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Effect of Creatine and β-Alanine Supplementation on Performance and Endocrine Responses in Strength/Power Athletes

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The effects of creatine and creatine plus β-alanine on strength, power, body composition, and endocrine changes were examined during a 10-wk resistance training program in collegiate football players. Thirty-three male subjects were randomly assigned to either a placebo (P), creatine (C), or creatine plus β-alanine (CA) group. During each testing session subjects were assessed for strength (maximum bench press and squat), power (Wingate anaerobic power test, 20-jump test), and body composition. Resting blood samples were analyzed for total testosterone, cortisol, growth hormone, IGF-1, and sex hormone binding globulin. Changes in lean body mass and percent body fat were greater ($P < 0.05$) in CA compared to C or P. Significantly greater strength improvements were seen in CA and C compared to P. Resting testosterone concentrations were elevated in C, however, no other significant endocrine changes were noted. Results of this study demonstrate the efficacy of creatine and creatine plus β-alanine on strength performance. Creatine plus β-alanine supplementation appeared to have the greatest effect on lean tissue accruement and body fat composition.

Key Words: nutritional supplementation, anaerobic exercise, ergogenic aids

Creatine supplementation has become one of the leading sport supplements used by strength power athletes today. Reports suggest that 48% of male collegiate athletes use or have used creatine during their preparation for competition (21). However, the prevalence of use among strength/power athletes is much greater, and may approach more than 80% in certain sports (21). Creatine use has also gained popularity among high school athletes, with 90% of athletes who supplement use creatine (33). Although widespread use of a sport supplement does not indicate safety or advocacy, creatine supplements may be the most studied ergogenic aid

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in recent history. Medline searches indicate that more than 600 studies have been published on creatine supplementation. Many of these investigations have demonstrated the efficacy of creatine supplementation for increasing muscular strength, power, and body mass (4, 6, 8, 17, 20, 22, 28, 30, 36, 38, 39) as well as increasing the synthesis of muscle contractile proteins (38, 41).

The efficacy demonstrated by sport scientists and the popularity of this ergogenic product have made creatine one of the more popular products on the sport supplement market. Annual sales of creatine supplements in 2001 were reported to exceed more than $400 million (25). However, that number has likely been exceeded in the past few years. To enhance its marketability, many of these products are formulated using various methods of delivery (i.e., drink, tablet, chewable candy). Recently, attempts have been made to enhance the effects of creatine by adding β-alanine to its formula. β-alanine, an amino acid derivative, has been shown to increase carnosine concentrations within skeletal muscle (5). Carnosine has been shown to enhance the buffering capacity during high-intensity exercise (31). This may provide an additional ergogenic benefit than creatine alone by further enhancing the muscle's ability to withstand the fatiguing effects of high-intensity exercise. Although creatine supplementation alone has been shown to improve fatigue rates in anaerobic exercise (15), additional benefits supplied by β-alanine may further reduce the rate of fatigue in muscle providing for a greater training stimulus.

The endocrine system has been shown to respond to changes in exercise intensity, volume, and rest (14, 19). Considering that creatine supplementation is thought to improve the quality of the workout, it may have important implications to endocrine function and influence on muscle remodeling. Although limited research has indicated that creatine supplementation does not influence the acute responses to an exercise stress (26, 37), its' ability to change resting hormonal concentrations is less understood. Volek and colleagues have indicated that alterations in resting hormonal concentrations are unable to explain performance and body composition changes during a 4 wk resistance training program (39). However, that study was designed to examine an overreaching protocol. The effect of creatine supplementation to alter resting endocrine measures during a periodized resistance training program, common to many strength/power athletes, is not well understood. Thus, the purpose of this study was to compare the effects of creatine plus β-alanine to creatine alone on strength, power, and body compositional changes during a 10 wk resistance training program in collegiate football players. In addition, a secondary purpose of this study was to examine the effect of creatine and creatine plus β-alanine supplementation on the hormonal responses to resistance training.

Methods

Subjects

Thirty-three male strength power athletes volunteered for this study. Following an explanation of all procedures, risks, and benefits each subject gave his informed consent to participate. The Institutional Review Board of the College of New Jersey approved the research protocol. Subjects were not permitted to use any additional nutritional supplementation and did not consume anabolic steroids or any other anabolic agents known to increase performance. Screening for steroid use and additional supplementation was accomplished via a health questionnaire filled out during subject recruitment.

Subjects were randomly assigned to one of three groups. The first group (CA) was provided with a daily creatine plus β-alanine supplementation (10.5 g/d of creatine monohydrate and 3.2 g/d of β-alanine), the second group (C) was provided with a daily creatine supplement only (10.5 g/d of creatine monohydrate), while the third group (P) was given a placebo (10.5 g/d of dextrose). These dosages were similar to those used in previous studies examining both creatine (4, 8, 17, 20, 28, 30, 40) and β-alanine supplementation (13). All subjects were athletes from the college's football team with at least 2 y of resistance training experience. The study followed a double-blind format. All groups performed the same resistance training program for 10 wk. The training program was a 4 d per week, split routine (see Table 1) that was supervised by study personnel. All subjects completed a daily training log and turned it in at the end of each week.

