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EFFECT OF CREATINE SUPPLEMENTATION DOSING STRATEGIES ON AGING MUSCLE PERFORMANCE

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Abstract: *Objective:* This study compared the effects of different creatine supplementation dosages, independent of resistance training, on aging muscle performance and functionality. *Design and Participants:* Using a double-blind, repeated measures design, participants were randomized to one of three groups: Creatine-High (CR-H; n=11; 0.3 g/kg/day of creatine + 0.1 g/kg/day of maltodextrin), Creatine-Moderate (CR-M: n=11; 0.1 g/kg/day of creatine + 0.3 g/kg/day of maltodextrin) or Placebo (PLA; n=11; 0.4 g/kg/day of maltodextrin) for 10 consecutive days. *Measurements:* The primary dependent variables measured at baseline and after supplementation included muscle strength (1-repetition maximum leg press, chest press, hand-grip), muscle endurance (leg press and chest press; maximal number of repetitions performed for 1 set at 80% and 70% baseline 1-repetition maximum respectively), and physical performance (dynamic balance). *Results:* There was a significant increase over time for muscle strength (Leg press: CR-H pre 161.5 ± 55.1 kg, post 169.2 ± 59.2 kg; CR-M pre 145.2 ± 47.7 kg, post 151.7 ± 45.0 kg; PLA pre 163.7 ± 51.5 kg, post 178.2 ± 65.6 kg, p = 0.001; Chest press: CR-H pre 57.0 ± 26.2 kg, post 58.8 ± 28.0 kg; CR-M pre 54.5 ± 27.9 kg, post 56.8 ± 30.1 kg; PLA pre 55.1 ± 26.9 kg, post 58.5 ± 30.1 kg, p = 0.001) and endurance (Leg press: CR-H pre 17.1 ± 6.0 reps, post 21.0 ± 7.2 reps; CR-M pre 24.1 ± 11.6 reps, post 29.1 ± 17.0 reps; PLA pre 23.8 ± 9.7 reps, post 29.5 ± 11.9 reps, p = 0. 001; Chest press: CR-H pre 15.6 ± 2.7 reps, post 18.9 ± 2.7 reps; CR-M pre 18.0 ± 5.0 reps, post 19.9 ± 7.1 reps; PLA pre 20.5 ± 6.2 reps, post 21.6 ± 5.5 reps, p = 0. 001), with no other differences. *Conclusion:* Short-term creatine supplementation, independent of dosage and resistance training, has no effect on aging muscle performance.

Key words: Strength, endurance, balance, falls, resistance training.

Introduction

The age-related loss of muscle strength (i.e., maximum load that can be performed in a single repetition) and muscle endurance (i.e., maximum number of repetitions that can be performed to volitional fatigue) decreases physical performance (i.e., functionality). Factors contributing to the decrease in aging muscle performance (strength, endurance, physical performance) include changes in muscle biology (22, 27), neuromuscular function (2), oxidative stress (3), endocrinology (12), nutrition and physical activity (31). Therefore, interventions which increase aging muscle performance are important.

One potential intervention is creatine supplementation. Creatine is a naturally occurring nitrogen-containing compound found in the diet, primarily in red meat and seafood (33). The majority of creatine (95%) is stored in skeletal muscle as phosphocreatine which is required to resynthesize adenosine triphosphate (ATP) during intense muscle contraction (33). Unfortunately, aging may have a negative impact on high-energy phosphate metabolism (4). Therefore, an increase in intramuscular creatine from exogenous creatine supplementation should lead to greater muscle performance in aging adults.

While the majority of research indicates that the combination of creatine and resistance training leads to significant aging muscle benefits (5, 8, 13), there is evidence that short-term (5-14 days), high-dosage (~ 15-30 grams/day), creatine supplementation, independent of resistance training, can positively influence aging muscle performance and indices of functionality (17, 18, 28). Several of our previous studies have shown that moderate-dosage creatine (0.1g/kg/day or ~ 8-10 grams) increases muscle strength in healthy aging adults (6, 7), however all these studies included resistance training. No study has directed compared the effects of different creatine dosages, independent of resistance training, on muscle performance and tasks of functionality in aging adults. Therefore, the purpose of this study was to determine whether high-dosage creatine (0.3g/kg/day) would produce greater muscle benefits compared to moderate-dosage creatine (0.1g/kg/day) in healthy aging adults. It was hypothesized that high-dosage creatine would improve muscle strength, endurance, and physical performance compared to moderate-dosage creatine. It was also hypothesized that creatine supplementation, independent of dosage, would be superior to placebo.

