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CREATINE MONOHYDRATE AND RESISTANCE TRAINING INCREASE BONE MINERAL CONTENT AND DENSITY IN OLDER MEN

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Abstract: Our purpose was to determine the effects of creatine supplementation combined with resistance training on bone mineral content and density in older men. Twenty-nine older men (age 71y) were randomized (double blind) to receive creatine (0.3 g/kg creatine for 5 d and 0.07 g/kg thereafter) or placebo while participating in resistance training (12 weeks). Bone mineral content and density were determined by dual energy X-ray absorptiometry before and after training. There was a time main effect for whole-body and leg bone mineral density ($p \leq 0.05$) with these measures increasing by approximately 0.5%, and 1%, respectively in the combined groups. There was a group by time interaction for arms bone mineral content, with the group receiving creatine increasing by 3.2% ($p<0.01$) and the group receiving placebo decreasing by 1.0% (not significant). Changes in lean tissue mass of the arms correlated with changes in bone mineral content of the arms ($r=0.67$; $p<0.01$). Resistance training of 12 weeks increases bone mineral density in older men and creatine supplementation may provide an additional benefit for increasing regional bone mineral content. The increase in bone mineral content may be due to an enhanced muscle mass with creatine, with potentially greater tension on bone at sites of muscle attachment.

Key words: Ageing, exercise, osteoporosis, strength, weight training.

Introduction

Creatine monohydrate has gained popularity in recent years as a nutritional ergogenic aid among strength-trained athletes. Supplementation with creatine during resistance training results in greater increases in muscle mass and strength compared to strength training alone (1-3). We have recently shown that supplementation with creatine during strength training can be of benefit for increasing muscle mass and strength in an older population of men (mean age 70 years) (4). Strength training that increases muscle mass in older men has also been shown to be effective for increasing bone mineral content and density (5-8). Indeed, bone mineral density is related to the strength and mass of anatomically related muscles (9, 10). It is theorised that muscles exert strains on bone at their tendon attachments, stimulating bone formation (11). An intervention such as creatine supplementation that provides an added increase in muscle mass above strength training alone may therefore also be of benefit for increasing bone mineral content or density.

It was recently shown that creatine supplementation increased bone mineral density in five wheelchair-independent dystrophic patients (12). The authors of the study concluded that creatine may potentiate the effect of muscle activity on bone mineral density in people suffering from bone demineralization. In our previous study of older men, we found that lean tissue mass, as determined by dual-energy X-ray absorptiometry, increased to a greater extent when subjects were given creatine compared to placebo during resistance training (4). Because dual energy X-ray absorptiometry also allows assessment of bone mineral content and density, this allowed us to reanalyze our data to see if bone mineral content or density was affected by creatine supplementation. We hypothesised that creatine supplementation during resistance training would increase bone mineral content and density to a greater extent than resistance training alone and that this would be related to increases in lean tissue mass.

Methods

Subjects

Thirty-three men volunteered for this study with written informed consent and physician approval. Subjects were randomly assigned (double blind) to receive either creatine monohydrate or placebo supplementation. Three subjects, one receiving creatine and two receiving placebo, withdrew from the study due to back or knee injuries that were unrelated to the training. One subject in the placebo group was excluded because he was taking a bisphosphonate (alendronate). All other subjects were free of any conditions that may affect bone mineral content or density and were not on medications that may affect bone mineral content or density. The number of subjects in the final analysis was 16 in the creatine group and 13 in the placebo group. Subjects in the creatine group were of age 70.8±6.6 y, mass of 88.0±14.3 kg, height of 177.6±6.9 cm, and had a mean daily calcium intake (determined by 3-day food diary) of 836±580 mg/day. Subjects in the placebo group were of age 71.5±6.7 y, mass of 81.1±10.1 kg, height of 176.2±4.5 cm, and had a daily calcium intake of 726±325 mg/day. Energy and macronutrient intake were determined by a 3-day food diary, at the end of the study, and analysed using FUEL

Nutrition Software 2.1a (LogiForm International Inc., Saint-Foy, Quebec, Canada) and are presented in Table 1. The study was approved by the participating university's Biomedical Ethics Review Committee for Human Experimentation and by the local District Board of Health.

Supplementation protocol

The group receiving creatine supplementation was required to consume 0.3 g·kg^{-1} body weight creatine per day for the first five days, according to the supplementation protocol of Hultman et al. (13), and 0.07 g·kg^{-1} body weight per day for the remainder of the study (79 days). The creatine was combined with a sucrose-flour mixture to mask the creatine. The placebo group consumed a sucrose-flour mixture with an equal portion added in place of the creatine, making it indistinguishable in flavour, texture, and appearance from the creatine mixture.

