Creatine supplementation combined with resistance training in older men

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ABSTRACT

CHRUSCH, M. J., P. D. CHILIBECK, K. E. CHAD, K. S. DAVISON, and D. G. BURKE. Creatine supplementation combined with resistance training in older men. *Med. Sci. Sports Exerc.*, Vol. 33, No. 12, 2001, pp. 2111–2117. **Purpose:** To study the effect of creatine (Cr) supplementation combined with resistance training on muscular performance and body composition in older men. **Methods:** Thirty men were randomized to receive creatine supplementation (CRE, $N = 16$, age $= 70.4 \pm 1.6$ yr) or placebo (PLA, $N = 14$, age $= 71.1 \pm 1.8$ yr), using a double blind procedure. Cr supplementation consisted of 0.3-g $Cr \cdot kg^{-1}$ body weight for the first 5 d (loading phase) and 0.07-g $Cr \cdot kg^{-1}$ body weight thereafter. Both groups participated in resistance training (36 sessions, 3 times per week, 3 sets of 10 repetitions, 12 exercises). Muscular strength was assessed by 1-repetition maximum (1-RM) for leg press (LP), knee extension (KE), and bench press (BP). Muscular endurance was assessed by the maximum number of repetitions over 3 sets (separated by 1-min rest intervals) at an intensity corresponding to 70% baseline 1-RM for BP and 80% baseline 1-RM for the KE and LP. Average power (AP) was assessed using a Biodex isokinetic knee extension/flexion exercise (3 sets of 10 repetitions at $60° \cdot s^{-1}$ separated by 1-min rest). Lean tissue (LTM) and fat mass were assessed using dual energy x-ray absorptiometry. **Results:** Compared with PLA, the CRE group had significantly greater increases in LTM (CRE, +3.3 kg; PLA, +1.3 kg), LP 1-RM (CRE, +50.1 kg; PLA +31.3 kg), KE 1-RM (CRE, +14.9 kg; PLA, +10.7 kg), LP endurance (CRE, +47 reps; PLA, +32 reps), KE endurance (CRE, +21 reps; PLA +14 reps), and AP (CRE, +26.7 W; PLA, +18 W). Changes in fat mass, fat percentage, BP 1-RM, and BP endurance were similar between groups. **Conclusion:** Creatine supplementation, when combined with resistance training, increases lean tissue mass and improves leg strength, endurance, and average power in men of mean age 70 yr. **Key Words:** ERGOGENIC AID, NEUTRACEUTICAL, HEALTH, EXERCISE, PHYSICAL ACTIVITY, STRENGTH, ENDURANCE, FATIGUE, ELDERLY

A rapid loss of muscular strength in adults after the age of 50 has been well documented (1,19) with muscle atrophy accounting for a portion of the strength decline (20,28). The loss of muscle size and strength may contribute to a decreased ability to perform activities of daily living and increased risk of falls (2,22,33). Older adults may prevent or limit this loss by increasing muscle size and strength through resistance exercise (5,10,16,27). However, the therapeutic benefits of resistance training are physiologically limited in older adults (18,32). One potential limitation may be that older adults contain lower concentrations of creatine and phosphocreatine, important primary energy-sources for performing high-intensity resistance activities (21,24).

Adults greater than 50 yr of age acutely supplemented with creatine have been found to have increased resting levels of intramuscular phosphocreatine and faster phosphocreatine resynthesis after exercise (24). This improvement in metabolism is reflected in greater muscular performance (24). One would expect that these acute increases in performance with supplementation would permit a more intense training and that this would translate into greater increases in strength and muscular mass during training. It seems confusing therefore that the only study to investigate the effects of creatine supplementation with resistance training (8 wk) in older adults found no added effect on body composition, strength, or muscular endurance as a result of creatine supplementation (4). Furthermore, several training studies in younger men and women have shown an ergogenic effect of creatine supplementation on resistance training adaptations (3,6,9,17,25,26,29,30). Thus, we feel there is a need for a longer (12 wk) training study in older men to help improve our understanding of the efficacy of creatine supplementation as an ergogenic aid in this population.