Table 1 10-Week Resistance Training Program

Days 1/3	Weeks 1 – 2 (Sets × Reps)	Weeks 3 – 6 (Sets × Reps)	Weeks 7 – 10 (Sets × Reps)
Power clean	–	4 × 4 –6	5 × 3 – 5
Bench press	4 × 8 – 10	4 × 6 – 8	5 × 4 – 6
Incline bench press	3 × 8 – 10	3 × 6 – 8	4 × 4 – 6
Incline fly	3 × 8 – 10	3 × 6 – 8	–
Hang pulls (clean grip)	4 × 6 – 8	–	–
Push press	–	4 × 4 – 6	5 × 3 – 5
High pulls (snatch grip)	–	3 × 4 – 6	4 × 3 – 5
Seated shoulder press	4 × 8 – 10	–	–
Power dumbbell shrugs	3 × 6 – 8	–	–
Dumbbell front raise	–	3 × 6 – 8	–
Lateral raises	3 × 8 – 10	–	–
Triceps pushdowns	3 × 8 – 10	3 × 6 – 8	–
Triceps dumbbell extensions	3 × 8 – 10	3 × 6 – 8	4 × 6 – 8
Trunk and abdominal routine	2 × 10	3 × 10	4 × 10
Days 2/4			
Squat	4 × 8 – 10	4 × 6 – 8	5 × 4 – 6
Dead lift	4 × 8 – 10	3 × 6 – 8	4 × 4 – 6
Leg extensions	3 × 8 – 10	–	–
Leg curls	3 × 8 – 10	3 × 6 – 8	3 × 6 – 8
Standing calf raises	3 × 8 – 10	3 × 6 – 8	3 × 6 – 8
Lat pulldown	4 × 8 – 10	4 × 6 – 8	4 × 4 – 6
Seated row	4 × 8 – 10	4 × 6 – 8	4 × 4 – 6
Hammer curls	3 × 8 – 10	3 × 6 – 8	4 × 6 – 8
Dumbbell biceps curls	3 × 8 – 10	3 × 6 – 8	–
Trunk and abdominal routine	2 × 10	3 × 10	4 × 10

Testing Protocol

Subjects reported to the college's human performance laboratory on two separate occasions. The first testing session occurred prior to the onset of supplementation, while the second testing session occurred at the conclusion of the 10 wk supplementation program. All testing sessions occurred at the same time of day, and subjects were requested to maintain a similar daily routine on testing dates.

Blood Measurements

Subjects were required to arrive at the laboratory in the early morning following an overnight fast for blood draws. However, due to class conflicts, nine of the subjects reported later in the morning, 2 h postprandial. All blood draws though occurred at the same time of day for each testing session. Each blood sample was obtained from an antecubital arm vein using a 20-gauge disposable needle equipped with a Vacutainer tube holder (Becton Dickinson, Franklin Lakes, NJ) with the subject in a seated position. Blood samples were collected into a Vacutainer tube containing SST Gel and Clot Activator. Serum was allowed to clot at room temperature and subsequently centrifuged at 1500 × g for 15 min. The resulting serum was placed into separate 1.8 mL microcentrifuge tubes and frozen at –80 °C for later analyses.

Biochemical and Hormonal Analyses

Serum total testosterone, growth hormone, IGF-I, sex hormone binding globulin (SHBG), and cortisol concentrations were determined using enzyme immunoassays (EIA) and enzyme-linked immunosorbent assays (ELISA) (Diagnostic Systems Laboratories, Webster, TX). Determinations of serum immunoreactivity values were made using a SpectraMax340 Spectrophotometer (Molecular Devices, Sunnyvale, CA). To eliminate inter-assay variance, all samples for a particular assay were thawed once and analyzed in the same assay run. All samples were run in duplicate with a mean intra-assay variance of < 10%. The molar ratio of total testosterone to cortisol (T/C ratio) was determined for each testing session.

Body Composition

Body composition was determined using whole body-dual energy X-ray absorptiometry (DEXA) scans (Prodigy; Lunar Corp., Madison, WI). Total body estimates of percent fat, bone mineral density, and bodily content of bone, fat, and non-bone lean tissue was determined using the manufacturer's recommended procedures and supplied algorithms. All measures were performed by the same technician. Quality assurance was assessed by daily calibrations and was performed prior to all scans using a calibration block provided by the manufacturer.

Strength Measures

During each testing session subjects performed a 1-repetition maximum (1-RM) strength test on the squat and bench press exercises. Each subject performed a warm-up set using a resistance that was approximately 40 to 60% of his perceived maximum, and then performed three to four subsequent attempts to determine the 1-RM. A 3 to 5 min rest period was provided between each lift.

Anaerobic Power Measures

To quantify anaerobic power performance all subjects performed the Wingate anaerobic power test (Lode Excalibur, Groningen, The Netherlands). Following a warm-up period of 5-min pedaling at 60 rpm interspersed with three all-out sprints last 5 s, the subjects pedaled for 30 s at maximal speed against a constant force (1.2 Nm/body mass). Following a 3 min active rest (pedaling at 60 rpm) the subjects performed a second 30 s sprint. Peak power, mean power, total work, and rate of fatigue were determined. Peak power was defined as the highest mechanical power output elicited during the test. Mean power was defined as the average mechanical power during the 30 s test, and the rate of fatigue was determined by dividing the highest power output from the lowest power output × 100.

