Original Research

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Effect of Ceasing Creatine Supplementation While Maintaining Resistance Training in Older Men

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The authors previously found that creatine (Cr) combined with 12 weeks of resistance training enhanced muscle strength and endurance and lean tissue mass (LTM) in older men. Their purpose in this study was to assess these variables with cessation of Cr combined with 12 weeks of reduced training (33% lower volume) in a subgroup of these men ($n = 8$, 73 years old) compared with 5 men (69 years old) who did not receive Cr. Strength (1-repetition maximum [1-RM]), endurance (maximum number of repetitions over 3 sets at 70–80% 1-RM), and LTM (dual-energy X-ray absorptiometry) were assessed before and after 12 weeks of Cr cessation combined with reduced-volume training. No changes in strength or LTM occurred. Muscle endurance was significantly reduced (7–21%; $p < .05$), with the rate of change similar between groups. Withdrawal from Cr had no effect on the rate of strength, endurance, and loss of lean tissue mass with 12 weeks of reduced-volume training.

Key Words: ergogenic, strength, dual-energy X-ray absorptiometry, muscle, age

Creatine supplementation for improving strength and muscle mass is an area of increasing interest. Most research has examined its effect on strength (Vandenberghe et al., 1997), muscle metabolism (Greenhaff, Bodin, Soderland, & Hultman, 1994), and high-intensity exercise performance in younger individuals, but there are still questions regarding the effect of creatine on older adults (Bermon, Venembre, Sachet, Valour, & Dolisi, 1998; Rawson & Clarkson, 2000). Research is also lacking as to the effect of creatine-supplementation cessation on muscle performance and lean tissue mass.

Research on older adults has reported decreases in muscle mass (Lindle, Metter, & Lynch, 1997; Tzankoff & Norris, 1977), strength (Aniansson, Hedberg, Henning, & Grimby, 1986; Larsson, Grimby, & Karlsson, 1979), endurance (Smith et al., 1998), and high-energy phosphate metabolism (Smith et al., 1998). As a result, significant declines in muscle performance can occur (Rawson, Wehnert, &

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Clarkson, 1999). Dietary creatine supplementation has been reported to increase muscle mass (Burke et al., 2001; Vandenberghe et al., 1997) and muscle performance (Burke et al., 2000; Earnest, Snell, Rodriguez, Almada, & Mitchell, 1995; Krieder et al., 1998) in younger individuals. Research on older adults, however, has been equivocal. Some report an ergogenic effect from creatine supplementation (Brose, Parise, & Tarnopolsky, 2003; Chrusch, Chilibeck, Chad, Davison, & Burke, 2001; Gotshalk et al., 2002; Rawson & Clarkson, 2000; Rawson et al. 1999; Smith et al., 1998; Wiroth et al., 2001), and others report minimal or no benefit (Bermon et al., 1998; Eijnde et al., 2003; Jakobi, Rice, Curtin, & Marsh, 2001). We recently showed that 12 weeks of creatine supplementation combined with resistance training enhanced muscle strength and endurance and lean tissue mass in older men, compared with resistance training alone (Chrusch et al.). This might be the result of older adults having reduced muscle creatine concentrations (Moller, Bergstrom, Furst, & Hellstrom, 1980; Smith et al., 1998) because of diet modifications or physical inactivity (Harris, Soderland, & Hultman, 1992).

Although most research regarding creatine supplementation relates to muscle performance, only a few studies have examined the effect of creatine-supplementation cessation on these variables in any population. Young men who supplemented with creatine during 6 weeks of resistance training had significant gains in muscle strength and lean tissue mass. Continuing training for an additional 6 weeks without supplementation did not reduce these positive gains (Burke et al., 2001). In a group of female volunteers who resistance trained and supplemented with creatine for 10 weeks, muscle phosphocreatine (PCr) concentration, arm-flexion torque, lean tissue mass, and muscle strength all increased. Withdrawal from creatine after 4 weeks caused arm-flexion torque and muscle PCr concentration to decline to baseline levels (Vandenberghe et al., 1997). In participants who supplemented with creatine at a rate of 20 g/day for the first 6 days and then 2 g/day for an additional 30 days, muscle total creatine concentration was elevated by 20%. Withdrawal from creatine of 2 g/day caused a gradual decline in muscle total creatine concentration so that 30 days after supplementation, concentrations matched those of presupplementation values (Hultman, Soderland, Timmons, Cederbald, & Greenhaff, 1996).