The purpose of this investigation was to examine the effects of creatine supplementation during resistance training in men aged 60–84 yr. Based on the potential for creatine supplementation to improve acute exercise performance in older men (23,24), we hypothesized that lean tissue mass and physical performance parameters would be enhanced with creatine supplementation during strength training in a group of older men of mean age 70 yr.

MATERIALS AND METHODS

Approach to the problem and experimental design. In the present study, a double-blind treatment placebo control design was used to make comparisons between subjects receiving a treatment (creatine) versus a placebo (carbohydrate mixture). To observe the effects of a 12-wk

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TABLE 1. Physical characteristics of subjects.

	Age (yr)	Height (cm)	Mass (kg)	Body Mass Index (kg·m^{-2})
CRE (N = 16)	70.4 ± 1.6	177.6 ± 1.7	88.0 ± 3.6	27.9 ± 1.1
PLA (N = 14)	71.1 ± 1.8	176.0 ± 1.2	79.9 ± 2.9	25.7 ± 0.7

Values are means ± SE.

resistance training program with and without creatine supplementation, subjects were randomly placed into either a creatine or placebo group. Major variables assessed in this study were physical performance measures (muscular strength, endurance, and power) of the upper and lower extremities and lean tissue mass. Muscular endurance and average power during repeated sets of exercise were chosen as performance measures because phosphocreatine levels have been shown to be important for prevention of fatigue during high-intensity exercise and recovery after high-intensity exercise (i.e., between sets) (7,12). The performance measures were gathered during pre-, mid-, and post-test periods, whereas lean tissue mass was assessed at only the pre- and post-test periods.

Study participants. Thirty-three sedentary to moderately active 60- to 84-yr-old men voluntarily participated in this study with written informed consent and physician approval. Descriptive characteristics are shown in Table 1. The study consisted of whole-body strength training and creatine supplementation. Three subjects, one receiving creatine and two receiving placebo, withdrew from the study as a result of reoccurring chronic degenerative knee or back injuries that prevented complete adherence to the required training and testing protocol.

During the preliminary testing or baseline (pre) period, participants were randomly assigned in a double-blind fashion to either an oral creatine (Cr) supplementation (CRE, N = 16) group or a placebo (PLA, N = 14) group, and participant characteristics such as age, height, and weight were recorded. Dietary intake and physical activity levels were estimated using a 3-d food record analyzed with FUEL Nutrition Software 2.1a (LogiForm International Inc., Saint-Foy, Quebec, Canada) and the Godin Leisure-Time Physical Activity questionnaire (11), respectively.

Creatine supplementation protocol. The CRE group was required to consume 0.3 g·kg^{-1} of body weight · d^{-1} of creatine for the first 5 d (loading phase; average dosages of 26.4 ± 1.2 g) as developed by Hultman and colleagues (13) and 0.07 g·kg^{-1} of body weight · d^{-1} of creatine thereafter, until completion of the final test period (maintenance phase; average daily dosage of 6.2 ± 0.3 g). The CRE group consumed creatine monohydrate powder with a sucrose-flour mixture to mask the substance. The PLA group consumed a sucrose-flour mixture with an equal portion of mix added in place of the creatine, making it indistinguishable in flavor, texture, and appearance to the CRE group's mixture. Supplements were divided into three equal portions within plastic Ziploc bags, and participants were encouraged to consume supplements during or after meals in approximately equal intervals throughout the day. Participants returned empty bags at every session, were reminded about proper compliance to the supplement consumption protocol, and given a new set of supplements to be consumed before the next training session. The consumption of supplements (creatine and placebo) began at the onset of the second week of the training sessions (session 4) and ceased after final posttesting was complete.

Resistance training program. A beginning whole-body resistance training program was performed by both groups (CRE and PLA) with supervision. Each training session began with a 5-min warm-up on a Monark (Ergomedic 818 E; Stockholm, Sweden) cycle ergometer and stretching exercises. Three sets of 10 repetitions with a 1-min break in between each set were performed for 12 different exercises. Exercises included: bench press, lat pull-down, shoulder press, bicep curl, back extension, and hip (extension, flexion, adduction, abduction) using Lever equipment (Pulse Fitness Systems; Winnipeg, Manitoba, Canada) and leg flexion, knee extension, and leg press using Hammer Strength equipment (Life Fitness; Franklin Park, IL). Training logbooks were given to each participant where expected training loads and total number of repetitions produced in each set were recorded by researchers and participants, respectively.