In addition to the Wingate anaerobic power test subjects also performed a 20 jump power test. Following a brief warm-up that included several light callisthenic exercises, the subjects stood on a portable force plate (Advanced Medical Technology, Inc., Watertown, MA). The subject's hands were placed on his waist at all times. On cue, the subject performed 20 consecutive vertical jumps with a standardized countermovement. The subject was instructed to maximize the height of each jump while minimizing the contact time with the force plate between jumps. Computer analysis was used to calculate peak power, mean power, and a fatigue index.

Dietary Recall

Caloric and protein intake was continuously monitored throughout the study using 3 d dietary records every week. Subjects were instructed to record as accurately as possible everything they consumed during the day including between meal and late evening snacks.

Supplement Schedule

Subjects consumed either the supplement or placebo twice per day. The supplement and placebo were in powdered form and mixed with 8 to 10 ounces of water. Subjects consumed the drink every morning. On days that they performed their resistance training program, they consumed another drink within 1 h of their workout. On the days that the subjects did not exercise, they consumed the supplement or placebo in the late afternoon or early evening.

Statistical Analysis

Statistical evaluation of the data was accomplished by a repeated measures analysis of variance. In addition, Δ comparisons between groups were analyzed with a one-way analysis of variance. In the event of a significant F- ratio, LSD post hoc tests were used for pairwise comparisons. A criterion alpha level of $P \leq 0.05$ was used to determine statistical significance. Effect size (ES) calculations were used to determine the magnitude of treatment effects, and are reported with all statistically significant results as a measure of practical significance. All data are reported as means ± standard deviation.

Results

No significant differences in average daily caloric intake were seen between P (2991 ± 809 kcal), CA (3222 ± 856 kcal), and C (2999 ± 546 kcal). Analysis of dietary composition showed that the daily dietary intake for all groups was comprised of 59% carbohydrates, 26% fat, and 15% protein. No significant changes in body mass were seen from PRE to POST in either P (102.2 ± 14.0 kg and 103.2 ± 13.8 kg, respectively), CA (94.1 ± 16.4 kg and 95.7 ± 16.6 kg, respectively), or C (91.9 ± 21.7 kg and 92.5 ± 21.5 kg, respectively). In addition, no significant differences were seen between the groups in Δ body mass. However, significant differences in Δ% body fat (–1.21 ± 1.12% versus 0.25 ± 1.53%, $P < 0.05$, ES = 1.15) and Δ lean body mass (1.74 ± 1.72 kg versus –0.44 ± 1.62 kg, $P < 0.05$, ES = 1.13) were seen between CA and P, respectively. No significant differences though in Δ fat mass were observed. Individual changes in percent body fat, lean body mass and fat mass are seen in Figures 1, 2, and 3, respectively.

Significant improvements from PRE 1-RM squat levels (159.4 ± 28.6 kg) were seen in all three groups. However, Δ strength comparisons showed that subjects in CA and C had significantly greater improvement in 1-RM squat strength compared to P (see Figure 4, panel a). In addition, significant improvements from PRE 1-RM bench press levels (115.9 ± 17.7 kg) were also seen in all three groups. When comparing Δ strength improvements in the bench press (see Figure 4, panel b) a two-fold greater improvement ($P < 0.05$) was seen in CA compared to P, and a two and a half-fold greater improvement ($P < 0.05$) was seen in C compared to P.

The average weekly training intensity and volume for the squat exercise can be seen in Figure 5, panels a and b, respectively. Subjects in both CA and C trained at a significantly higher exercise intensity during the 10 wk training program than

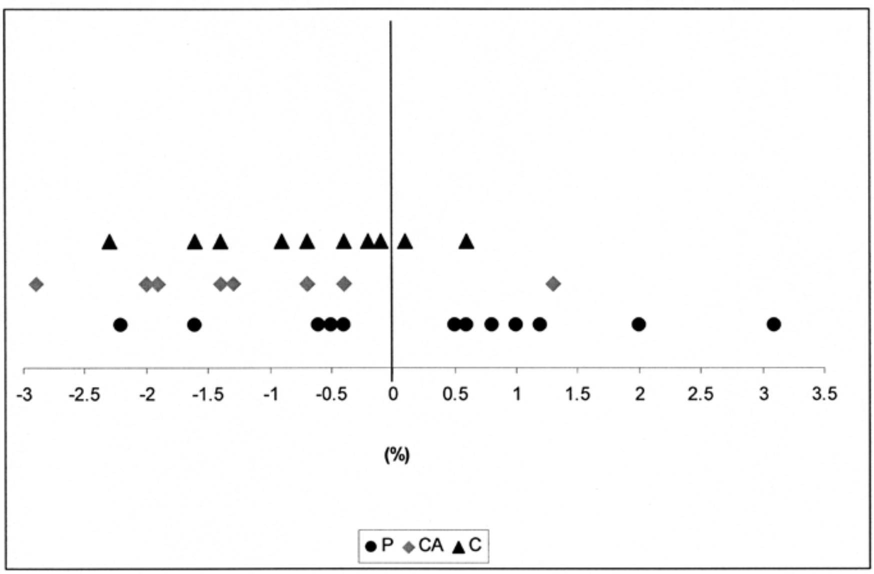


Figure 1 — Individual changes in body fat percentage.

