Does Nutritional Supplementation Influence Adaptability of Muscle to Resistance Training in Men Aged 48 to 72 Years

Jack M. Carter, MS;[1] Debra A. Bemben, PhD;[1]
Allen W. Knehans, PhD;[2] Michael G. Bemben, PhD;[1] Michael S. Witten, MS[1]

[1]Department of Health and Exercise Science, University of Oklahoma, Norman Campus, Norman, OK
[2]Department of Nutritional Sciences, University of Oklahoma, Health Science Center Campus, Oklahoma City, OK

ABSTRACT

Background and Purpose: Isotonic strength training can result in neuromuscular improvements evidenced in other forms of muscular effort, ie, isokinetic or isometric, especially in young subjects; however, it is unclear if older muscle maintains this same adaptive ability. Additionally, it is not known if the benefits of resistance training can be augmented by creatine and protein supplementation in older men. Therefore, the purpose of this study was to assess changes in isokinetic parameters at varying speeds in men aged 48 to 72 years (mean = 57 ± 2.1) following 16 weeks of isotonic resistance training and creatine and/or protein supplementation. **Methods:** Forty-two male subjects were randomly assigned to 1 of 4 training groups: (1) resistance training placebo (n = 10), (2) resistance trained creatine supplemented (n = 10), (3) resistance trained protein supplemented (n = 11), and (4) resistance trained creatine and protein supplemented (n = 11). The program consisted of progressive overload resistance training (3 d/wk) and supplement consumption following the workout. **Results:** There were significant time effects ($P \leq .05$) for peak torque (PT), time to PT, and average power for both the knee extensors and flexors at all velocities. However, no significant group or group by time interactions were noted, indicating that the supplementation protocols had no added benefits. **Conclusions:** Men aged 48 to 72 years maintained their ability to improve isokinetic muscle function following isotonic training, however, supplementation did not enhance muscle adaptability.

Key Words: muscle adaptability, creatine supplementation, protein supplementation

INTRODUCTION

Quality of life tends to decline with age due to the onset of many age-related pathologies and decreases in physiological parameters like: muscle protein, fat free mass (FFM), muscle strength and power, and endurance. Skeletal muscle protein is particularly diminished with advanced age, whereas nonmuscle protein losses are minimal. In young, healthy adults, muscle comprises about 60% of the FFM, whereas in elderly individuals, muscle accounts for only 45% of FFM,[1,2] representing about a 30% to 40% decline between the ages of 30 and 80 years.[3-4] Most of the decline occurs after the age of 50 years and is mostly due to the loss of motor units[5] and muscle fiber atrophy.[6-8] This loss in FFM contributes to the progressive loss of physical function,[9] limited recreational[10] and occupational pursuits,[11] and an increased dependency on others.[12,13]

Address correspondence to: Michael G. Bemben, PhD, University of Oklahoma, Department of Health and Exercise Science, Neuromuscular Research Laboratory, 1401 Asp Avenue, Norman, OK 73019, Ph: 405-325-2717, Fax: 405-325-0594 (mgbemben@ou.edu).

Creatine is one of the most popular nutritional supplements on the market and is often used in conjunction with resistance training. Research suggests that increasing resting levels of phosphocreatine might delay its depletion and attenuate the decline in adenosine triphosphate (ATP) provision during high-intensity exercise,[14-18] especially if it is consumed with a sugar containing drink. Creatine loading is associated with an increase in body weight and FFM[7,19,20] but its effects on older individuals are somewhat controversial.[15,21] Researchers have documented that elderly subjects have lower concentrations of creatine and phosphocreatine, due to decreases in type II muscle fibers, and therefore might benefit from supplementation during resistance training programs.[7,18,21]

Research also has indicated that protein intake for the elderly should be higher than the daily recommendation of 0.8-1.5 g/kg of body weight, depending on physical activity levels.[23,24] Others have suggested that older individuals should consume 1-1.25 g of protein/kg/day due to the decrease in muscle volume and inferior dietary habits,[3,20] especially if engaged in an exercise program.

Whey protein has been shown to posses a greater compliment of essential amino acids and branched chain amino acids than other forms of protein, which can result in greater biological value to humans.[25] Only one group has examined the effects of whey protein and creatine supplementation on exercising individuals. They reported that males who supplemented with whey protein and creatine had greater increases in FFM and relative increases in maximal strength (1-Repetition Maximum, 1-RM) bench press than did those who supplemented with whey protein alone, or the placebo group. However, squat strength and isokinetic knee flexion performance were unaffected.[25] Resistance training performed by older adults does result in an increase in protein synthesis, which can contribute to improvements in muscular strength, as long as the exercise intensity is kept at a relatively high load ($\geq$ 80% 1-RM).[2,19]

The principle of specificity of training indicates that the greatest improvements in performance occur when the training is most similar to the performance. In other words, resistance training in one mode (ie, isotonic) normally results in the greatest improvements in performances that use the same mode of contraction (ie, isotonic). However, there can also be improvements in other performances that use different modes of action (ie, isometric or isokinetic). This deviation from the specificity of training principle has been fairly well established in young healthy subjects, however, it is unclear if older muscle maintains this same adaptive ability.[26,27] Additionally, it is not known if creatine and/or protein supplementation can provide an ergogenic effect for older men.