Materials and methods

Experimental approach to the problem

After matching for gender and age, participants were randomized (double blind) to one of three groups: Creatine-High (CR-H; n = 11; 59.3 ± 3.2 yrs, 170.8 ± 8.7 cm, 82.6 ±

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16.8 kg, BMI = 28.3; 0.3 g/kg/day of creatine + 0.1 g/kg/day of maltodextrin), Creatine-Moderate (CR-M: n = 11; 58.8 ± 5.9 yrs, 170.9 ± 10.5 cm, 82.3 ± 16.1 kg, BMI = 28.2; 0.1 g/kg/day of creatine + 0.3 g/kg/day of maltodextrin) or Placebo (PLA; n = 11; 57.3 ± 4.6 yrs, 170.9 ± 11.3 cm, 84.1 ± 11.4 kg, BMI = 28.8; 0.4 g/kg/day of maltodextrin) for 10 consecutive days. A research assistant who was not involved in any other aspect of the study was responsible for randomizing the participants to groups to ensure all participants and investigators remained blinded throughout the study. The primary dependent variables measured at baseline and after the intervention included muscle strength (1-RM leg press, chest press, hand-grip), muscle endurance (maximal number of repetitions performed for 1 set at 80% and 70% baseline 1-RM for the leg press and chest press, respectively), and physical performance (balance, falls). The different percentages of 1-RM used for the muscular endurance tests reflect observations that for a given percentage of 1-RM, more repetitions can be performed during lower-body exercises than during upper-body exercises (9). Participants performed a familiarization trial for strength, endurance and physical performance at least 96 hours prior to baseline assessments.

Participants

Thirty-three (58.5 ± 4.7 years) participants who were not engaged in supervised resistance training for ≥ 6 weeks prior to the start of the study were enrolled. An a priori power analysis (G*Power v. 3.1.5.1) showed that 42 participants were required. This calculation was based on a moderate effect size (Cohen's d = 0.25), an alpha level of .05, a ß-value of 0.8 for a repeated measure: within-between interactions, ANOVA approach (14). Prior to the start of the study, participants filled out a physical activity (16) and general health questionnaire. Participants also completed a Physical Activity Readiness Questionnaire. This questionnaire included questions related to chronic medical conditions.

Participants were excluded if they had taken medications that affected muscle biology or creatine monohydrate ≤ 12 weeks prior to the start of the study; if they had a history of fragility fractures; if they had diseases that were known to affect muscle biology (i.e., Crohn's Disease); if they suffered from severe osteoarthritis; if they were vegetarian; or if they had pre-existing kidney or liver abnormalities.

Participants were instructed not to change their habitual dietary intake or physical activity patterns or consume over-the-counter medications during the study as these interventions can affect muscle protein and recovery (32). The study was approved by the Research Ethics Board at the University of Regina and participants were informed of the risks and purposes of the study before their written consent was obtained.

Procedures

Creatine (Creapure, AlzChem AG, Trostberg, Germany) and placebo (Globe Plus 10 DE Maltodextrin, Univar Canada) were provided to each participant in study packages which contained 10 daily supplement bags. Participants were instructed to consume their supplement in 2-3 equal dosages throughout the day with food. Adherence to the supplementation protocol was monitored using compliance logs. Creatine dosages, on average, were approximately 8-25 g/day or 80-250 g over the duration of the study. Most typical creatine loading phases which increase muscle total creatine stores amount to 100-140 g of creatine over 5-7 days (21). Justification for the 10 day supplementation protocol was based on the findings of Little et al. (23) who showed that this duration of creatine supplementation (~ 10 grams/day) increased upper-body muscle performance.

Muscle strength and endurance

Leg press and chest press strength and endurance was assessed using a 1-RM standard testing procedure as previously described (20). Muscle strength and endurance were assessed in order: (a) leg-press strength, (b) chest-press strength, (c) leg-press endurance, and (d) chest-press endurance. Five minutes of rest separated each test. Muscle strength and endurance determination was separated by 10 minutes of rest.