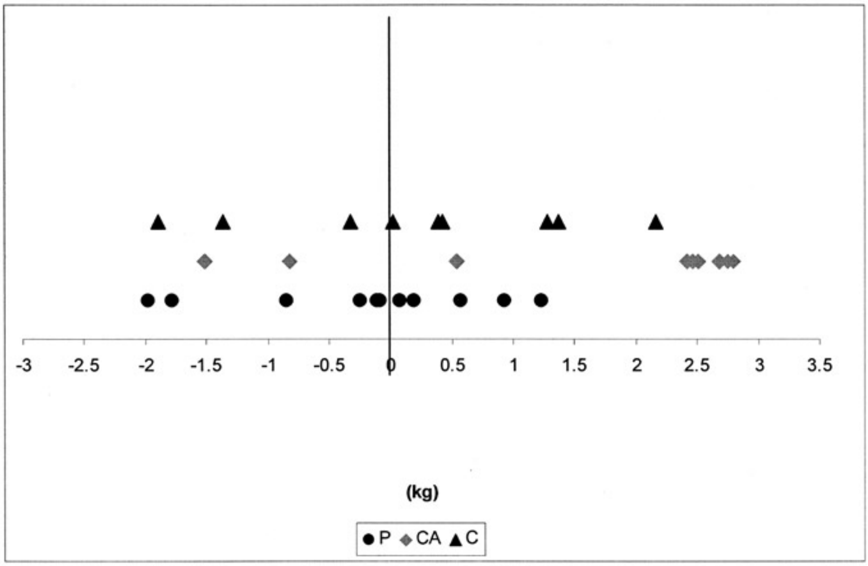


Figure 2 — Individual changes in lean body mass.

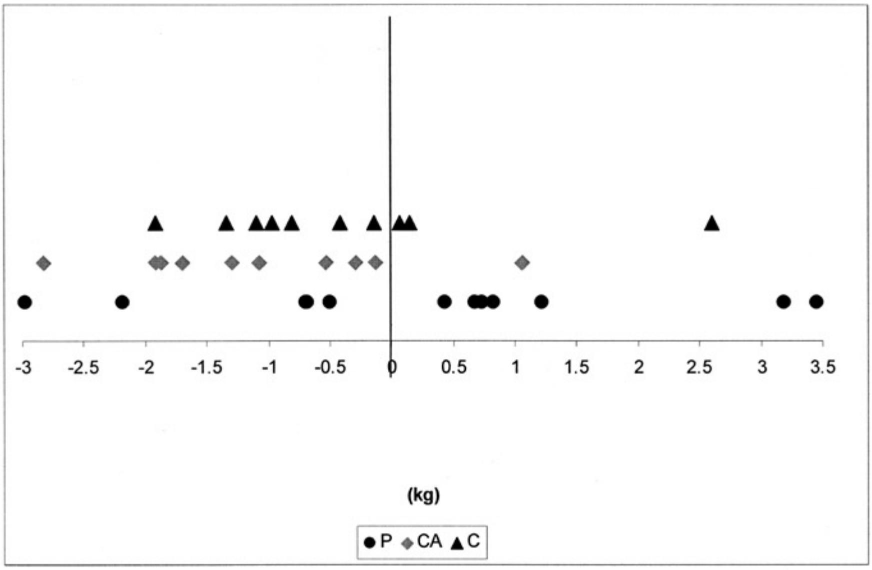


Figure 3 — Individual changes in fat mass.