The aim of the present study was to determine whether creatine-supplementation cessation with maintenance of total-body resistance training would result in a decrease in muscle strength and endurance and lean tissue mass. This was accomplished by comparing two groups of older men on identical strength-training programs: one group who had previously supplemented with creatine and a second group who had not. This research is important for developing guidelines for creatine-dosing schedules. Individuals taking creatine often take it in cycles, wherein they consume creatine for a period of time and then cease supplementation for a period of time because of fears of possible long-term side effects of creatine usage (Juhn & Tarnopolsky, 1998), down-regulation of the muscle creatine transporter (Guerrero-Ontiveros & Wallimann, 1998), and the costs of supplementation. When intramuscular creatine levels are increased, it takes about a month before levels decline to baseline after supplementation ceases (Hultman et al., 1996). In theory, one could therefore supplement with creatine for a given time period and then cease supplementation for a time without losing benefits previously gained.

We had previously shown that 6 weeks of creatine cessation did not reduce the gains made during supplementation in young men (Burke et al., 2001). The purpose of this study was to determine whether 12 weeks of creatine cessation would affect gains previously made during supplementation in a group of older men.

Methods

PARTICIPANTS

Thirteen healthy men (age 61–83 years) volunteered to participate in the study. The study was approved by the Ethics Review Board of the University of Saskatchewan, Saskatoon, SK, Canada. The participants were informed of the risks and purposes of the study before their written consents were obtained. All participants had previously been involved in a 12-week study examining the effects of creatine supplementation combined with total-body resistance training (Chrusch et al., 2001). The supplementation period used a double-blind repeated-measures design in which every participant participated in strength training and was randomized to a creatine or placebo treatment condition. The final testing values recorded at the end of the 12-week supplementation phase were used as baseline measures for this study.

EXPERIMENTAL GROUPS

The creatine-cessation group consisted of 8 participants (age 73 ± 6.5 years, body mass 87 ± 5.2 kg) who had previously trained and supplemented with creatine monohydrate powder for twelve weeks (0.3g/kg body weight/day for 5 days; 0.07g/kg body weight/day thereafter) (Chrusch et al., 2001). For the present study, they trained an additional 12 weeks with no supplementation

The placebo group consisted of 5 participants (age 69 ± 7.6 years, body mass 76.2 ± 9.8 kg) who had previously trained and supplemented with placebo for 12 weeks. For the present study they continued to train an additional 12 weeks with no supplementation.

Before training sessions, each participant warmed up for 5 min on a stationary Monark (Ergomedic 818E, Stockholm, Sweden) cycle ergometer and completed light stretching before exercise. Proper breathing technique with full range of motion was demonstrated and encouraged for each exercise. Participants were advised to perform exercises using large muscle groups before small-muscle-group exercises. Resistance exercises included leg press, leg (knee) extension, and leg (knee) flexion using Hammer Strength® equipment (Life Fitness, Franklin Park, IL) and bench press, shoulder press, lateral pull-down, biceps curl, back extension, and hip extension, flexion, adduction, and abduction using lever equipment (Pulse Fitness Systems, Winnipeg, MB, Canada). Participants trained 2 days/week (at least 48 hr apart) for three sets of 10 repetitions with 1-min rests between sets for each exercise at an intensity corresponding to approximately 70% one-repetition maximum (1-RM) for the leg press, bench press, and knee extension and at a resistance corresponding to their 10-RM for remaining exercises. All training sessions were supervised by qualified kinesiologists, and all participants maintained daily training logs in which expected training loads and total number of repetitions produced in each set were recorded by researchers and participants, respectively. Resistance was increased by 2.3 kg once a participant could complete three sets of 10 repetitions for an exercise with good form.