One practice session was provided for each participant before start of study. Proper breathing and form, with full range of motion was demonstrated and encouraged for the performance of each exercise. Participants were also advised to perform exercises consisting of large muscle groups before small muscle group exercises, continue normal activity and eating routines, and refrain from strenuous physical activities outside the exercise protocol of the present study.

The training sessions were performed three times per week for 12 wk (or 36 total exercise sessions). Attendance rate for resistance training participation was 95.3% and did not differ significantly between groups. At the start of the resistance training program, leg press, knee extension, and bench press exercises were performed at 50% of pre 1-RM, whereas all other exercises were performed at levels below 50% pre 1-RM. Training volumes for hip and back exercises were progressed throughout the study at equal levels for all participants. For all other exercises, the resistance was individually progressed during training sessions 3 to 13 and 18 to 31 by 5% or 2.2 kg (whichever was greater) once a subject was able to complete 10 repetitions on the third set. Tapering occurred during the three sessions before testing (i.e., sessions 14–16 and 32–34) at a 5% or 2.2-kg reduction (whichever was greater) in weight lifted. The rationale behind tapering was to ensure that participants were not hindered by training fatigue during the test periods performed the following week. Participants maintained their lowered

workloads during the first week of weight training (i.e., sessions 1–3, baseline) to reduce risk of injury and the mid- and post-test periods (i.e., sessions 16–18 and 34–36). Training volumes (kg·reps) for all except the hip and back exercises were recorded for both groups (CRE and PLA) at baseline (week 1) and intervention (i.e., supplementation period, weeks 2–12).

Body composition assessment. Headless estimations for bone-mineral free lean tissue mass, fat mass, and fat percentage were measured by whole-body dual-energy x-ray absorptiometry (DEXA; QDR-2000, Hologic, Inc., Waltham, MA) in array mode. Before scanning all participants were required to take off all removable objects containing metal (i.e., jewelry, glasses, clothing with buttons, and/or zippers). Scans were performed with subjects lying in a supine position along the scanning table's centerline longitudinal axis. Feet were taped together at the toes (i.e., first phalanges) to immobilize the legs while the hands were maintained in a pronated position within the scanning region. Scans were performed before and after the completion of the training-supplementation protocol. Reproducibility of the DEXA was determined on 10 male subjects assessed on two separate occasions. The correlation coefficient (r) for lean and fat tissue mass was 0.99, and the coefficients of variation were and 0.54% for lean and 2.95% for body fat mass.

Muscular strength, endurance, and power testing. All muscular performance testing occurred after the completion of a 5-min warm-up on a Monark (Ergomedic 818 E) cycle ergometer and stretching exercises. Muscular strength, endurance, and power were tested on three separate days before training (pre), at the mid-point (mid) of training, and on the final week of training (post). Mid-testing occurred after 28 d of supplementation on the days of but before the scheduled training sessions 16, 17, and 18. Posttesting occurred during the last week of training after 70 d of supplementation on the days of but before the scheduled training sessions 34, 35, and 36.

On the first day of testing, muscular strength was assessed using one-repetition maximum (1-RM) testing for leg press, knee extension, and bench press exercises. Exercise testing continued in the same order as pre for mid and post periods. The 1-RM protocol consisted of an eight-repetition set with low weight and a 1-min break before the first 1-RM attempt. Weight was then progressively increased and a 2-min rest period was given between each subsequent 1-RM attempt. Subjects were permitted four to six attempts to determine the 1-RM value. Each test exercise was separated with a 3-min rest break. Reproducibility of the strength measures was assessed on 10 subjects from the study sample on two separate occasions, 2 d apart. The leg press, bench press, and knee extension strength measures had interclass correlation coefficients of 0.99, 0.99, and 0.96, respectively, and method errors, expressed as coefficients of variation of 3.0%, 3.6%, and 3.3%, respectively.