Therefore the purpose of this study was to determine if older muscle remains adaptive by assessing changes in isokinetic parameters of the knee extensors and flexors following 16 weeks of isotonic resistance training. In addition, we were interested in determining if creatine and/or protein supplementation could enhance the possibilities of improved muscle adaptability. We assumed that older muscle would maintain similar adaptive qualities as young muscle but that supplementation would have a greater beneficial effect with this age group.

METHODS

Subjects

Forty-two healthy male subjects (age 48-72 years) volunteered for the study. Exclusion criteria encompassed any orthopedic or arthritic conditions that would prevent completion of the training program, heart conditions like congestive heart failure or arrhythmias, uncontrolled hypertension, high caffeine usage, vegetarian diets, or any resistance training during the previous 6 months. All subjects that participated in the training program obtained medical clearance from their own personal physicians and were considered healthy, community dwelling individuals. Subjects were randomly assigned to 1 of 4 groups: resistance training placebo (RTP), resistance training creatine (RTCr), resistance training protein (RTPr), or resistance training creatine and protein (RTCrPr). The RTP and RTCr each had 10 subjects, and the RTPr and RTCrPr groups had 11 subjects that completed the entire program. Five subjects withdrew from the study because of their inability to maintain a satisfactory attendance record, either because of personal schedules (n=3) or nontraining related illnesses (n=2). Prior to beginning the study, subjects received a complete explanation of the purpose and procedures of the investigation, were informed of their right to withdraw from the study at any time, and signed a consent form.

Research Design

The study was double blinded, randomized, and placebo controlled. Once the subjects were randomly assigned to their 16-week training groups, the loading phase commenced for each group. The loading phase consisted of the ingestion of 7g of creatine monohydrate with 480mL of glucose solution (Gatorade®) for the 2 creatine containing groups (RTCr and RTCrPr) and Gatorade® only for the other 2 groups (RTP and RTPr). During this week long loading period (Monday, Wednesday, and Friday), baseline strength, muscle size, body composition, PT, time to PT, average power, and isokinetic muscle endurance of the knee flexors and extensors were measured. Subjects were also familiarized with the weight training equipment and the required lifting techniques (Figure 1).

Procedures

Isotonic muscular strength was tested using the 1-RM in order to ensure that progressive overload was incorporated throughout the training program. All strength testing and training involved Cybex isotonic equipment (Division of Lumex, Owatonna, Minn) located at the University of Oklahoma Neuromuscular Laboratory. Muscle cross-sectional area of the rectus femoris was assessed using Diagnostic Ultrasound (Fukuda Denshi FF, Redmond, Wash). Total and regional body composition were assessed using Dual Energy X-ray Absorptiometry (DXA, Lunar DPX-IQ, Madison, Wisc). All isokinetic parameters, of the knee flexors and extensors, were measured using the Biodex System II (Biodex Medical Systems Inc., Shirley, NY).

After baseline data collection and loading phases were complete, the 16-week training protocol began. The training protocol was designed using the overload principle to maximize potential strength gains. Groups met 3 times per week, with the RTCr and RTCrPr groups (n=21) training at an early morning session (8:00 am) and the RTP and RTPr groups (n=21) training at a later morning session (10:00 am). All subjects performed 3 sets of 8 repetitions of 8 exercises, 3 of which focused on the lower extremities (knee extensions, knee flexions, double leg-press). Exercises were performed during a single session at 80% of each subject's 1-RM. Subjects performed each exercise to a 1, 2, 3 count during the concentric phase, and a 1, 2, 3 count during the eccentric phase. Each session began with a total body stretching routine, followed by a 5 minute warm-up on stationary bicycles