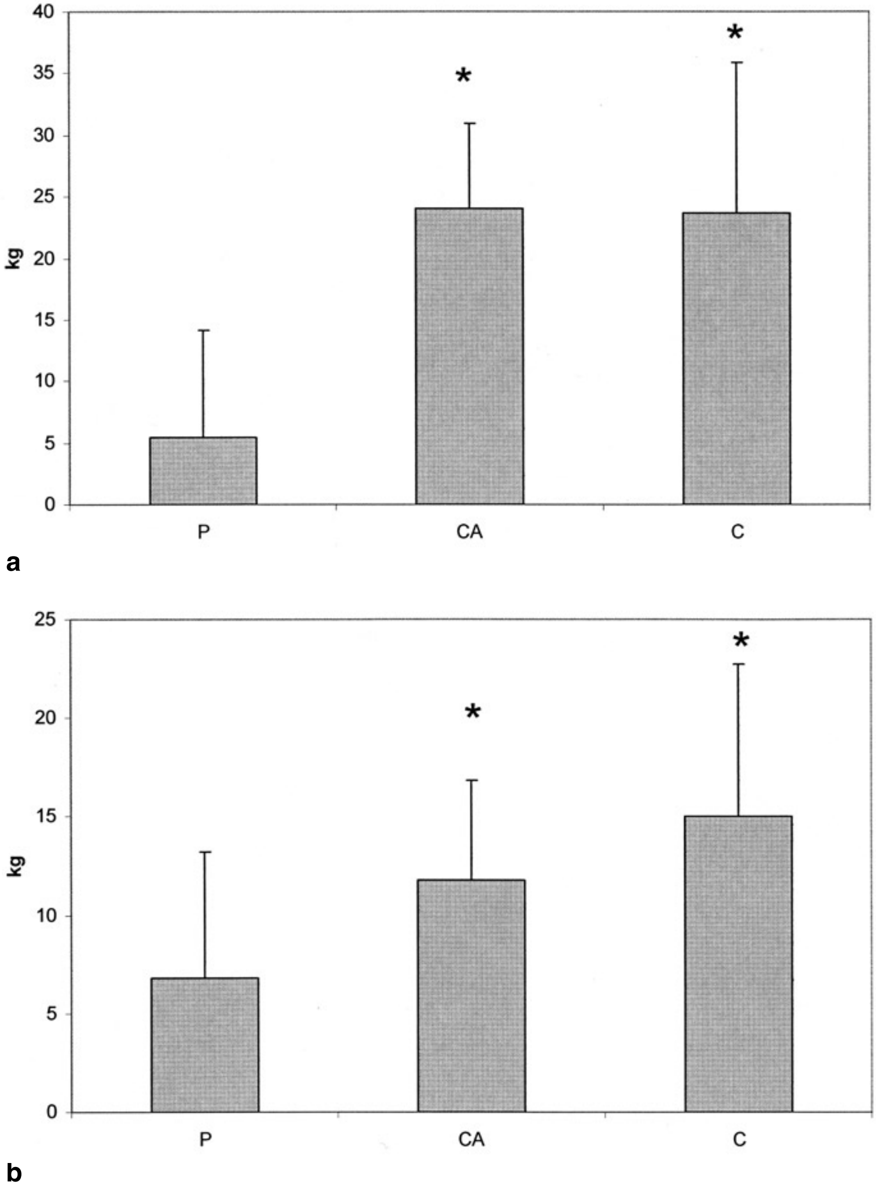
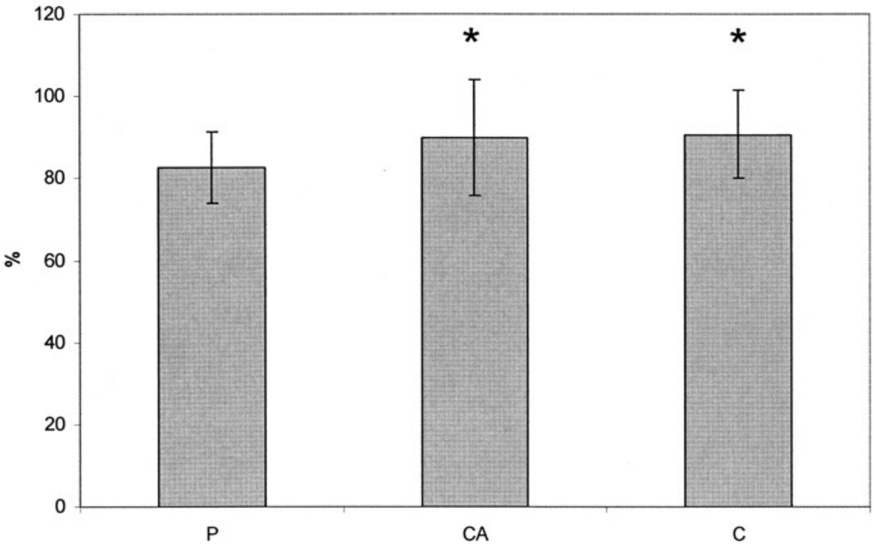


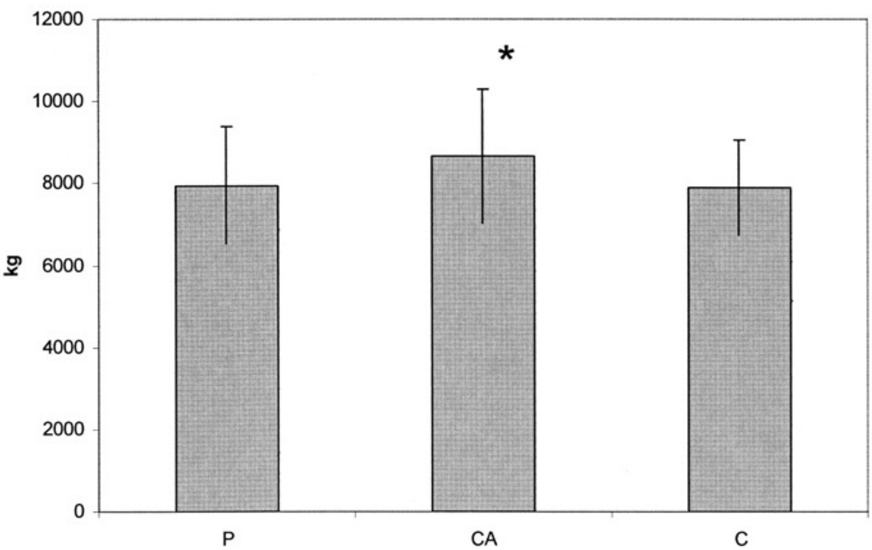
Figure 4 — (a) Δ 1-RM squat strength; (b) Δ 1-RM bench press strength; * $P < 0.05$ from P, ES > 0.89; data are presented as means ± standard deviation.