On day 2, leg press, knee extension, and bench press muscular endurance performances were determined as the maximum number of repetitions that could be performed during three sets separated by 1-min rests. Each test was separated with a 3-min rest break, and exercise testing continued in the same order during each test period. Participants warmed up with one set of eight repetitions at 50% of pre 1-RM with a 2-min break before muscular endurance testing began. Resistance corresponded to 70% pre 1-RM for the bench press and 80% pre 1-RM for the leg press and knee extension exercises. The different percentages of 1-RM used for the muscular endurance tests took into account previous observations that for a given percentage of 1-RM, more repetitions can be performed during lower body exercises as compared to upper body exercises (8). Reproducibility was assessed on eight subjects from the study sample on two separate occasions, 2 d apart. The leg press, bench press, and knee extension endurance measures had interclass correlation coefficients of 0.95, 0.90, and 0.95, respectively, and method errors, expressed as coefficients of variation, of 9.6%, 7.5%, and 16.7%, respectively.

On day 3, muscular endurance and fatigue were further assessed by measuring average power for the knee extensors and flexors of the dominant leg over three sets of 10 repetitions at $60°\cdot s^{-1}$ on an isokinetic dynamometer (Biodex System 3, Biodex Medical Systems Inc., Shirley NY). One-minute rest periods were enforced between sets. Range of motion consisted of movement from 90° to 10° of knee flexion. Subjects sat against a back support, producing an angle of 85° of hip flexion. Stabilizing belts were placed over the lap, across the chest, and across the distal one-third of the tested leg thigh. The rotational axis of the dynamometer was positioned to be coaxial with the knee axis (lateral epicondyle) during testing. Torque measures were corrected for the effects of gravity on the lower leg and the dynamometer's resistance pad. The torque output on the dynamometer was checked with a calibration weight on a weekly basis throughout the study. Reproducibility was assessed on 11 subjects on two occasions, 2 d apart. The average power measure used had an interclass correlation coefficient of 0.97 and a coefficient of variation of 4.3%.

Retrospective creatine side effects and treatment identification assessment. A retrospective creatine side-effect assessment and treatment identification were administered to all the participants upon completion of the study. The retrospective assessment consisted of yes-no responses based on anecdotal reports concerning energy level, everyday strength, muscle fatigue or soreness, stiffness or tightness and pulls or strains, joint soreness, headaches, emotional states, feelings of physical appearance, sleep quality, gastrointestinal function abnormalities, appetite, thirst, and sex drive (14,15). The magnitude and week of occurrence of each reported side effect was also assessed. The use of the treatment identification was also assessed to see whether participants perceived they were on creatine, placebo, or were unsure what supplement they consumed.

Analysis of data. A two (creatine and placebo groups) $\times$ three (pre-, mid-, and post-test periods) ANOVA was used for the strength, endurance, power, and scale body mass variables. A two $\times$ three ANCOVA was used to analyze bench press strength, with baseline measurements

TABLE 2. Body mass before, at mid-point and after 12 wk of progressive resistance training.

Body Mass (kg)	Pre	Mid	Post
CRE	88.0 ± 3.6	89.4 ± 3.8*	91.0 ± 3.8*†
PLA	79.9 ± 2.9	80.2 ± 2.9	79.9 ± 2.8

Values are means ± SE.
* $P < 0.05$ significantly different from pre value.
† $P < 0.05$ significantly different from mid value.

as a covariate, because differences were observed at baseline in this measure between groups. A two (creatine and placebo groups) × two (pre- and post-test periods) ANOVA was used for body composition variables. Multiple comparison testing using Tukey *post hoc* analysis was used, when significant differences were confirmed with ANOVA testing, to assess where differences occurred between means. Unpaired *t*-tests were used to determine potential differences between groups for baseline variables, treatment identification, and training volumes. Unpaired *t*-tests with Bonferroni adjustments were used to assess retrospective side effects. Significance was set at an alpha level of 0.05 for all statistical tests.