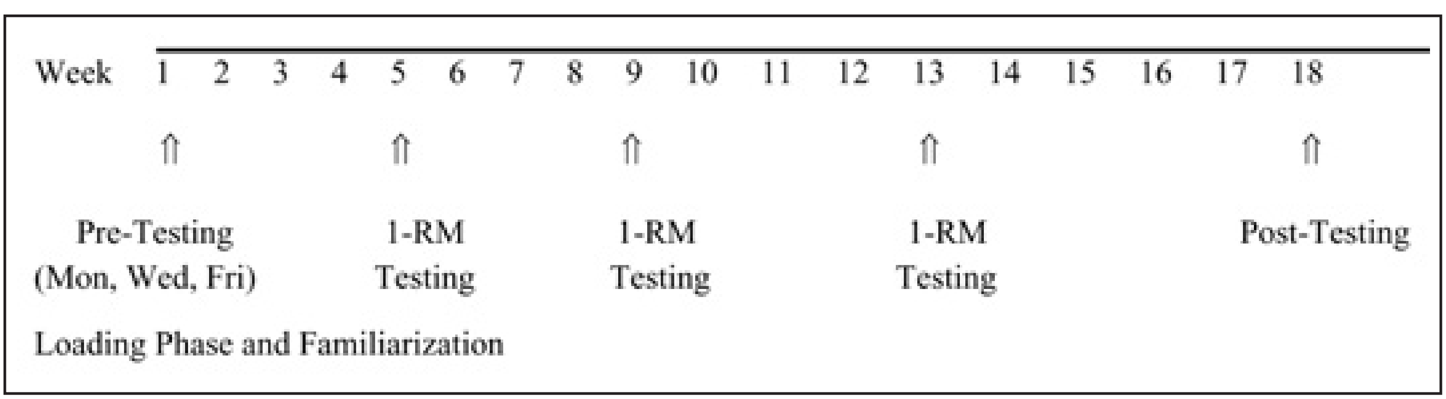

Figure 1. Study timeline.

or treadmills. The resistance-training workout lasted about an hour and was supervised by staff members who kept training logs for each subject. The 4th, 8th, and 12th weeks of the program were used to reassess muscular strength for each subject and to increase workloads during training in an attempt to maximize strength gains. Isokinetic testing was done prior to the 1st week of training, during the mid training period (weeks 7 and 8), and the week post-training.

Supplementation

Once subjects were randomly assigned to their 16-week training groups, the supplement loading phase began for each group. This was only necessary for the individuals in the 2 creatine groups, however, to control for nuisance variables, the other 2 groups went through a loading phase consisting of a placebo only (480mL of Gatorade®). The RTP and RTPr groups loaded the placebo solution for 3 days during the initial week, while the RTCr and RTCrPr groups loaded 7g of creatine with 480mL of the glucose solution (Gatorade®). This was done to increase the concentrations of both creatine and phosphocreatine levels in skeletal muscle. Once training began, the RTP group consumed the placebo (480mL of Gatorade®), the RTCr group consumed 5g creatine mixed in 480mL of glucose solution, the RTPr group consumed 35g of whey protein mixed in 480mL of glucose solution, and the RTCrPr group consumed 5g creatine and 35g of whey protein mixed in 480mL of glucose solution. A different research assistant administered the supplementation and all solutions were consumed immediately after training. Treatments were blinded to the primary investigators and the subjects. Subjects consumed the solution immediately following each training session in the presence of a research assistant to confirm consumption of the solution.[23,28,29]

Peak Torque and Isokinetic Muscle Endurance

All isokinetic (PT, time to PT, average power, and muscle endurance characteristics) measurements were obtained from the right lower extremity after subjects warmed up on a cycle ergometer or treadmill prior to testing. The unilateral isokinetic protocol was used, which assessed isokinetic muscle function at 3 speeds (60˚/sec, 180˚/sec, 240˚/sec). An isokinetic muscle endurance test (180˚/sec knee extension only) was also administered using this equipment.[30]

The dynamometer was calibrated prior to testing and all measurements were gravity compensated for the mass of the right leg. To standardize the measurements, the subjects were seated in an adjustable chair with adjustable support for the back and hips. When placed into the chair, the axial rotation of the dynamometer was lined up with the anatomical axis of the knee joint. Velcro straps were used to fasten the subject into the chair, using a waist strap, dual shoulder straps, right thigh strap, and right tibial strap. The pad of the adjustable dynamometer lever was placed on the anterior aspect of the shin, about 5 cm above the lateral malleaulus, for all the subjects. The range of motion was from 0˚ (dynamometer perpendicular to the floor) to 90˚ (knee extension). Extension of 90˚ was defined with the lever arm parallel to the floor.

With the subject in position, the testing protocol was explained. A warm-up of 5 to 10 submaximal repetitions, at 60˚/sec, was performed prior to beginning the test. When the 'horn' sounded, 3 consecutive maximal knee extensions and flexions were preformed at 60˚/sec. After a 1 minute rest period, 3 consecutive maximal knee extensions and flexions were performed at 180˚/sec, then following another 1 minute rest period, a third trial of maximal knee extensions and flexions was conducted at 240˚/sec.

After completing the PT measurements, the subject had another 1 minute rest period prior to the start of the standardized Thorstensson and Karlsson muscular endurance test.[30] This test was performed to evaluate the percent force decrement, as well as to acquire total energy (J) and average power output (W). The test started when the 'horn' sounded. The subjects performed 50 consecutive knee extensions at maximal effort (180˚/sec).