Resistance Training Program

We have previously described the training program in detail (4); therefore, only a brief summary is given here. Both groups performed a supervised whole-body resistance training program, three times per week for 12 weeks. Three sets of 10 repetitions were performed on 12 different exercises. Exercises included: bench press, lat pulldown, shoulder press, leg press, biceps curl, back extensions, knee flexion, knee extension, and hip (extension, flexion, abduction, adduction). Intensity was initially set at 50% of the subject's 1-repetition maximum and was progressively increased once a subject was able to complete 10 repetitions on all three sets with proper form. Strength testing for determination of the 1-repetition maximum is described in detail elsewhere (4). Attendance at training sessions averaged 95.3% and did not differ significantly between groups.

Bone Mineral Assessment

Bone mineral content (g) and areal bone mineral density (g/cm^2) for the whole body (excluding head) and sub-regions (arms, legs, and trunk) were measured by whole body dual-energy X-ray absorptiometry (QDR 2000; Hologic Inc., Waltham MA, U.S.A) in array mode. The legs sub-region included pelvis and legs since muscle groups attached to these bone sites were used during the lower body exercises of the training program. The trunk sub-region included ribs, lumbar spine and thoracic spine. Subjects were scanned before and after the training-supplementation protocol. Reproducibility was determined on ten subjects assessed on two separate occasions. The coefficients of variation for bone mineral content and density of the whole body were 0.60%, and 0.51%, respectively.

Statistical Analyses

Unpaired t-tests were used to assess differences in baseline variables between groups. A two (creatine and placebo groups) by two (before and after training) analysis of variance, with repeated measures on the second factor, was used to analyse bone mineral content and bone mineral density. Multiple comparisons testing using Tukey post-hoc analysis was used, when differences were confirmed with analysis of variance. All results are expressed as means±SD. Significance was set at an alpha level of 0.05.

Results

There were no differences in baseline anthropometric variables between the groups. There were no differences in calcium, energy, or macronutrient intake between groups (Table 1). Both groups had significant increases in strength with training, with the creatine group demonstrating a significantly greater increase in leg press, but not bench press strength compared to the placebo group ($p<0.05$). These results are described in detail elsewhere (4) and presented in Table 2.

Table 1
Energy and Macronutrient Intake

	Energy (Kcal)	Carbohydrates (g)	Fat (g)	Protein (g)
Creatine group	2139±584	242±68	84±28	89±28
Placebo group	2124±425	282±65	70±22	79±18

All values are means±SD; There were no differences between groups

Table 2
Strength (kg) before and after training, and the absolute change in groups receiving creatine and placebo

	Before training	After training	Change
Leg press			
Creatine group	140±44	190±56*	50±30**
Placebo group	134±32	165±35*	31±12
Bench press			
Creatine group	76±24	98±26*	22±11
Placebo group	61±17	77±17*	17±10

All values are means±SD; *value after training is significantly different from before training ($p<0.05$); **change in the creatine group is greater than the change in the placebo group ($p<0.05$)

There were no differences in bone mineral content or bone mineral density between groups at baseline. Bone mineral content and bone mineral density before and after training for groups supplemented with creatine and placebo are shown in Tables 3 and 4. Whole body bone mineral density increased by approximately 0.5% in both groups (time main effect; $p=0.05$). Legs bone mineral density increased by 1.2% and 1.1% respectively for creatine and placebo groups (time main effect; $p=0.001$). There was a significant group by time interaction for arms bone mineral content ($p=0.0005$). The group

supplemented with creatine increased arms bone mineral content by 3.2% (Tukey post-hoc; p=0.0009), while the group receiving placebo had a non-significant decrease of 1.0%. There were no other changes in bone mineral content or density with training or creatine supplementation.

Table 3
Bone mineral content (g) in whole body and sub-regions before and after training in groups receiving creatine and placebo

	Before training	After training
Whole body		
Creatine group	2170±396	2187±386
Placebo group	2212±454	2207±451
Arms		
Creatine group	433±77	447±82*
Placebo group	405±97	401±98
Legs		
Creatine group	1312±246	1320±227
Placebo group	1385±265	1391±263
Trunk		
Creatine group	427±91	425±91
Placebo group	422±103	414±101

All values are means±SD; *value after training is significantly different from before training (p<0.05)