RESULTS

Participant characteristics. No differences in baseline physical characteristics between groups were found (Table 1). Both groups were determined to have previously participated in similar levels of strenuous, moderate, and mild physical activity. Daily energy intake (CRE, 2138.6 ± 145.6 kcal; PLA, 2173.7 ± 123.1 kcal) and dietary protein per kilogram body mass (CRE, 0.98 ± 0.07 g; PLA, 1.07 ± 0.08 g) were also similar between groups.

Body composition. There were no differences in body composition measures between groups at baseline. Changes in body mass and body composition with training are shown in Tables 2 and 3, respectively.

There was a significant group × time interaction for body mass ($P < 0.001$). Body mass was greater in the CRE group compared with the PLA group at mid- and post-testing ($P < 0.05$).

A significant group × time interaction was observed for lean tissue mass ($P < 0.001$), with the change over the training period greater in the CRE compared with the PLA group (Fig. 1). The CRE group had significantly higher lean tissue mass compared with the PLA group posttraining ($P < 0.05$). Group × time interactions were not significant for fat mass or percent body fat.

TABLE 3. Body composition before (pre) and after (post) 12 wk of progressive resistance training.

Characteristic	Pre	Post
Lean mass (kg)		
CRE	54.2 ± 1.6	57.5 ± 1.7*
PLA	50.8 ± 1.4	52.1 ± 1.3*
Fat mass (kg)		
CRE	25.7 ± 2.6	24.5 ± 2.6*
PLA	20.5 ± 1.8	19.0 ± 1.8*
Body fat (%)		
CRE	30.4 ± 1.8	28.3 ± 2.6*
PLA	27.4 ± 1.6	25.5 ± 1.5*

Values are means ± SE.
* $P < 0.05$ significantly different vs corresponding pre value.

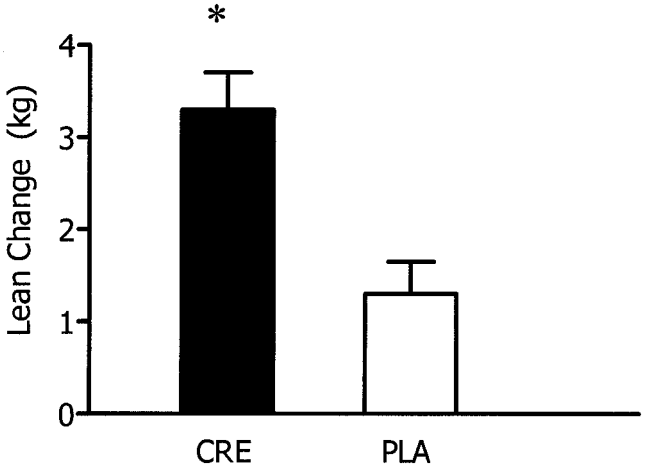

FIGURE 1—Change in lean tissue mass with 12 wk of strength training in creatine (CRE) and placebo (PLA) groups. *Bars* are means ± SE. * Significantly greater than PLA.

Muscular strength, endurance, and average power. There were no differences in any of the baseline strength, endurance, or average power measures between groups, with the exception of bench press strength, which was greater in the CRE group ($P = 0.05$). As subjects were randomly assigned to groups, we attribute this difference to a chance occurrence. Changes in muscular endurance, strength and power with training are shown in Figures 2, 3, and 4, respectively.

A significant group × time interaction was observed for leg press ($P < 0.03$) and leg extension ($P = 0.05$) strength but not for bench press strength. The CRE group had significantly greater leg press strength at mid and post-test periods compared with the PLA group ($P < 0.05$).

A significant group × time interaction was observed for leg press ($P < 0.01$) and leg extension ($P < 0.04$) endurance but not for bench press endurance ($P = 0.09$). For leg press endurance, the CRE group had a significantly greater number of total repetitions than PLA at the posttest period ($P < 0.05$). For leg extension endurance, a significantly greater number of total repetitions was indicated at mid- and post-test periods for the CRE group over PLA ($P < 0.05$).

Changes in average power (W) with training are shown in Figure 4. A significant group × time interaction was observed for average isokinetic knee extension/flexion power ($P < 0.02$).

Resistance training volume. No differences in baseline training volumes were noted between groups. Training volumes during the intervention period were 31% greater ($P = 0.05$) in the creatine group (267,914 ± 18,055 kg·reps) compared with the placebo group (227,693 ± 15,704 kg·reps).