Statistical Analyses

Statistical analyses were performed using SPSS 11.0 for Windows. Data were summarized descriptively using means ± standard error, as well as percent change [(final - initial measure)/initial measure x 100]. Two-way analysis of variance (ANOVA) procedures with repeated measures were used to examine the effects of group (4) and time (3) on the neuromuscular parameters. Bonferroni post-hoc analyses were used to explore group differences while paired t-tests determined where significant differences existed over the 3 times (pre, mid, post). Statistical significance was set at $P \leq .05$.

RESULTS

There were no statistically significant differences between the 4 groups (RTP, RTCr, RTPr, and RTCrPr) at baseline for any of the dependent variables. Descriptive and anthropometric variables were also similar. The average age for each of the groups was 57.0±1.9 years. The groups' average height was 177 ± 2.1 cm, their weight was 92.5 ± 5.6 kg, their percent fat was 26 ± 1.6 % (DXA), and their rectus femoris muscle cross-sectional area was 5.12 ± 0.5 cm^2 (Table 1).

Table 1. Descriptive Data (Mean ± SE)

Group*	n	Age (yrs)	Height (cm)	Weight (kg)	Fat (%)	Rectus Femoris Muscle Cross-sectional Area (cm^2)
RTP	10	56.1±1.4	177.0±1.8	98.0±7.6	27.9±1.7	5.505±0.590
RTCr	10	56.1±1.8	177.4±2.4	91.1±5.2	28.7±1.4	4.715±0.390
RTPr	11	58.2±2.0	175.6±2.0	88.3±4.4	24.5±1.8	4.709±0.315
RTCrPr	11	57.2±2.2	179.6±2.3	92.6±5.1	25.1±1.5	5.540±0.501

*RTP – Resistance Trained Placebo; RTCr – Resistance Trained Creatine Supplemented; RTPr - Resistance Trained Protein Supplemented; RTCrPR – Resistance Trained Creatine and Protein Supplemented.

Isokinetic Parameters (60˚/sec)

Based on the repeated measures ANOVA, all 4 groups had significant increases ($P \leq .05$) over time in PT (170.5 to 201 Nm) and average power (104.4 to 137 W). For knee flexion, there were significant increases over time ($P \leq .05$) in PT (80.1 to 103.7 Nm) and average power (48.5 to 70.3 W), and a significant decrease ($P \leq .05$) in time to PT (677 to 474.5 ms). For both knee extension and flexion measures, there were no significant differences between the groups and no significant group by time interactions. Table 2 shows the percent changes in knee extension and flexion isokinetic parameters from baseline measures. It is interesting to note that even though there were no significant group differences, the 2 groups that had the creatine supplementation (RTCr and RTCrPr) had the greatest improvements. Figure 2a depicts PT for knee extension at 60˚/sec, and Figure 2b represents PT for knee flexion at 60˚/sec.

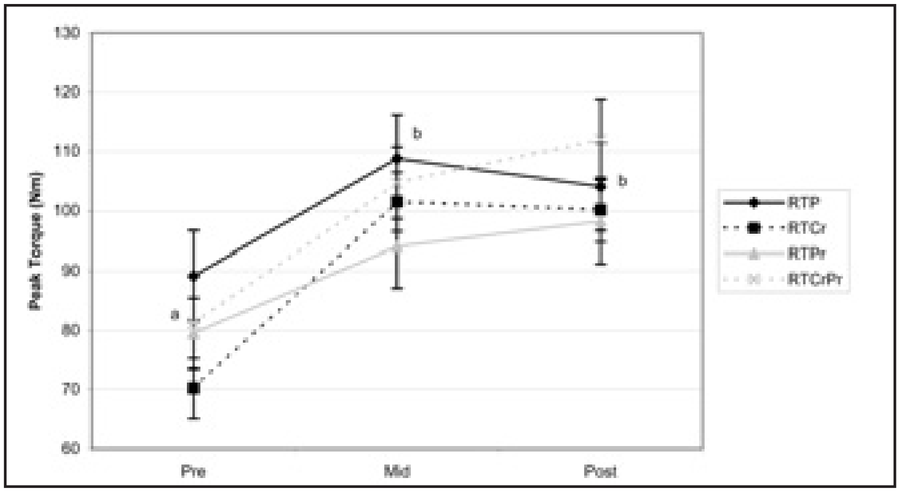

Figure 2b. Comparison of knee flexion peak torque at 60˚/sec between groups. (Values are means ± SE with no difference between the groups or group by time interactions, but differences between times; letters a, b indicating significant time effects.)