P. In addition, the average weekly volume of training in the squat exercise was significantly greater in CA in comparison to P.

The average weekly training intensity and volume for the bench press exercise can be seen in Figures 6, panels a and b, respectively. No significant between-



a



b

Figure 5 — (a) Average weekly training intensity (% 1-RM) squat exercise; (b) average weekly training volume squat exercise; * = $P < 0.05$ from P, ES > 1.47; data are presented as means ± standard deviation.

group differences were seen when comparing the average training intensity for the bench press exercise. However, when comparing the average training volume for the bench press exercise a significant difference was seen between CA and P.

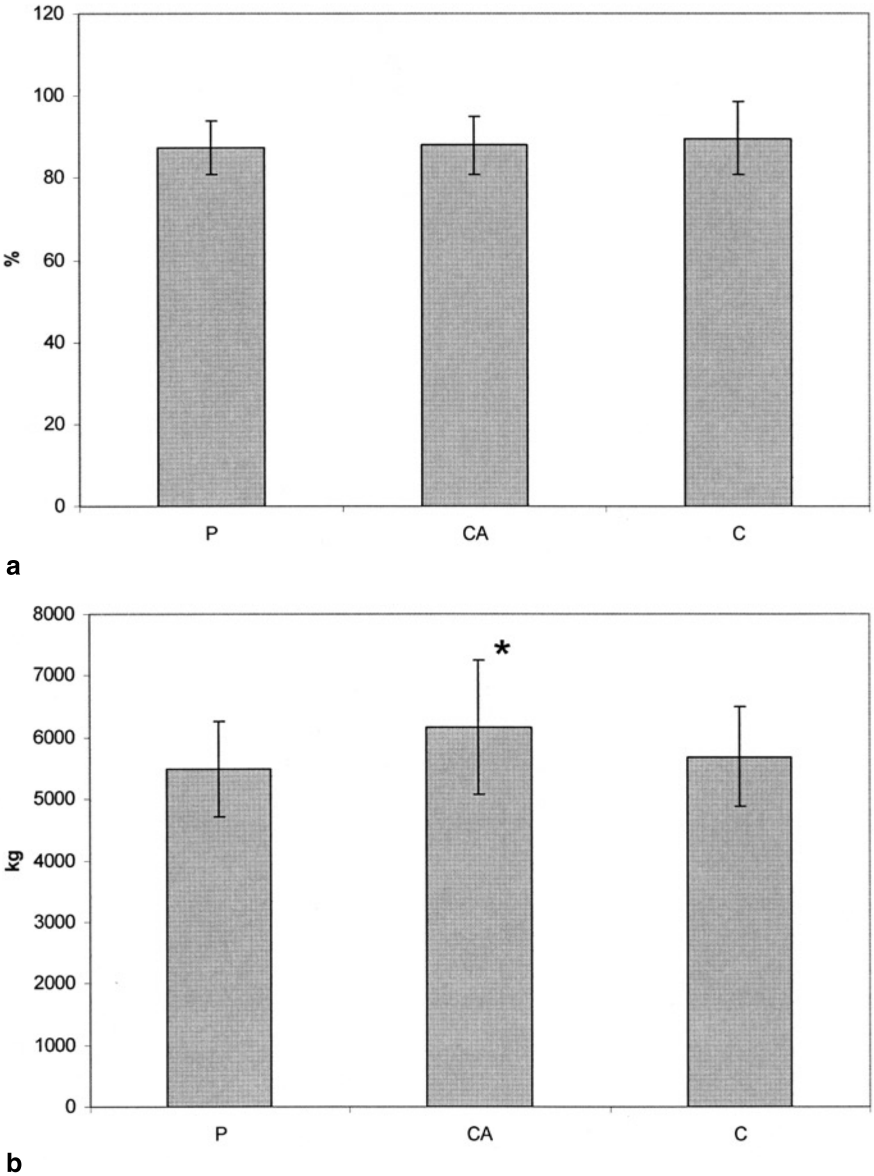


Figure 6 — (a) Average weekly training intensity (% 1-RM) bench press exercise; (b) average weekly training volume bench press exercise;* = $P < 0.05$ from P, ES = 0.78; data are presented as means ± standard deviation.

Anaerobic power measures can be seen in Table 2. No significant improvement was seen for any group in any of the performance measures assessed in the 20 jump or the Wingate Anaerobic Power tests. In addition, no significant differences between the groups were observed.

Endocrine measures can be seen in Table 3. Although no significant changes were seen in resting total testosterone concentrations in P and CA during the 10-wk study, a significant elevation in resting testosterone concentration was seen in C between PRE and POST. The differences between the groups though were not significant. In addition, the free testosterone index (FT index) calculated from the ratio of testosterone to SHBG demonstrated a trend ($P = 0.056$, ES = 0.53) towards an increase from PRE to POST in C. No other significant hormonal changes were seen, and no between group differences were noted.