Retrospective creatine side effects and treatment identification assessment. Three side effects were significantly more frequent within the creatine than placebo group. Loose stools ($P < 0.01$) was a negative side effect reported during the loading phase (week 1) of supplementation, whereas increased muscle cramping

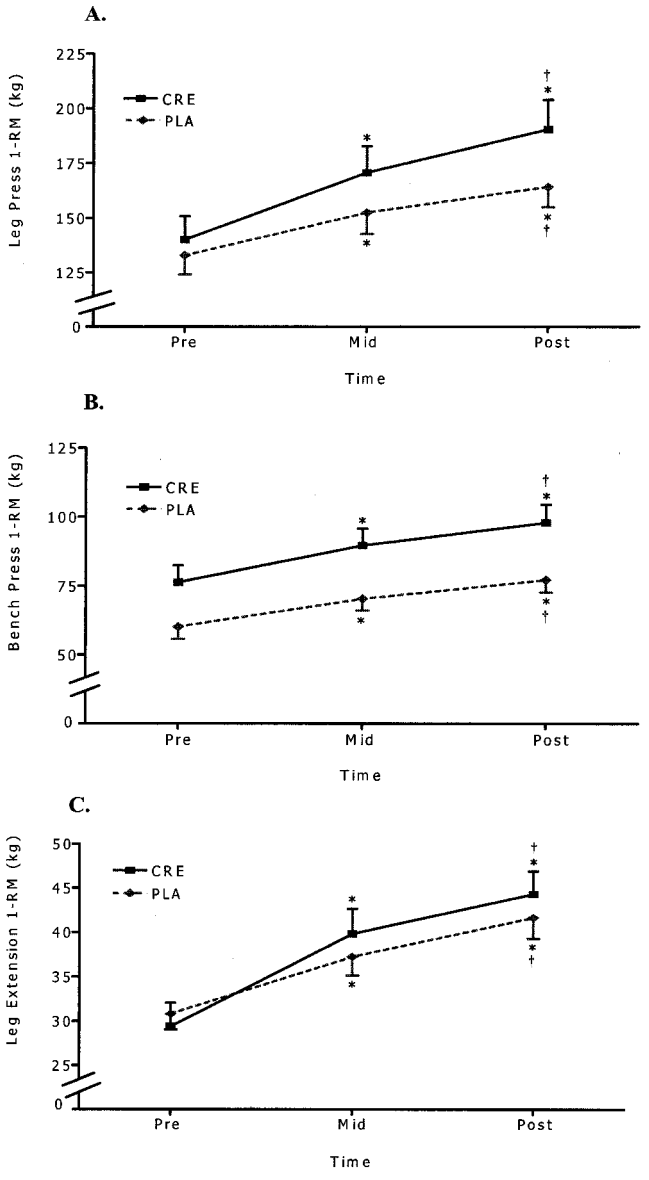

FIGURE 2—Muscular strength (1-RM) for (A) leg press, (B) bench press, and (C) leg extension for creatine (CRE) and placebo (PLA) groups. Values are means ± SE. * Significantly different from pre values. † Significantly different from mid values.