Table 2. Percent Change in Isokinetic Parameters at 60°/sec Following 16 Weeks of Isotonic Resistance Training

Group*	Peak Torque	Average Power	Time to Peak Torque
Knee Extension			
RTP	9.5	22.7	-1.1
RTCR	31.0	45.2	-5.6
RTPr	14.5	30.6	9.3
RTCrPr	19.3	29.3	-18.4
Knee Flexion			
RTP	16.7	26.9	-32.0
RTCr	42.6	58.7	-31.3
RTPr	23.5	18.7	-17.8
RTCrPr	37.9	57.3	-38.6

*RTP – Resistance Trained Placebo; RTCr – Resistance Trained Creatine Supplemented; RTPr - Resistance Trained Protein Supplemented; RTCrPR – Resistance Trained Creatine and Protein Supplemented.

Isokinetic Parameters (180˚/sec)

All 4 groups had significant increases over time ($P \leq .05$) in PT (126.6 to 147.2 Nm) and average power (167.4 to 214.8 W) and decreased significantly ($P \leq .05$) in time to PT (331.2 to 301.2 ms) following the training program. For knee flexion, there were significant increases ($P \leq .05$) in PT (69.9 to 87.9 Nm), and average power (85.1 to 122 W), and a significant decrease ($P \leq .05$) in time to PT (359.5 to 259 ms). For both knee extension and flexion, there were no significant group effects or group by time interactions. Table 3 shows the percent changes in knee extension and flexion isokinetic parameters from baseline measures. Similar to the findings at 60°/sec, the groups that supplemented their programs with creatine and or protein (RTCr, RTPr, and RTCrPr) appeared to have somewhat larger improvements compared to the placebo group (RTP). Figure 3a depicts PT for knee extension at 180˚/sec and Figure 3b represents PT for knee flexion at 180˚/sec.

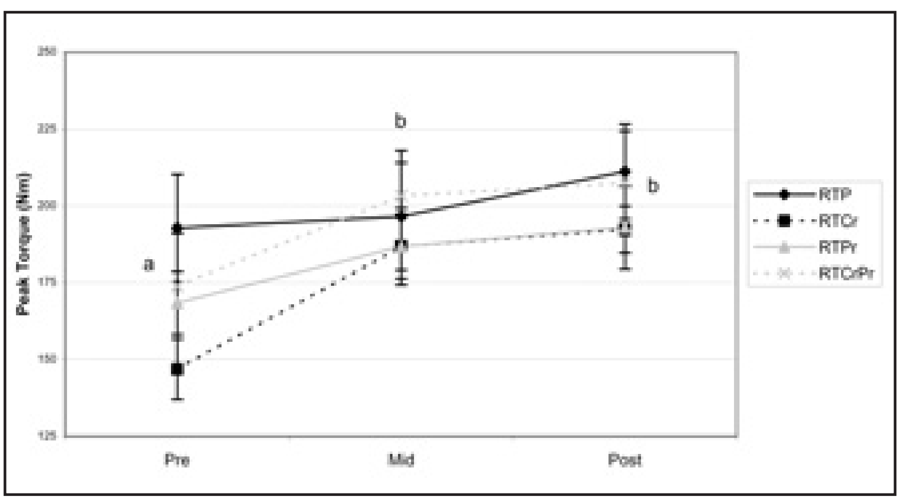

Figure 2a. Comparison of knee extension peak torque at 60˚/sec between groups. (Values are means ± SE with no difference between the groups or group by time interactions, but differences between times; letters a, b indicating significant time effects.)

Isokinetic Parameters (240˚/sec)

All 4 groups increased significantly over time ($P \leq .05$) in PT (116.4 to 131.4 Nm) and average power (210.6 to 255.8 W). For knee flexion, there were significant increases ($P \leq .05$) in PT (73.1 to 84.1 Nm) and average power (110.3 to 149.3 W) and a significant decrease ($P \leq .05$) in the time to PT (349.8 to 262.6 ms). There were no significant group effects or group by time interactions for either the knee extensors or flexors. Table 4 shows the percent changes in knee extension and flexion isokinetic parameters from baseline measures. As with the other 2 testing speeds, groups that used supplements had slightly greater improvements. Figure 4a depicts PT for knee extension at 240˚/sec and Figure 4b represents PT for knee flexion at 240˚/sec.

It is interesting to note that most of the improvements in PT at each of the 3 testing

Table 3. Percent Change in Isokinetic Parameters at 180°/sec Following 16 Weeks of Isotonic Resistance Training

Group*	Peak Torque	Average Power	Time to Peak Torque
Knee Extension			
RTP	13.1	22.5	-3.2
RTCR	26.8	38.4	-11.1
RTPr	9.8	27.5	-14.3
RTCrPr	17.2	26.7	-5.9
Knee Flexion			
RTP	18.8	36.2	-36.8
RTCr	30.7	54.6	-19.6
RTPr	26.2	42.0	-30.4
RTCrPr	27.6	42.7	-25.9

*RTP – Resistance Trained Placebo; RTCr – Resistance Trained Creatine Supplemented; RTPr - Resistance Trained Protein Supplemented; RTCrPR – Resistance Trained Creatine and Protein Supplemented.