Table 2 Anaerobic Power Performance Results

Variable	Group	PRE	POST
20-Jump Test Peak power (W/kg)	P	66.1 ± 12.1	63.4 ± 14.7
	CA	57.4 ± 9.4	56.9 ± 6.2
	C	62.6 ± 13.8	62.7 ± 10.1
20-Jump Test Mean power (W/kg)	P	53.2 ± 10.0	53.0 ± 9.3
	CA	49.8 ± 7.2	48.7 ± 5.6
	C	52.8 ± 12.1	54.8 ± 9.2
20-Jump Test Fatigue index (%)	P	63.0 ± 12.0	66.5 ± 19.8
	CA	73.6 ± 8.1	66.1 ± 14.9
	C	74.7 ± 10.7	73.8 ± 13.6
WAnT Test Average peak Power (W)	P	992 ± 232	1066 ± 255
	CA	990 ± 121	1024 ± 142
	C	991 ± 174	1053 ± 218
WAnT Test Average mean Power (W)	P	561 ± 76	591 ± 65
	CA	597 ± 42	612 ± 32
	C	564 ± 67	580 ± 66
WAnT Test Fatigue rates (W/s)	P	29.7 ± 7.7	30.1 ± 6.9
	CA	25.9 ± 5.5	26.8 ± 5.9
	C	27.5 ± 8.0	29.9 ± 8.2
WAnT Test Total work (J)	P	16,841 ± 2284	17,742 ± 1952
	CA	17,902 ± 1274	18,365 ± 952
	C	16,933 ± 2006	17,386 ± 1973

Values are means ± standard deviation; P = Placebo; CA = Creatine + β-alanine; C = Creatine.

Discussion

The results of this 10-wk study demonstrated the efficacy of creatine and creatine plus β-alanine on strength performance. The use of these supplements appeared to provide for a higher quality workout, and the addition of β-alanine to creatine

Table 3 Endocrine Measures

Variable	Group	PRE	POST
Testosterone (nmol/L)	P	21.8 ± 9.9	22.9 ± 11.5
	CA	23.2 ± 9.3	20.5 ± 8.6
	C	20.0 ± 5.9	24.4 ± 6.4*
Cortisol (nmol/L)	P	420 ± 138	468 ± 214
	CA	379 ± 145	408 ± 173
	C	421 ± 139	416 ± 162
Testosterone/cortisol ratio (10^3)	P	54.2 ± 21.7	53.5 ± 22.8
	CA	65.1 ± 27.0	56.8 ± 30.8
	C	52.4 ± 22.0	66.4 ± 30.6
SHBG (nmol/L)	P	72.2 ± 27.6	78.1 ± 30.5
	CA	88.8 ± 33.6	93.6 ± 44.4
	C	99.2 ± 54.2	100.0 ± 49.3
Free Testosterone Index (%)	P	36.8 ± 25.3	32.3 ± 17.2
	CA	29.8 ± 14.1	26.7 ± 16.3
	C	25.7 ± 15.3	31.5 ± 20.9
Growth Hormone (µg/L)	P	0.05 ± 0.05	0.13 ± 0.14
	CA	0.17 ± 0.33	0.21 ± 0.30
	C	0.05 ± 0.03	0.11 ± 0.12
IGF-1 (nmol/L)	P	69.3 ± 23.0	63.4 ± 15.1
	CA	79.8 ± 24.0	76.1 ± 19.4
	C	67.6 ± 26.2	63.3 ± 27.9

Values are means ± standard deviation; P = Placebo; CA = Creatine + β-alanine; C = Creatine; * = $P < 0.05$ pre vs. post, ES = 0.83.

appeared to enhance training volume more so than supplementing with creatine alone. In addition, β-alanine supplementation appeared to have the greatest effect on lean tissue accruement and improvements in body fat composition.

The significant strength improvements observed in this study are consistent with numerous other studies demonstrating the efficacy of creatine supplementation in competitive strength/power athletes (4, 8, 17, 20, 28, 30, 40). The ability of creatine supplementation to enhance strength is generally thought to be related to an elevated muscle creatine content (7, 16). As muscle creatine stores increase fatigue rates during exercise are thought to decrease, providing the athlete with a higher quality workout. Unfortunately, little information is available concerning workout performance in subjects supplementing with creatine. Most studies have focused primarily on performance outcomes. This appears to be one of the first investigations to demonstrate that a higher quality workout resulting from both creatine and creatine plus β-alanine supplementation may directly lead to greater strength performance. Subjects of both CA and C trained at an average exercise intensity in the squat exercise that was significantly higher than seen in P during the 10 wk training study. In addition, subjects in CA trained at an average weekly training volume that was significantly greater than subjects in P in both the squat and bench press exercises. Wilder and colleagues (40) showed that creatine supplementation can elevate exercise volume, but that these changes are primarily seen in the early phases of the training program. Our results indicate that these changes are significant throughout the 10 wk training program.