MUSCLE STRENGTH

Muscle strength was assessed using 1-RM testing for leg press, leg extension, and bench press at baseline and after 12 weeks. These three exercises were chosen for strength and muscle-endurance testing (described following) because they involve most of the major muscle groups in the upper and lower body. The warm-up consisted of one set of eight repetitions with low weight. Weight was then progressively increased for each subsequent 1-RM attempt followed by a 2-min rest interval. The 1-RM was usually reached in three to five trials. Two assistants changed the weight on the machine between sets. All test exercises for leg press, leg extension, and bench press were separated by 3-min rest intervals. Reproducibility of the strength measures was assessed on 10 participants from the study sample on two separate occasions, 2 days apart. The leg-press, leg-extension, and bench-press strength measures had coefficients of variation of 3.0%, 3.3%, and 3.6%, respectively (Chrusch et al., 2001), and there were no significant differences between measurements made on different days.

MUSCLE ENDURANCE

Forty-eight hours after strength testing, all participants were brought back into our laboratory for muscle-endurance testing. Leg-press, leg-extension, and bench-press muscle endurance were assessed by the total number of repetitions that could be performed to volitional fatigue during three sets separated by 1-min rest intervals. The order of testing was adhered to, and test exercises were separated by 3-min rest intervals. All participants warmed up with one set of eight repetitions corresponding to 50% pre-1-RM with a 2-min rest interval before testing began. Resistance corresponded to 80% 1-RM for leg press and leg extension and 70% 1-RM for bench press. The difference in 1-RM percentages took into account previous observations that for a given percentage of 1-RM, more repetitions could be performed with lower extremity muscle groups than with upper body muscle groups (Chilibeck, Calder, Sale, & Webber, 1998). Reproducibility was assessed on 8 participants from the study sample on two separate occasions, 2 days apart. Leg press, leg extension, and bench press had coefficients of variation of 9.6%, 16.7%, and 7.5%, respectively (Chrusch et al., 2001), and there were no significant differences between measurements on different days.

LEAN TISSUE MASS

Lean tissue mass was assessed by whole-body dual-energy X-ray absorptiometry (DXA; QDR-2000, Hologic, Inc., Waltham, MA) in array mode and analyzed (excluding the head region) using System 7.01 software. The same technician analyzed all DXA scans. Scans were performed with the participant lying in the supine position along the table's longitudinal centerline axis. Reproducibility was determined on 10 participants on two separate occasions. The coefficient of variation for lean tissue mass was 0.54% (Chrusch et al., 2001). Body weight was measured on a Toledo scale, accurate to the nearest 0.1 kg.

STATISTICAL ANALYSIS

A 2 (creatine-cessation and placebo groups) × 2 (post-creatine-supplementation Week 0 and Week 12) ANOVA with repeated measured on the second factor was used to determine whether there were any differences 12 weeks after creatine supplementation for the dependent variables of strength, endurance, and lean tissue mass. All results were expressed as mean ± standard error. Statistical significance was set at $p < .05$. Statistical analyses were carried out using SPSS® version 10.02 for Windows®.

Results

No differences in physical characteristics between groups were found (Table 1).

MUSCLE STRENGTH

For both groups, there were no significant changes in strength over time (Figures 1–3). There were no significant Group × Time interactions because the rate of change between groups was similar. For differences in relative changes between groups (Figures 1–3), statistical power was adequate (where adequate is defined as 80%) at 85% for bench press, 93% for leg press, and 91% for leg extension.

MUSCLE ENDURANCE

There was a time main effect ($p < .05$) for all measures of muscle endurance, with both groups experiencing decreases in performance (Figures 4–6); again, though, there were no Group × Time interactions. The creatine-cessation group had relative decreases of 22% for bench press (Figure 4), 20% for leg press (Figure 5), and 9% for leg extension (Figure 6). The placebo group decreased by 8% for bench press, 10% for leg press, and 21% for leg extension. For the differences in relative changes between groups, statistical power was adequate or close to adequate at 77% for bench press, 76% for leg press, and 88% for leg extension.