Hand-grip strength was measured using a hand-grip dynamometer (Jamar® Hydraulic Hand Dynamometer; Chicago, IL USA). Participants performed two attempts for each hand with the best attempt recorded. For convenience, hand-grip strength was measured when physical performance was assessed.

Physical Performance

The time taken to walk backwards as fast as possible on an elevated board (6 m long, 10 cm wide, 4 cm high) and the number of times the participant stepped off the board (falls) was used to assess physical performance. This test has been previously used in aging adults (10).

Adverse events

Participants completed an adverse event form in order to provide details on the type of adverse event if they arose.

Statistical Analyses

A 3 (CR-H vs. CR-M vs. PLA) × 2 (pre- and post-test periods) analysis of variance (ANOVA) with repeated measures on the second factor was used to determine differences between groups over time for muscle strength, endurance and physical performance. A one-factor ANOVA was used to assess baseline data and absolute change scores (post mean - pre mean). All results are expressed as means (standard deviation) or mean absolute change scores (95% confidence interval). Significance was set at an alpha level of $p < 0.05$. Statistical analyses were performed using IBM® SPSS® Statistics, v. 24.

Table 1
Baseline data

	CR-H	CR-M	PLA	p-value
Age (yrs)	59.3 (3.1)	58.8 (5.8)	57.3 (4.9)	0.604
Mass (kg)	82.5 (16.8)	82.3 (16.0)	84.1 (12.3)	0.973
Height (cm)	170.8 (8.7)	170.9 (10.5)	171.8 (11.8)	0.999
Strength (kg)				
Leg press	161.5 (55.1)	145.2 (47.7)	163.7 (51.5)	0.660
Chest press	57.0 (26.2)	54.5 (27.9)	55.1 (26.9)	0.975
Hand grip	69.0 (25.2)	79.5 (44.3)	63.1 (23.5)	0.489
Endurance (total repetitions)				
Leg press	17.1 (6.0)	24.1 (11.6)	23.8 (9.7)	0.182
Chest press	15.6 (2.7)	18.0 (5.0)	20.5 (6.2)	0.091
Physical Performance				
Walking time (sec)	38.5 (21.7)	39.4 (21.7)	36.2 (11.5)	0.918
Number of falls	1.5 (1.4)	0.9 (1.2)	1.5 (1.8)	0.537

Values are means (standard deviation).

Results

Baseline data are presented in Table 1. There were no differences between groups for any baseline measure. There was no change in body mass over time (CR-H: pre 82.6 ± 16.8 kg, post 83.1 ± 16.9 kg; CR-M: pre 82.3 ± 16.0 kg, post 82.2 ± 14.3 kg; PLA: pre 84.1 ± 11.4 kg, post 83.7 ± 12.1 kg, p = 0.867). Changes in all measurements over time were similar between males and females (p > 0.05).

Adverse events reported included a chest cold (CR-M: n = 1, PLA: n = 1), knee pain (PLA: n = 1, CR-H: n = 1), pulled groin muscle (CR-M: n = 1), gastrointestinal symptoms such as gas (CR-M: n = 1), constipation (CR-H: n = 1), bloating and feeling full (CR-H: n = 1), and muscle cramps (CR-H: n = 1). One participant in the CR-H group was unable to complete the leg press exercises due to poor hip flexion.

Supplementation compliance was 97%. Following post-testing, participants were asked to guess whether they thought they were taking creatine or placebo. Fifteen participants thought they were taking placebo, 8 thought they were on creatine and 10 did not know. Only 1 person correctly guessed they were on creatine whereas 5 correctly guessed they were on placebo.