It does appear that the addition of β-alanine to creatine provides an additive benefit in reducing fatigue rates during training sessions compared to creatine alone. Previous research has demonstrated that β-alanine is involved with the synthesis of muscle carnosine (2, 3), and that oral ingestion of β-alanine may elevate muscle carnosine levels (5). Carnosine, a histidine-containing dipeptide, is known to contribute to acid-base buffering in skeletal muscle (23). It has also been shown that carnosine levels are greater in the vastus lateralis of sprinters compared to endurance athletes (27), and can be significantly elevated following sprint training (32). In addition, carnosine levels are significantly greater in the vastus lateralis of bodybuilders compared to untrained controls (35). Increasing muscle buffering capacity from a nutritional supplement, such as β-alanine, would likely provide a strength/power athlete the ability to withstand and maintain higher intensity workouts resulting in improved performance. The results of this study appear to support this hypothesis. In addition, Δ changes in lean body mass and percent body fat were significantly greater in CA compared to both P and C. Interestingly, the individual data responses do indicate a degree of variability within the treatment groups. This is consistent with previous research demonstrating that a certain percentage of subjects will not respond or be a quasi responder to creatine supplementation (34).

One of the effects generally associated with creatine supplementation is weight gain. Surprisingly, none of the experimental groups in this study experienced any significant gains in body mass. Caloric intakes in this study (3065 ± 728 kcal/d) were similar to those reported in other creatine supplementation studies using only male subjects that also failed to see any significant improvement in body mass (8, 17), but 200 to 1000 kcal/d lower than those studies reporting significant body mass gains (4, 36).

No significant changes were seen during the 10 wk training program in any of the power performance measures for C, CA, or P. Although creatine supplementation has been shown to significantly enhance power performance (4, 8, 17, 37), in most of those studies the power performance measures were often part of the subjects' normal training regimen. One study (4) has shown significant improvements in a power assessment (Wingate Anaerobic Power Test) when that exercise was not part of the training program. It is likely that the lack of specificity between the training program and exercises used to assess power performance was the primary factor that negated any potential effects of the supplement on power assessments.

An additional purpose of this study was to examine whether resting hormonal concentrations can be influenced by creatine and creatine plus β-alanine supplementation. A significant elevation in total testosterone concentrations was seen in this 10 wk training study for C only. In addition, a trend ($P = 0.056$) was seen for a greater free testosterone index in C as well, suggesting a greater availability of testosterone to interact with androgen receptors. It is difficult to explain why resting testosterone concentrations were elevated for C but not for CA. Although this may be related to the 16% difference ($P > 0.05$) seen between C and CA in testosterone concentrations at PRE, it may also reflect the inconsistency found in the literature concerning resting hormonal changes during prolonged training studies in experienced resistance-trained individuals. In the only other study evaluating resting endocrine function during creatine supplementation, cortisol concentrations were significantly elevated during the first week of creatine supplementation in an overreaching study, but no other significant interactions were seen during the 4 wk supplementation study for testosterone, GH, IGF, SHBG, and free testosterone index (39). The authors suggested that the elevated cortisol concentrations may have reflected the greater exercise volume that creatine supplementation may have promoted. Although they did not report any changes in exercise volume, the results seen in the present study suggest that a higher quality workout may also have contributed to their results.

The ability of experienced resistance-trained strength/power athletes to alter resting testosterone concentrations during a resistance training program is unclear. Several studies have reported significant elevations in resting testosterone concentrations (1, 12, 18), while others have reported no changes from baseline levels (10, 11). Even in elite weightlifters changes in resting testosterone concentrations are difficult to achieve, and only following prolonged training (2 y) have increases in resting testosterone concentrations been reported (12). A recent study demonstrated that resting testosterone concentrations in experienced resistance-trained athletes may be influenced by elevations in training volume (1). However, our results do not support the relationship between training volume and elevations in resting testosterone concentrations.

The responses of SHBG, GH, and IGF in this study were similar to that commonly found in the literature. Generally, a reduction (10, 24) or no change in resting SHBG concentrations have been reported following prolonged resistance training, while little to no change is generally seen in resting GH and IGF concentrations during prolonged resistance training programs (10, 18, 24). It is likely that changes in the acute response of these hormones and binding proteins to an exercise session would provide for a greater indicator of changes in endocrine response patterns to prolonged training programs. Interestingly, resting IGF concentrations seen in this study were relatively high, and appear to support previous research suggesting that IGF concentrations are elevated in experienced resistance-trained men (29)

Resting cortisol concentrations are generally used to provide a measure of the stress of a training program (14, 19). Results from studies investigating cortisol changes during prolonged resistance training have been inconsistent. During training programs that result in overreaching or insufficient recovery, elevations in cortisol concentrations can be seen (9). However, for resistance training programs that manipulate exercise intensity and volume to provide sufficient recovery, cortisol concentrations would be expected to remain relatively stable. The results of this study suggest that the training program employed was well tolerated. In further support, the T/C ratio, which serves as an endocrine marker of recovery and possibly the anabolic/catabolic properties of skeletal muscle (14, 19), was unchanged for all groups in this study.

In conclusion, the results of this 10 wk study demonstrate the efficacy of creatine and creatine plus β-alanine on strength performance. The use of these supplements appears to provide for a higher quality workout, and the addition of β-alanine appears to enhance training volume more so than creatine alone. In addition, β-alanine supplementation appears to have the greatest effect on lean tissue accruement and body fat composition. Supplementation did not alter resting hormonal concentrations. However, future studies should focus on the effect of creatine on the acute hormonal response to an exercise program.

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