Table 4. Percent Change in Isokinetic Parameters at 240°/sec Following 16 Weeks of Isotonic Resistance Training

Group*	Peak Torque	Average Power	Time to Peak Torque
Knee Extension			
RTP	10.7	15.5	20.0
RTCR	20.8	34.1	-13.3
RTPr	11.2	21.2	-3.4
RTCrPr	10.5	17.4	-1.7
Knee Flexion			
RTP	6.8	22.5	-16.3
RTCr	20.1	41.9	-42.9
RTPr	14.1	28.2	-18.6
RTCrPr	19.8	48.6	-24.6

*RTP – Resistance Trained Placebo; RTCr – Resistance Trained Creatine Supplemented; RTPr - Resistance Trained Protein Supplemented; RTCrPR – Resistance Trained Creatine and Protein Supplemented.

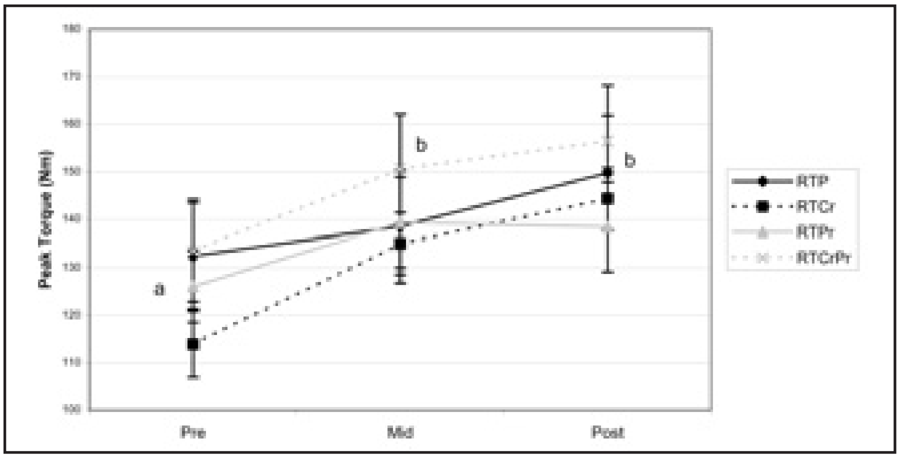

Figure 3a. Comparison of knee extension peak torque at 180˚/sec between groups. (Values are means ± SE with no difference between the groups or group by time interactions, but differences between times; letters a, b indicating significant time effects.)

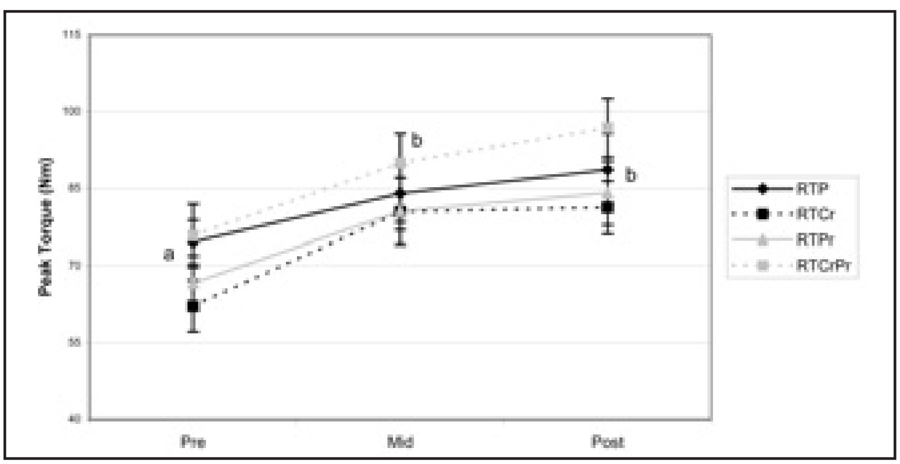

Figure 3b. Comparison of knee flexion peak torque at 180˚/sec between groups. (Values are means ± SE with no difference between the groups or group by time interactions, but differences between times; letters a, b indicating significant time effects.)

speeds and for each muscle group, occurred in the first half of the study (week 8) and that the final 8 weeks of isotonic training had no further carry-over on PT (Figures 2-4).

Muscle Endurance

There was a significant time effect ($P \leq .05$) for total work (4387 to 5171 J) and average power (109 to 133.5 W) obtained during the endurance trials; however, there were no significant group or group by time effects. Table 5 represents percent changes in total work and average power. In this case, it appears that there was little difference between the improvements for each of the 4 groups.