There was a significant increase over time (Table 2) for leg press strength (CR-H: pre 161.5 ± 55.1 kg, post 169.2 ± 59.2 kg; CR-M: pre 145.2 ± 47.7 kg, post 151.7 ± 45.0 kg; PLA: pre 163.7 ± 51.5 kg, post 178.2 ± 65.6 kg, p = 0.001), chest press strength, (CR-H: pre 57.0 ± 26.2 kg, post 58.8± 28.0 kg; CR-M: pre 54.5 ± 27.9 kg, post 56.8 ± 30.1 kg; PLA: pre 55.1 ± 26.9 kg, post 58.5 ± 30.1 kg, p = 0.001), leg press endurance (CR-H: pre 17.1 ± 6.0 reps, post 21.0 ± 7.2 reps; CR-M: pre 24.1 ± 11.6 reps, post 29.1 ± 17.0 reps; PLA: pre 23.8 ± 9.7 reps, post 29.5 ± 11.9 reps, p = 0. 001) and chest press endurance (CR-H: pre 15.6 ± 2.7 reps, post 18.9 ± 2.7 reps; CR-M: pre 18.0 ± 5.0 reps, post 19.9 ± 7.1 reps; PLA: pre 20.5 ± 6.2 reps, post 21.6 ± 5.5 reps, p = 0. 001), with no differences between groups. There was no change over time for hand-grip strength or physical performance.

Discussion

This is the first study to directly compare the effects of high-dosage creatine to moderate-dosage creatine in healthy aging adults. It was hypothesized that high-dosage creatine would increase muscle performance compared to moderatedosage creatine and that creatine, independent of dosage, would be superior to placebo. However, creatine had no effect on muscle performance. These results support the previous findings of Baker et al. (1) who found no effect from acute (bolus) creatine ingestion (20 g) on leg press or chest press muscle endurance (total repetitions across 3 sets at 70% 1-RM) in healthy aging males (n = 9; 54 ± 4 years of age). Furthermore, Lobo et al. (24) found no effect from very-low dosage creatine (1g/day for 365 days) on whole-body lean tissue mass and physical performance (i.e. timed-up-and-go, timed stand) in aging postmenopausal women (n = 56; 58 ± 5 years of age). While methodological differences exist between these studies (i.e. timing, duration and dosage of creatine supplementation), a common feature involved no resistance training intervention which may have influenced the lack of findings. For example, three meta-analyses have now concluded that the combination of creatine and resistance training increases muscle strength and a task of physical performance in aging adults compared to resistance training alone (5, 8, 13). Therefore, creatine may produce more

Table 2
Mean absolute change scores (95% CI) from baseline to 10 days for muscle strength (kg), endurance (total repetitions), walking time (sec) and number of falls

	CR-H	CR-M	PLA	Supplement p-value	Interaction p-value
Strength					
Leg press	7.6 (0.7, 14.4)	6.4 (0.8, 11.9)	14.4 (1.5, 27.3)	0.001*	0.330
Chest press	1.7 (-0.6, 4.2)	2.2 (-0.2, 4.8)	3.3 (0.5, 6.0)	0.001*	0.634
Hand grip	-1.3 (-3.7, 1.0)	1.2 (-7.6, 10.2)	-13.4 (-36.7, 9.8)	0.268	0.519
Endurance					
Leg press	3.5 (-0.5, 7.6)	4.9 (-0.7, 10.5)	5.7 (1.7, 9.7)	0.001*	0.838
Chest press	3.3 (2.0, 4.5)	1.9 (-1.3, 5.1)	1.0 (-0.6, 2.8)	0.001*	0.327
Physical performance					
Walking time	4.5 (-1.0, 10.0)	4.1 (-0.3, 8.5)	2.8 (-0.1, 5.7)	0.226	0.718
Falls	0.6 (-0.2, 1.5)	0.2 (-0.5, 0.9)	-0.1 (-1.3, 0.9)	0.368	0.069

* Time main effect ($p < 0.05$)

consistent muscle performance benefits in aging adults when combined with resistance training.

Although limited, there is evidence that creatine supplementation alone can have beneficial effects in aging adults. For example, Stout et al. (28) showed that short-term (14 days) creatine supplementation (20 g/day for 7 days followed by 10 g/day for 7 days; 210 g in total) increased hand-grip strength and physical working capacity in elderly men and women (67-82 year of age) with no change for the placebo group. Furthermore, Rawson et al. (26) showed that 30 days of creatine supplementation (20 g for 10 days followed by 4 g for 20 days; 280 g in total) in aging males (60-82 years of age) reduced lower-body muscle fatigue (an indicator of muscle endurance). Finally, Gotshalk et al. (17, 18) showed that creatine supplementation (0.3g/kg/day) for 7 days increased upper- and lower-body strength and tasks of functionality. While it is difficult to compare results across studies, these positive results from creatine may be related to its purported effects on high-energy phosphate metabolism, cellular hydration status, muscle protein kinetics, myogenic transcription factors, satellite cells, anabolic growth factors (i.e. IGF-1) and inflammation (for reviews see 5, 8, 19).