Table 1 Physical Characteristics of Participants, *M* ± *SE*

Group	Age (years)	Height (cm)	Weight (kg), Week 0	Weight (kg), Week 12
Creatine cessation, *n* = 8	73 ± 6.5	181.1 ± 5.4	87.0 ± 5.2	86.3 ± 4.99
Placebo, *n* = 5	69 ± 7.6	178.3 ± 3.6	76.2 ± 9.8	74.6 ± 3.91

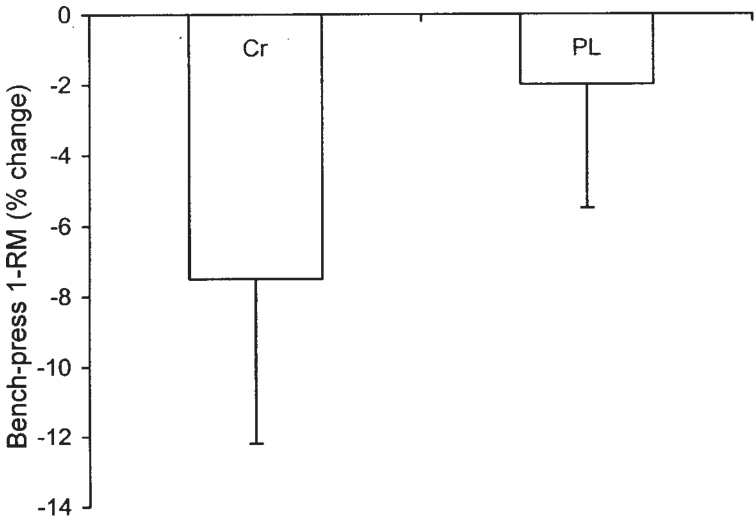

Figure 1. Bench-press strength changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are *M* ± *SE*. No significance difference between groups.

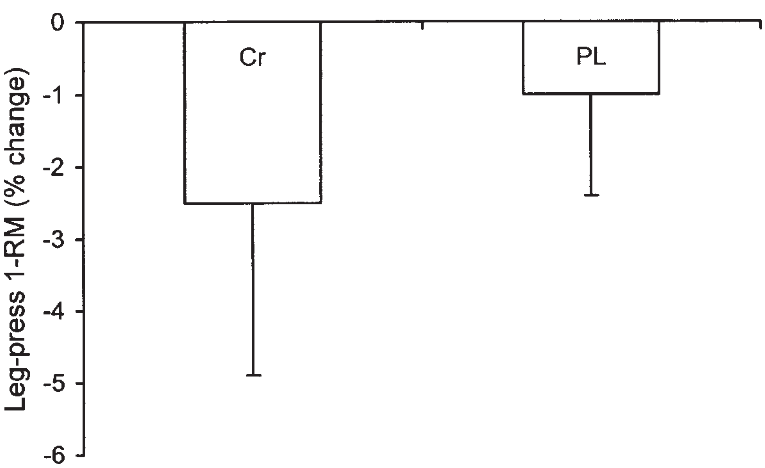

Figure 2. Leg-press strength changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are *M* ± *SE*. No significance difference between groups.

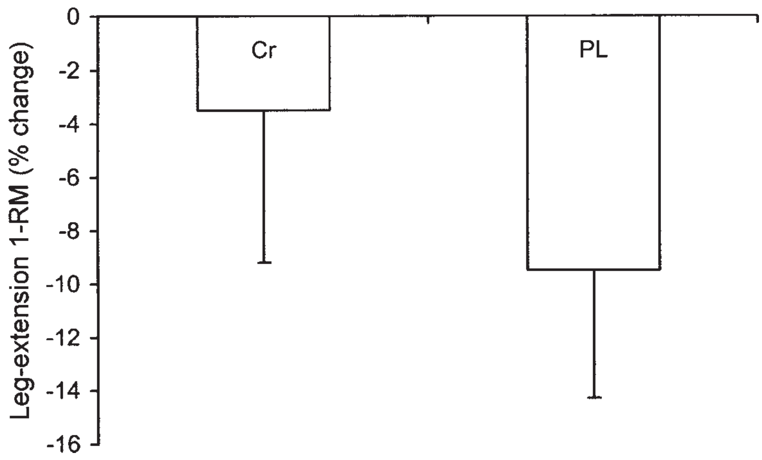

Figure 3. Leg-extension strength changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are *M* ± *SE*. No significance difference between groups.