Body Composition and Muscle Size

There were significant ($P \leq .05$) time effects for an increased total body FFM as well as for the FFM of the right lower extremity ($P \leq .05$) for each group following training. The increase averaged 1.7% for total body and 1.8% for the right lower extremity FFM across all groups (since there was no significant group or group by time interaction). Similar findings (18.7% average increase) were also determined for the cross-sectional area of the rectus femoris ($P \leq .01$), indicating that all groups experienced the addition of FFM following the resistance training program but that the supplements had no additional benefits.

DISCUSSION

It is well documented that older adults can limit muscle loss by resistance training, with hypertrophy occurring in both major fiber types, but especially in the type II fibers, depending on the mode and intensity of exercise.[31-33] One potential limitation for improved force production following training for the elderly is the lower concentrations of creatine and phosphocreatine, which are important primary energy sources for performing high-intensity exercises.[7,18,34,35] Theoretically, creatine supplementation could increase adenosine triphosphate/adenosine diphosphate (ATP/ADP) ratios, facilitate adenosine triphos-

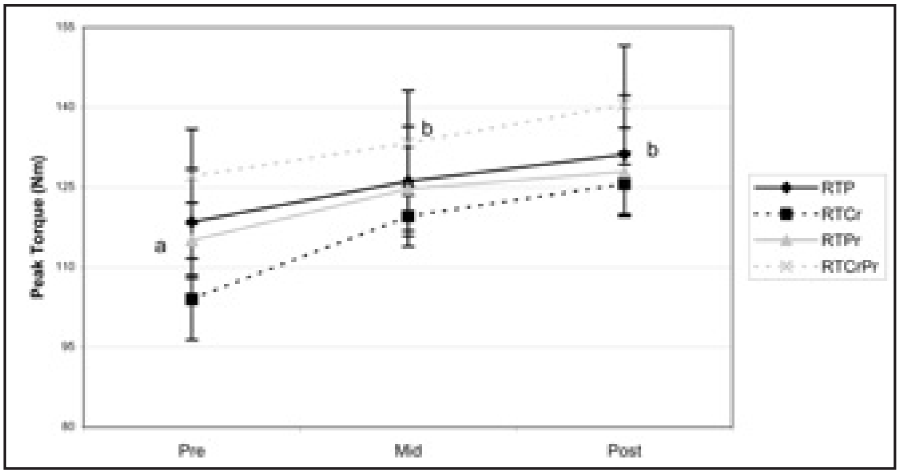

Figure 4a. Comparison of knee extension peak torque at 240˚/sec between groups. (Values are means ± SE with no difference between the groups or group by time interactions, but differences between times; letters a, b indicating significant time effects.)

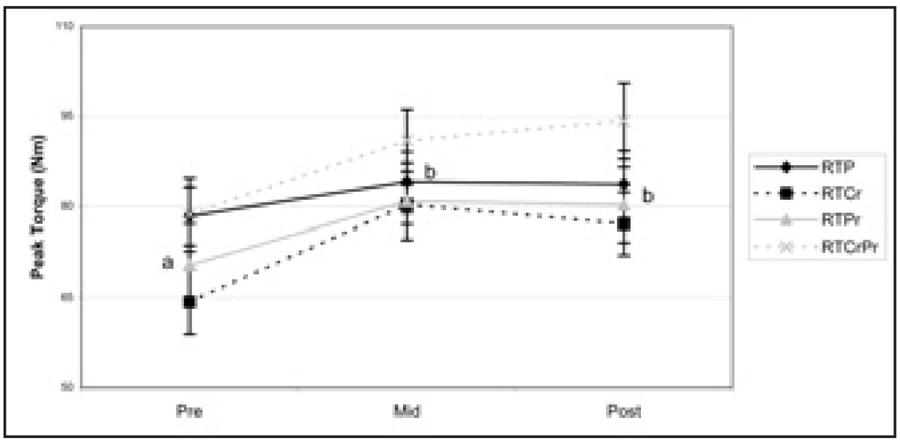

Figure 4b. Comparison of knee flexion peak torque at 240˚/sec between groups. (Values are means ± SE with no difference between the groups or group by time interactions, but differences between times; letters a, b indicating significant time effects.)

Table 5. Percent Change in Knee Extension Muscle Endurance Parameters (Thorstensson-Karlsson Fatigue Test at 180°/sec) Following 16 Weeks of Isotonic Resistance Training

Group*	Total Work	Average Power
RTP	17.5	23.8
RTCR	26.6	32.4
RTPr	15.3	14.5
RTCrPr	13.9	20.3

*RTP – Resistance Trained Placebo; RTCr – Resistance Trained Creatine Supplemented; RTPr - Resistance Trained Protein Supplemented; RTCrPR – Resistance Trained Creatine and Protein Supplemented.

phate-phosphocreatine (ATP-PC) system to a greater extent, and stimulate protein synthesis. This would therefore increase the volume of work done in an exercise bout leading to greater increases in FFM and muscle strength.