There were several limitations to this study. First, it is possible that the inclusion of both males and females may have influenced the results. Females may have higher resting intramuscular creatine levels than males (15) and therefore may not respond as well to creatine supplementation (30). Creatine also appears to have no effect on muscle protein kinetics in females (20, 25). Secondly, the estimated sample size required to achieve 80% power was 42 subjects. Unfortunately, only 33 participants completed the study which decreased our statistical power. Third, no measure of habitual dietary intake was performed. Creatine is naturally found in red meat and seafood and consumption of these food products may have influenced the results. Fourth, muscle biopsies were not performed which eliminates the ability to assess responders and non-responders to creatine supplementation. The ergogenic effects of creatine may depend on the initial muscle creatine concentration, which varies with age and gender (11, 29). Finally, muscle cross-sectional area, myogenic transcription factors, muscle protein kinetics, hormonal properties and satellite cell number and activity were not measured.

In summary, creatine supplementation, independent of dosage and resistance training, had no effect on aging muscle performance. Future research should compare different dosages of creatine and resistance training in healthy aging adults. Furthermore, longer-term studies investigating the effects of creatine dosing strategies on aging musculoskeletal health are needed.

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Conflict of Interest: The authors report no conflict of interest.

Ethical standards: This experiment complies with the current laws in Canada.

References

1. Baker TP, Candow DG, Farthing JP. Effect of preexercise creatine ingestion on muscle performance in healthy aging males. J Strength Cond Res 2016;30(6): 1763-1766.
2. Bea JW, Cussler EC, Going SB, Blew RM, Metcalfe LL, Lohman TG. Resistance training predicts six-year body composition change in postmenopausal women. Med Sci Sports Exerc 2009;42(7): 1286-1295.
3. Buford TW, Anton SD, Judge AR, Marzetti E, Wohlgemuth SE, Carter CS et al. Models of accelerated sarcopenia: Critical pieces for solving the puzzle of age-related muscle atrophy. Ageing Res Rev 2010;9(4): 369–383.
4. Candow DG, Chilibeck PD. Timing of creatine or protein supplementation and resistance training in the elderly. Appl Physiol Nutr Metab 2008;33(1): 184-190.
5. Candow DG, Chilibeck PD, Forbes SC (2014) Creatine supplementation and aging musculoskeletal health. Endocrine 2014;45(3): 354–361.
6. Candow DG, Vogt E, Johannsmeyer S, Forbes SC, Farthing, JP. Strategic ingestion of creatine supplementation and resistance training in healthy older adults. Appl Physiol Nutr Metab 2015;40(7): 689-694.
7. Candow DG, Zello GA, Ling B, Farthing JP, Chilibeck PD, McLeod K et al. Comparison of creatine supplementation before versus after supervised resistance training in healthy older adults. Res Sports Med 2014;22(1): 61-74.
8. Chilibeck PD, Kaviani M, Candow DG, Zello GA. Effect of creatine supplementation