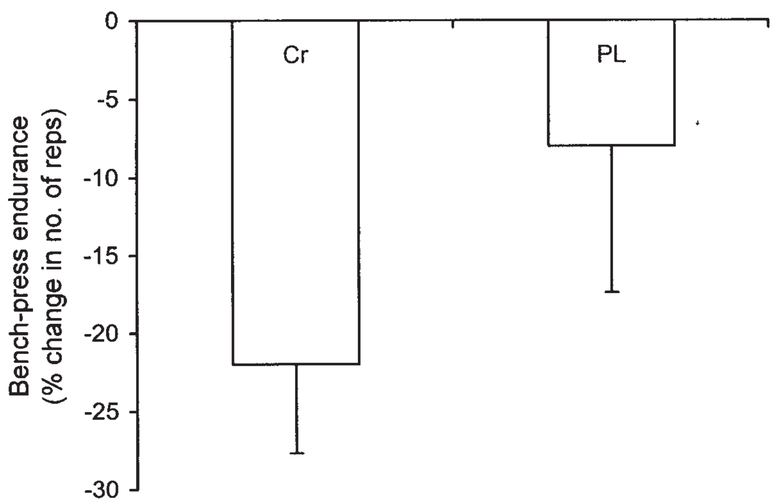

Figure 4. Bench-press muscle-endurance (maximal repetitions over 3 sets) changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are *M* ± *SE*. No significance difference between groups.

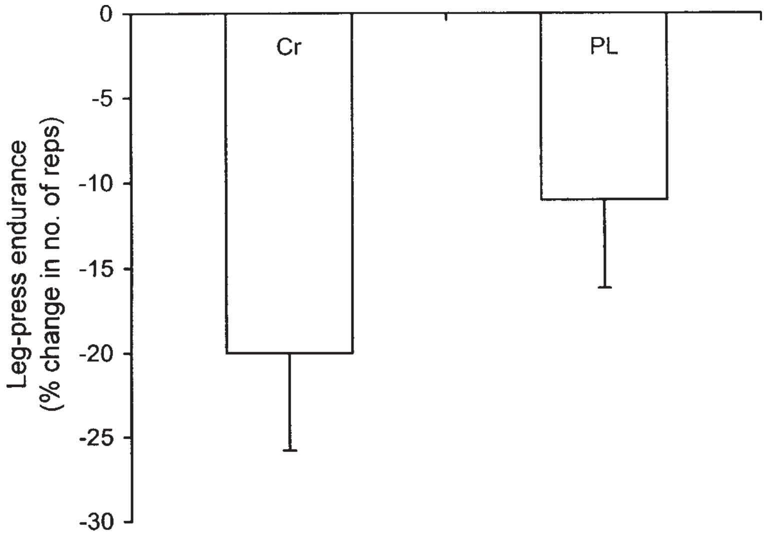

Figure 5. Leg-press muscle-endurance (maximal repetitions over 3 sets) changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are *M* ± *SE*. No significance difference between groups.