Rawson et al assigned 20 older (67 ± 2 years of age) males to either a placebo or creatine supplementation groups.[18] The creatine group received 30 days of supplementation and all subjects performed 5 sets of 30 knee extensions at 60˚/sec. The sum of knee extension PT for each repetition was greater following 10 days and 30 days of supplementation (9% increase for creatine group vs. 5% decrease for placebo). In a second study using the same procedures, a small but significant increase was observed in the sum of PT values as compared to the placebo group.[7] Similar improvements in isokinetic PT following creatine ingestion were also determined by Vandenberghe et al,[36] Johnson et al,[37] and Greenhaff et al[38] who reported that isokinetic PT increased significantly ($P \leq .05$) following creatine supplementation relative to their placebo groups.

Pearson et al studied 16 collegiate football players consuming either creatine (5 g/day) or a placebo during a 10-week periodized resistance-training program.[39] Parameters of interest included PT measured at 60˚/sec and 240˚/sec. They reported no significant group, time, or group by time interaction for PT at either speed. They concluded the performance measures were tightly linked to the specificity of training principle, which states that adaptations are specific to the characteristics of the training demands imposed.[39] Our findings from the current study contradict those found by Pearson et al.[39] Unlike the highly trained athletes in the earlier research,[39] our healthy, but inactive older volunteers were able to demonstrate significant improvements in isokinetic parameters following isotonic resistance training. Possible reasons for the different results could be the length of the 2 training programs, the initial level of fitness of the participants in the 2 studies, or improved neural drive for the older subjects.[40]

Only 1 study examined the effects of whey protein supplementation and creatine supplementation over a 12-week resistance training program, on isokinetic knee extension and flexion PT at 60˚/sec.[25] The authors indicated that the whey/creatine and whey groups significantly increased knee extension PT, and that the PT of the whey/creatine group was significantly greater than the placebo posttest. Regarding knee flexion, there were no significant time or group differences. The present study found significant time differences ($P \leq .05$) for knee extension and flexion, but no significant differences between the training groups.

Effective resistance training programs have been shown to increase the synthesis rates of myosin heavy chains, which may contribute to improvements in muscular strength, as long as the exercise intensities remain appropriate (≥ 80% of 1-RM). Considering that type II muscle fibers are most influenced by resistance training due to their individual characteristics, it should not be surprising that all of our training groups had significant improvements in the time to PT at each testing velocity (60˚/sec, 180˚/sec, and 240˚/sec).

During short-duration, high-intensity exercises, the energy responsible for the resynthesis of adenosine triphosphate is primarily met by the phosphocreatine and anaerobic glycolysis energy systems. The depletion of the phosphocreatine energy system occurs at an extremely high rate.[39] Research has shown similar creatine loading protocols to improve muscle PT, rate of phosphocreatine resynthesis, total work, and time to fatigue during short-term high-intensity intermittent exercise.[41] Bemben et al found that after 9 weeks of isotonic resistance training, college-aged athletes demonstrated significant time and group effects; the creatine supplementation group (loading: 20 g/day; maintenance: 5 g/day) had a 15.9% improvement ($P \leq .05$) in the Thorstensson and Karlsson isokinetic test, whereas the placebo and control groups' performances did not improve.[14] Those findings are contrary to the current study, in which significant improvements were found in isokinetic muscular endurance, total work, and average power for all groups regardless of supplementation status.

It is interesting to note that even though all 4 groups in the current study had significant improvements in isokinetic muscle endurance, the RTCr group had the greatest increase in total work (26.6%) and average power (32.4%) when compared to the other 3 training groups (17.5% and 23.8% respectively for the RTP group; 15.3% and 14.5% respectively for the RTPr group; and 13.9% and 20.3% for the RTCrPr group; Table 4). The level of force production of the muscle dictates the rate at which adenosine triphosphate is hydrolyzed. The rephosphorylation of adenosine diphosphate to provide energy for continued muscle contractions is mandatory for continued function of power output. By increasing resting levels of phosphocreatine, this could delay phosphocreatine depletion and attenuate the decline in adenosine triphosphate provision during intense exercise.[7,14,17,18,34] Unfortunately, this rationale does not explain why the RTCrPr did not have as large of improvements as the RTCr group (26.6% vs 13.9%, respectively for total work and 32.4% vs 20.3% for average power).

In conclusion, this study determined that men aged 48 to 72 years maintained their neuromuscular plasticity since they were able to improve isokinetic muscle function at 3 different isokinetic velocities following isotonic training; however, creatine and/or protein supplementation did not significantly enhance muscle adaptability. These findings have two practical implications. First, the training of middle aged and elderly men in one mode does not preclude progress in others. Second, the expenditure of funds on creatine and protein supplements for these men is not warranted.

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