during resistance training on lean tissue mass and muscular strength in older adults: a meta-analysis. Open Access J Sports Med 2017;2: 213-226.
9. Chilibeck PD, Calder AW, Sale DG, Webber CE. (1998). A comparison of strength and muscle mass increases during resistance training in young women. Eur J Appl Physiol 77(1-2): 170-175.
10. Chilibeck PD, Vatanparast H, Pierson R, Case A, Olatunbosun O, Whiting SJ et al. Effect of exercise training combined with isoflavone supplementation on bone and lipids in postmenopausal women: A randomized clinical trial. J Bone Min Res 2013;28(4) : 780–793.
11. Dalbo VJ, Roberts MD, Lockwood CM, Tucker PS, Kreider RB, Kerksick CM. The effects of age on skeletal muscle and the phosphocreatine energy system: can creatine supplementation help older adults. Dyn Med 2009;8(1):6.
12. Deschenes MR. Effects of aging on muscle fibre type and size. Sports Med 2004;34 : 809–824.
13. Devries MC, Phillips SM. Creatine supplementation during resistance training in older adults—A meta-analysis. Med Sci Sports Exerc 2014;46: 1194-1203.
14. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39(2): 175-191.
15. Forsberg AM, Nilsson E, Werneman J, Bergström J, Hultman E. Muscle composition in relation to age and sex. Clin Sci 1991;81(2) 249-256.
16. Godin G, Shephard. A simple method to assess exercise behavior in the community. Can J Appl Sport Sci 1985;10(3): 141-146.
17. Gotshalk LA, Kraemer WJ, Mendonca MA, Vingren JL, Kenny, AM, Spiering BA et al. Creatine supplementation improves muscular performance in older women. Eur J Appl Physiol 2008;102: 223–231.
18. Gotshalk LA, Volek JS, Staron RS, Denegar CR, Hagerman FC, Kraemer WJ. Creatine supplementation improves muscular performance in older men. Med Sci Sports Exerc 2002;34: 537–543.
19. Gualano B, Rawson ES, Candow DG, Chilibeck PD. Creatine supplementation in the aging population: effects on skeletal muscle, bone and brain. Amino Acids 2016;48(8): 1793-1805.
20. Johannsmeyer S, Candow DG, Brahms CM, Michel D, Zello GA. Effect of creatine supplementation and drop-set resistance training in untrained aging adults. Exp Gerontol 2016;83: 112-119.
21. Kreider RB, Kalman DS, Antonio J, Ziegenfuss, TN, Wildman R, Collins R et al. International Society of Sports Nutrition position stand: safety and efficacy of creatine supplementation in exercise, sport, and medicine. J Int Society Sport Nutr 2017;3:4-18.
22. Larsson L, Yu F, Hook P, Ramamurthy B, Marx JO, Pircher P. Effects of aging of regulation of muscle contraction at the motor unit, muscle cell, and molecular levels. Int J Sport Nutr Exerc Metab 2001;11:S28-43.
23. Little JP, Forbes SC, Candow DG, Cornish SM, Chilibeck PD. Creatine, arginine alpha-ketoglutarate, amino acids, and medium-chain triglycerides and endurance and performance. Int J Sport Nutr Exerc Metab 2008;18(5): 493-508.
24. Lobo DM, Tritto AC, Da Silva LR, De Oliveira PB, Benatti FB, Roschel H et al. Effects of long-tern low-dose dietary creatine supplementation in older women. Exp Gerontol, 2015;70: 97-104.
25. Parise G, Mihic, S, MacLennan D, Yarasheski KE, Tarnopolsky MA. Effects of acute creatine monohydrate supplementation on leucine kinetics and mixed-muscle protein synthesis. J Appl Physiol 2001;91(3): 1041-1047.
26. Rawson ES, Wehnert ML, Clarkson PM. Effects of 30 days of creatine ingestion in older men. Eur J Appl Physiol Occup Physiol 1999;80: 139–144.
27. Short KR, Nair KS. Muscle protein metabolism and the sarcopenia of aging. Int J Sport Nutr Exerc Metab 2001;11: S119–S127.
28. Stout J, Graves B, Cramer J, Goldstein E, Costa B, Smith A et al. Effects of creatine supplementation on the onset of neuromuscular fatigue threshold and muscle strength in elderly men and women (64-86 years). J Nutr Health Aging 2007;11(6): 459-464.
29. Syrotuik DG, Bell GJ. Acute creatine monohydrate supplementation: a descriptive physiological profile of responders versus non responders. J Strength Cond Res 2004;18(3): 610-617.
30. Tarnopolsky MA. Gender differences in metabolism; nutrition and supplements. J Sci Med Sport 2000;3(3): 287-298.
31. Tipton KD. Muscle protein metabolism in the elderly: Influence of exercise and nutrition. Can J Appl Physiol 2001;26: 588–606.
32. Trappe TA, White F, Lambert CP, Cesar D, Hellerstein M, Evans WJ. Effect of ibuprofen and acetaminophen on post exercise muscle protein synthesis. Am J Physiol Endocrinol Metab 2002;282(3): E551-556.
33. Wyss M, Kaddurah-Daouk R. Creatine and creatinine metabolism. Phys Rev 2000;80(3): 1107-1213.