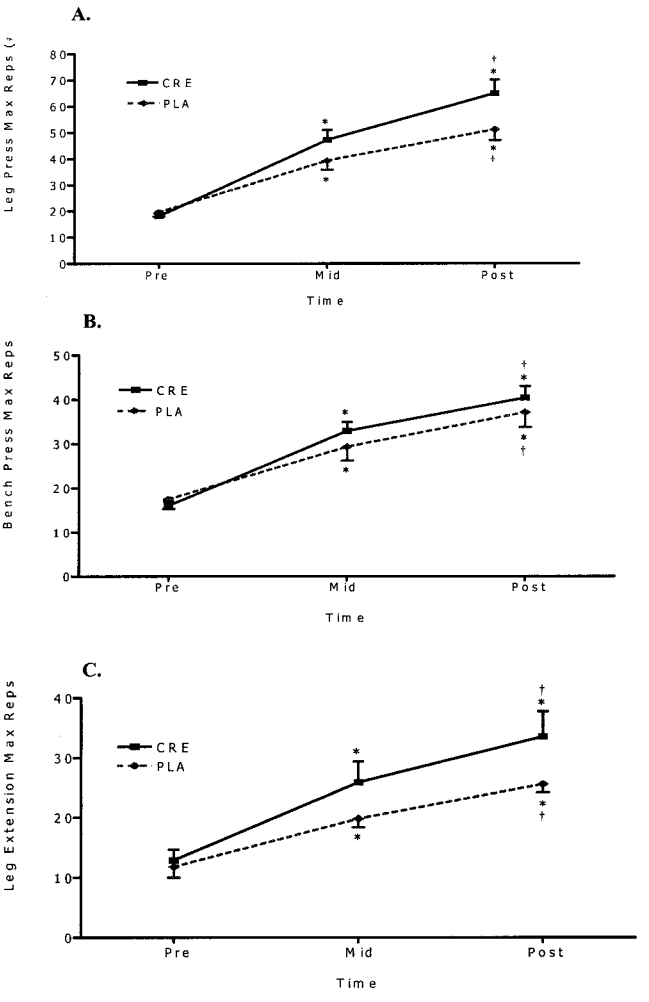

FIGURE 3—Muscular endurance (maximal repetitions over 3 sets) for (A) leg press, (B) bench press, and (C) leg extension for creatine (CRE) and placebo (PLA) groups. Values are means ± SE. * Significantly different from pre values. † Significantly different from mid values.

($P < 0.01$) and muscle pull or strain ($P < 0.01$) were negative side effects that began between weeks 3 and 5 of creatine supplementation. Individuals experiencing negative side effects continued to follow the standardized training program and had training volumes and test performances similar to individuals who did not experience these side effects.

No significant difference was noted in treatment identification between groups as half the participants indicated they did not know whether they were on the supplement (CRE, 56.3%; PLA, 42.9%). Correct treatment identification for the CRE and PLA groups were 31.3% and 42.9%, respectively.

DISCUSSION

The current study is the first to demonstrate an ergogenic effect of creatine supplementation during strength training in older men (mean age 70 yr). Muscular strength, endurance, and power of the lower body and lean tissue mass were enhanced with supplementation. We hypothesized that creatine supplementation would be ergogenic during resistance training in older men based on a previous finding that supplementation increased intramuscular phosphocreatine levels and acute muscular performance in men over 50 yr of age (24). Phosphocreatine availability has been shown to be important for prevention of fatigue during moderate- to high-intensity exercise (7,12). We therefore predicted that supplementation with creatine would allow older men to train with a higher volume, resulting in enhanced muscular performance and lean tissue mass during 12 wk of strength training. Our hypothesis was clearly supported in that older men taking creatine supplementation were able to train with a 31% greater volume and that measures of muscular performance and lean tissue mass were enhanced. Our study supports the use of creatine for men of mean age 70 yr and is consistent with previous studies using other subject populations (3,6,9,17,25,26,29,30).

Only one previous study has looked at the effects of prolonged creatine supplementation and training with older

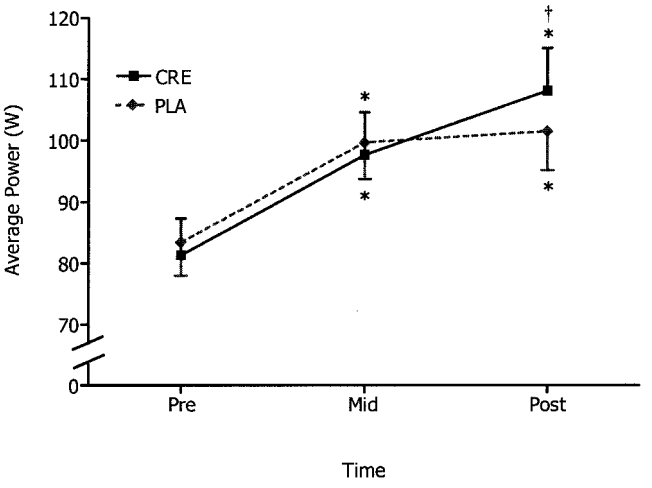

FIGURE 4—Average power for knee extension and flexion (3 sets of 10 repetitions) for creatine (CRE) and placebo (PLA) groups. * Significantly different from pre values. † Significantly different from mid values.

