weeks.

Some studies investigating creatine supplementation on performance have reported increases in body mass (1,2,9,19,21,30,31). As early as 1928, body mass increases were reported among subjects administered creatine (18). Creatine supplementation and resistance training increased the average body mass of our subjects 2.0 kg, while resistance training alone had no average increase. The individual data correspond with these mean changes. For Placebo, four subjects increased, seven subjects had no change, and two subjects decreased body mass. For Cr, seven subjects increased, one subject had no change, and two subjects decreased body mass. These results strongly suggest that creatine supplementation is a stimulus for body mass increases.

Body mass increases with creatine supplementation have been attributed to changes in skeletal muscle hydration. Recently, total body water was shown to increase in direct proportion to the increased muscle creatine concentration (20,21). The present study demonstrates that 80% of the increase in body mass for Cr was the result of increased fat-free mass. The increases in upper arm muscle area confirm these fat-free mass increases. Upper arm muscle area increased by 11% for Cr with no change for Placebo. Creatine supplementation appears to directly stimulate (3) increases in the size of the exercising musculature.

The other changes in anthropometric measurements were consistent with the significant increases in body mass and fat-free mass for Cr. Upper arm circumferences for Cr increased at all points of measurement. Only one upper arm circumference increased for Placebo. This result is consistent with the lack of increase in body mass and fat-free mass.

In conclusion, 6 wk of creatine supplemented arm flexor strength training lead to greater increases in arm flexor strength, fat-free mass, and upper arm muscle area than strength training alone.

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