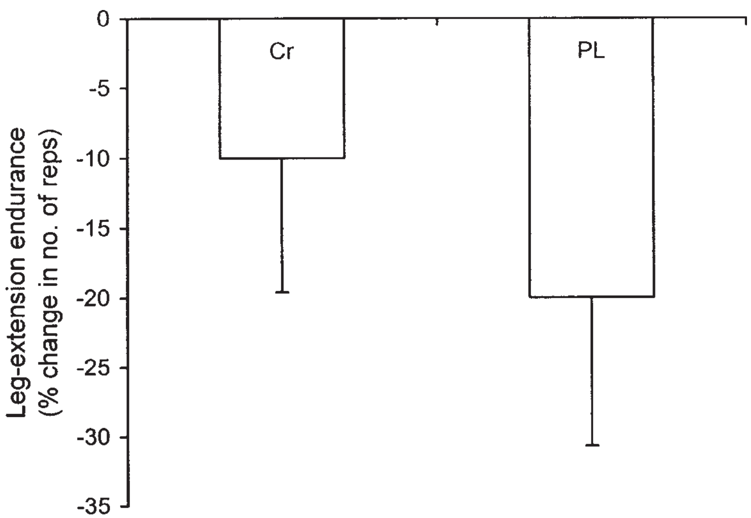

Figure 6. Leg-extension muscle-endurance (maximal repetitions over 3 sets) changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are *M* ± *SE*. No significance difference between groups.

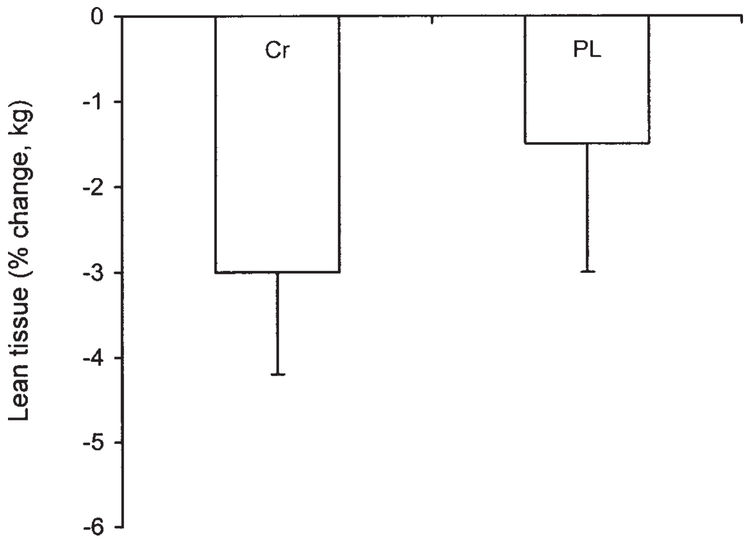

Figure 7. Lean-tissue-mass changes after 12 weeks strength training following supplementation cessation. *Note*. PL = group previously supplemented with placebo; Cr = group previously supplemented with creatine. Values are $M \pm SE$. No significance difference between groups.

LEAN TISSUE MASS

Twelve weeks after creatine supplementation lean tissue mass was not significantly reduced for either the creatine-cessation or placebo group (Figure 7), with decreases of 3% (1.8 ±1.9 kg) for the creatine-cessation group and 1.4% (0.7 ± 1.0 kg) for the placebo group. Again, there was no significant Group × Time interaction because the rate of change between groups was similar. For the differences in relative changes between groups, statistical power was close to adequate at 74%.

Discussion

Creatine supplementation has been reported to increase muscle performance (Greenhaff et al., 1994; Vandenberghe et al., 1997) and lean tissue mass (Burke et al., 2001; Krieder et al., 1998) in young individuals, but research on older adults has been equivocal (Chrusch et al., 2001; Jakobi et al., 2001). With the reductions in muscle mass (Lindle et al., 1997; Tzankoff & Norris, 1977) and muscle performance associated with aging (Aniansson et al., 1986; Larsson, Grimby, & Karlsson, 1979; Rawson et al., 1999; Smith et al., 1998), the ramifications of creatine in combination with strength training being able to offset these negative consequences is highly significant. The present study was carried out to assess any changes that might occur in muscle performance and lean tissue mass once creatine supplementation has ceased. This was accomplished by comparing two groups of older men on identical strength-training programs—one that had previously supplemented with creatine for 12 weeks and another that had received placebo.

Our results showed no statistical difference in the rate of change between groups for muscle strength or endurance or lean tissue mass 12 weeks after creatine supplementation with the maintenance of total-body resistance training. These results are important for individuals who cycle creatine supplementation. Creatine cycling is practiced as a precaution against long-term side effects (Juhn & Tarnopolsky, 1998) and loss of effectiveness of the muscle creatine transporter (Guerrero-Ontiveros & Wallimann, 1998) and to save on monetary costs. Our results imply that one could cease taking creatine for 12 weeks without significant losses in strength, muscle endurance, or lean tissue mass.