adults (4). Bermon and colleagues (4) studied the effects of creatine supplementation in older men and women with and without 8 wk of resistance training. Creatine supplementation added no benefits to body composition estimated by skin folds, maximal strength (1-RM), dynamic endurance (12-RM), and isometric intermittent endurance upon completion of the study (4). However, one should note that the Bermon et al. (4) study contained four nongender-specific subgroups (creatine-training, placebo-training, creatine-no training, and placebo-no training) with low subject numbers ($N = 8$) that may have reduced the power necessary for detecting significant differences resulting from creatine supplementation.

The only muscular performance measures that were not improved with creatine supplementation in the current study were bench press strength and endurance. This lack of enhancement in strength and endurance compared with the lower body tests is most likely due to the type of resistance training program employed. The program used one upper body exercise for the chest and triceps muscle groups (bench press), whereas a greater number of exercises were used for the lower body (i.e., leg extension and leg press). Thus, training one leg exercise could have contributed to the performance improvements in the other (leg press training may have enhanced leg extension performance and *vice versa*). The lack of enhancement in bench press performance may also be related to the lesser ability of older individuals to respond to bench press compared with leg training. Two studies that compared adaptations to bench press and leg press training in older male subjects demonstrated equivalent changes in strength for the two exercises (5,27); however, change in leg press muscular endurance (maximum number of repetitions) was more than double the change in bench press muscular endurance (5). The type of "tapering" that we used before testing occasions may have affected leg and bench press performance differently. There may be some threshold of training intensity below which the additive effects of creatine supplementation are not realized, and maybe this threshold was not met by the upper-body training program used in this study. An alternative explanation for the lack of enhancement in strength in the bench press is the higher initial levels of strength in the creatine-supplemented group. This would allow for a smaller potential for improvement compared with the placebo group. An enhancement in strength with supplementation may also have been masked because of a rapid learning effect when performing this exercise. Only one practice session was given to subjects before baseline testing; this may not have been sufficient to overcome the influence of learning on the early gains in strength (8). Our failure to demonstrate an enhancement in bench press muscular endurance may be due to a lack of statistical power. The CRE group tended ($P = 0.09$) to have an enhancement in muscular endurance above that of the PLA group over the first half of the study, with an improvement of 101% compared to 67% (Fig. 3B). A greater number of subjects may have been required to achieve a level of statistical significance.

As mentioned above, one limitation of this study was that only one practice session was given before baseline strength measurements were taken. This may have resulted in a rapid learning effect at the start of the study, which may have masked any differences in bench press strength due to creatine supplementation. Two to four weeks may be necessary to overcome a learning curve, especially in older adults unaccustomed to strength training. Despite this limitation, we were still able to demonstrate an ergogenic effect of creatine on measures of muscular strength and endurance in the lower body. An adequate practice phase before baseline testing may have allowed for detection of an even greater ergogenic effect of creatine than that observed.

In the current study, side effects reported by our creatine-supplemented subjects were few and minor (i.e., loose stools, cramping, pulls, or strains). These were not serious enough to impair progression of training or enhancement of muscular performance and lean tissue mass. Volek et al. (31) recently administered a similar questionnaire on side effects in a younger population supplemented with a similar dose of creatine as that used in the current study. They did not report any side effects among their subjects. The few side effects reported by our older men are difficult to explain, and our questionnaire is limited in that it is highly qualitative and does not indicate a mechanism by which side effects may be occurring. Therefore, the few minor side effects that were reported should be interpreted with caution.

In conclusion, our study demonstrated that creatine supplementation augments muscular performance and lean tissue adaptations to resistance training in untrained older men during a beginning strength training program. Creatine supplementation used in conjunction with resistance training in trained older men, or with longer resistance training programs (i.e., years), may allow for an even greater enhancement of adaptations in strength performance, an endeavor

that warrants further investigation in the interest of improving our understanding of healthy aging for men.

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