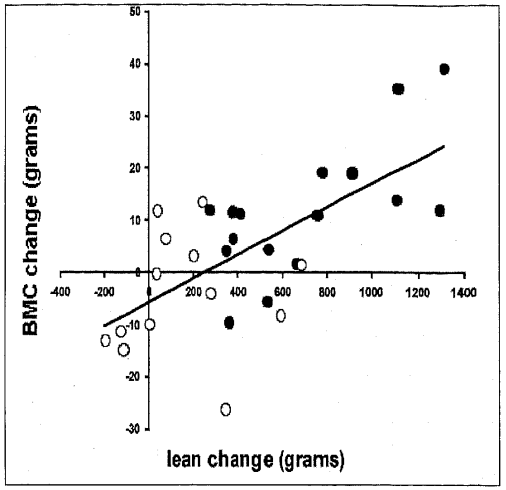
Table 4
Bone mineral density (g/cm^2) in whole body and sub-regions before and after training in groups receiving creatine and placebo

	Before training	After training
Whole body		
Creatine group	0.980±0.088	0.985±0.088*
Placebo group	1.008±0.112	1.014±0.113*
Arms		
Creatine group	0.829±0.060	0.825±0.064
Placebo group	0.804±0.088	0.801±0.084
Legs		
Creatine group	1.150±0.101	1.164±0.104*
Placebo group	1.188±0.125	1.201±0.131*
Trunk		
Creatine group	0.775±0.106	0.777±0.096
Placebo group	0.801±0.135	0.799±0.136

All values are means±SD; *value after training is significantly different from before training for combined groups (p≤0.05)

To see if the greater increase in arms bone mineral content in the creatine group corresponded to a greater increase in lean tissue mass, we performed a correlation between changes in arms bone mineral content and changes in arms lean tissue mass. This correlation was statistically significant (r=0.67; p<0.0001) (Figure 1).

Figure 1
Correlation between changes in bone mineral content and lean tissue mass of the arms in subjects supplemented with creatine (dark circles) and subjects on placebo (open circles) after 12 weeks of resistance training. r = 0.67; p<0.0001



Discussion

The major new finding of this study is that creatine monohydrate supplementation adds additional benefit for increasing bone mineral content of the arms of older men engaged in a resistance training program. This may have clinical importance in that after 50 years of age for men the risk of forearm fracture due to osteoporosis is increased (14).

The increase in bone mineral content may be related to increases in muscle mass, which would increase muscle pull and strain on bone, providing stimulus for bone formation. This has been suggested by others who found that 3 months of creatine supplementation increased bone mineral density in dystrophic patients (12) and is supported by our significant correlation between changes in bone mineral content and lean tissue mass of the arms (Figure 1). Other possible mechanisms for an increase in bone mineral content or density with creatine supplementation include an activation of osteoblasts or a decrease in activity of osteoclasts. Osteoblasts, the cells that are involved in bone formation, contain creatine kinase, a key enzyme involved in energy metabolism, which is activated by compounds that stimulate bone formation (15). Creatine supplementation could theoretically increase levels of creatine phosphate, which is a substrate for creatine kinase, which in turn would increase metabolic activity of osteoblasts. Other recent studies indicate that creatine supplementation decreases

urinary markers of bone resorption (12, 16), which would imply that creatine is reducing the activity of osteoclasts, the cells involved in resorption. Our results partially support our original hypothesis in that bone mineral content at one bone site (arms) was increased with creatine supplementation. A longer period of supplementation may be necessary to realise increases at other bone sites.

It should be noted that creatine supplementation resulted in increased bone mineral content (measured in grams) in the arms without a corresponding increase in areal bone mineral density (measured as g/cm^2). This would result if bone area was increasing in proportion to the increase in bone mineral content. Others have previously shown this to occur in the forearm with exercise training, where cross-sectional area and bone mineral content of cortical bone increased with no change in bone mineral density (17). This geometric change results in a favourable increase in bone strength (17).

As mentioned above, there is one previous study finding a positive effect of creatine supplementation on bone mineral density (12). Two other studies in humans have shown that creatine supplementation has no effect on bone mineral density in young athletic subjects (18) or markers of bone formation in older subjects (19). The study of young athletic subjects may have been too short a duration (28 days) to result in changes in bone mineral density, and blood markers of bone formation (in this case osteocalcin) are quite variable.

The current study was a follow-up to a study that assessed changes in lean tissue mass from whole-body scans by dual energy X-ray absorptiometry (4). Future research should investigate the effects of creatine supplementation in older individuals using scans of specific sites that are susceptible to loss of bone with age (i.e. the proximal femur and the lumbar spine).

A limitation of our study was that we did not include a control group and a supplementation-only group. Because all the older men recruited for the study had relatively low muscle mass, we felt it was most ethical to offer each subject the strength training program to increase their muscle mass and strength.

In summary, 12 weeks of resistance training resulted in increases in bone mineral density of the whole body and legs sub-region in older men. Creatine supplementation had the additional benefit of increasing bone mineral content of the arms. Future research should investigate the effects of creatine supplementation on bone mineral of post-menopausal women, given that they have a higher incidence of osteoporosis than older men (14).

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