Our study is the first to evaluate the effects of creatine cessation in older men and covers the longest time period (12 weeks) evaluated thus far. In young women who resistance trained and supplemented with creatine for 10 weeks, muscle PCr, arm-flexion torque, strength, and lean tissue mass increased. Withdrawal from creatine after 4 weeks caused muscle PCr and arm-flexion torque to decline back to baseline levels (Vandenberghe et al., 1997). In participants who supplemented with creatine at a rate of 20 g/day for the first 6 days followed by 2 g/day for an additional 30 days, total muscle creatine concentration increased by 20%. Withdrawal from creatine of 2 g/day eventually caused the elevated total muscle creatine concentration to decline to presupplementation levels in 4 weeks (Hultman et al., 1996). In the current study, 12 weeks after creatine supplementation, changes in muscle strength and endurance and lean tissue mass were not affected when older men who had previously supplemented with creatine were compared over time with those that had not previously supplemented with it. This is in agreement with our results for strength and lean tissue mass over 6 weeks of creatine cessation in younger men (Burke et al., 2001) and for lean tissue mass over 4 weeks of creatine cessation in young women (Vandenberghe et al.). Although intramuscular PCr and creatine levels might decline back to baseline levels 4 weeks after supplementation, the ergogenic effects of creatine supplementation, such as increased strength and lean tissue mass, might take longer to decrease. Transcription factors that are thought to be involved in muscle hypertrophy are up-regulated during creatine supplementation (Hespel et al., 2001; Willoughby & Rosene, 2003), and this signal for protein synthesis might persist for a time after creatine cessation. This might lead to continued enhancement of protein synthesis, lean tissue mass, and muscle performance for a time after muscle creatine levels have returned to baseline. Changes in transcription factors and protein synthesis on cessation of creatine are an area for future research.

Muscle endurance was significantly reduced within groups over time ($p < .05$). This might be explained by the fact that total training volume was reduced during the maintenance period without supplementation. Previously, participants followed a 3-day resistance-training program (Chrusch et al., 2001). In the present study, compliance was reduced to 2 days a week. This 33% reduction in training might explain why both groups had significant reductions over time for all measures of muscle endurance. One limitation of the muscle-endurance measurements was the relatively high coefficients of variation, which ranged from 7.5% to 16.7%. This is comparable to other reports on muscle endurance in which coefficients of variation ranged from 6.6% to 15% (Tesch, 1980; Vandervoort, Sale, & Moroz, 1984; Vandervoort, Sale, & Moroz 1987). The relative decreases over time in muscle endurance were quite large (14–17% for combined groups); therefore, our coefficients of variation were most likely adequate for detecting the time main effects, but they might have been too large for detecting small differences between groups (Chilibeck, Calder, Sale, & Webber, 1994).

Strength was maintained in the current study despite a 33% reduction in training frequency. The slight decreases in mean strength were not significant (Figures 1–3), with all values remaining above baseline (i.e., pretraining) levels. Others have also found that strength can be well maintained in older adults when training frequency is reduced by up to 66% (e.g., from 3 days per week to once a week) for 24–27 weeks (Lexell, Downham, Larsson, Bruhn, & Morsing, 1995; Trappe, Williamson, & Godard, 2002) or when training intensity is reduced (from 80% 1-RM to 60–70% 1-RM) for 3 years (Smith, Winegard, Hicks, & McCartney, 2003).

In conclusion, creatine-supplementation cessation for up to 12 weeks does not affect the rate of change in muscle strength and endurance and lean tissue mass in older individuals who continue to strength train at the same intensities as when they were on the creatine supplement. A limitation of this study is that we did not measure intramuscular creatine concentrations, which might have provided us with a better indication of how creatine levels are affected once supplementation is ceased. This is the first study to measure changes in muscle performance and lean tissue mass after creatine supplementation in older men. Future research could assess longer periods of creatine cessation to determine exactly when gains made during supplementation return to baseline.

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