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Creatine Monohydrate Enhanced Fixed and Planned Load Reduction Resistance Training without Altering Ratings of Perceived Exertion

Original Research

Jaqueline M Paiva[1], Carolina O S Souza[1], Vitor O Valle[1], Scott C. Forbes[2], Rafael Pereira[4], Marco Machado[1,3]

[1]*Laboratory of Physiology and Biokinetic, Faculty of Biological Sciences and Health, UNIG Campus V at Itaperuna, Brazil*
[2]*Department of Physical Education, Brandon University, Brandon, MB, Canada*
[3]*Laboratory of Human Movement Studies, University Foundation of Itaperuna, Itaperuna, Brazil*
[4]*Integrative Physiology Research Center, Department of Biological Sciences, Universidade Estadual do Sudoeste da Bahia (UESB), Jequie 45210-506, Bahia, Brazil*

Abstract
Creatine enhances resistance training adaptations and may alter ratings of perceived exertion (RPE). Planned load reduction training (10% reduction in load per set) lowered RPE compared to traditional fixed load resistance training (3 sets at a constant load) with similar muscle adaptations. The purpose was to examine the effects of creatine on performance and RPE during both traditional fixed and planned load reduction training compared to placebo. Forty resistance trained males were randomly assigned to either creatine (20 g·day^{-1}) or placebo for 7 days. Following the loading phase, all participants completed 3 resistance training protocols (3 sets of bench press and smith machine squats) in random order; a constant load (CON), 5% load reduction each set (RED 5), and a 10% load reduction each set (RED 10). Total repetitions and RPE were recorded each set. Creatine supplementation increased bench press repetitions with no significant difference in RPE compared to placebo. There were no other differences between supplements or protocols. Creatine supplementation was able to augment bench press performance compared to placebo without increasing RPE. Creatine did not differentially influence fixed compared to planned load reduction training nor was it able to enhance lower body squat total repetitions.

Key Words: supplement; performance; strength.

Corresponding author: Marco Machado, marcomachado1@gmail.com

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Introduction

Resistance training is well known to enhance muscular strength and muscle size over time [1]. Combining resistance training and creatine monohydrate, a nitrogen-containing compound found in red meat and seafood [2], has shown promise for augmenting training volume, muscle mass and strength gains (for reviews see [3-6]). Ninety-five percent of creatine is stored in skeletal muscle while the remainder is found in brain, liver, kidneys, and testes [2]. Within the muscle, ~two-thirds is stored as phosphocreatine (PCr), the remaining one-third is unbound free creatine [2, 7, 8]. Creatine monohydrate supplementation can increase PCr and total creatine content (~20%) enhancing the capacity for ATP re-synthesis during sustained intense muscular work or may enhance PCr recovery between working sets [9, 10], leading to a greater training volume [11, 12] or enhanced muscular performance [8].

Recently, there has been a great interest into various resistance training protocols in an attempt to either maximize resistance training adaptive responses [13] or alter ratings of perceived exertion while maintaining similar adaptive responses [14]. In theory, if an exercise protocol can reduce ratings of perceived exertion while achieving similar resistance training adaptations, this may lead to enhanced adherence and compliance over time. Lima and colleagues [14] have recently demonstrated similar hypertrophic responses and strength adaptations with planned load reductions (5% or 10% load reductions) compared to fixed loading when training to voluntary failure over 16 weeks. Despite similar training volume, hypertrophy, and strength gains, the 10% load reduction had a lower average session ratings of perceived exertion. It is plausible that creatine supplementation can influence the energetic demands altering the ratings of perceived exertion. For example, Astorino et al. [15] found no effect on 5000 meter running performance following creatine supplementation compared to placebo, however, they reported lower RPE. Jacob et al. [16] found improvements in upper body endurance capacity without an increase in RPE, suggesting that creatine attenuated the perception of effort. The precise mechanism(s) explaining how creatine impacts RPE is unknown; theoretically, elevating phosphocreatine via creatine supplementation may reduce anaerobic glycolysis and metabolic by-product accumulation which are associated with increases in perceived effort. To extend previous literature and to our knowledge, no one has directly compared the impact of creatine on RPE following planned load reduction training. Thus, the purpose of this study was to examine the acute effects of creatine loading (7 days) on total repetitions completed and RPE during fixed and planned load reduction training compared to placebo. Based on previous literature, we hypothesized that planned load reduction training would result in a lower RPE compared to fixed load training. We also hypothesized that creatine would further lower RPE, or allow a greater training volume at a similar RPE compared to placebo.

Methods

Experimental Approach to the problem

A randomized double blind placebo controlled trial was used. During the first laboratory visit, anthropometric measures (height and body mass) were collected and 12 repetition maximum (12-RM) for bench press and smith machine squat were determined. To assess test-retest reliability, 12-RM tests were repeated 72 hours apart. Participants were then supplemented with creatine monohydrate (20 g per day for 7 days) or placebo (Dextrosol; 20 g per day for 7 days). This dose has been shown to saturate skeletal muscle creatine content [10]. Following creatine loading, participants completed three conditions (described below) over a 14-day period. Although, creatine was not provided during this 14 day period, it is well known that once the muscle is loaded with creatine, it takes approximately 6 weeks for the creatine in muscle return to baseline [10]. Each exercise session involved three sets of bench press and smith machine squats but varied based on loading schemes; 1. A constant 12RM load for all three sets (CON); 2. A 5% reduction following each set (RED 5) (i.e. 100% of 12RM, 95% of 12RM, and 90% of 12RM); and 3. A 10% reduction following each set (RED 10). Furthermore, food intake was assessed with three 24 hour dietary recalls.

Participants

Forty male participants (age = 23 ± 7 years, body mass = 74.8 ± 12.1 kg, height = 175 ± 6 cm) with at least two years of recreational resistance training experience (i.e., minimum 3 sessions per week with experience training to failure) volunteered for the study. Exclusion criteria included: a) using anabolic drugs b) bone, joint, metabolic, or muscular problems that would impact the study and c) vegetarians or vegans, since they have lower muscle creatine stores and may respond differently to creatine supplementation [17]. All participants read and signed an informed consent that was approved by local ethics committee.

Procedures

Each exercise session was conducted on a consistent day and time. A strength and conditioning specialist supervised each exercise session to ensure proper technique and provide spotting and verbal encouragement. During the first laboratory visit a 12 repetition maximum (12RM) load was established for both the smith machine squats and bench press (on a machine) according to previously published procedures [14]. Furthermore, the 12RM was re-assessed following 72 hours of recovery to determine test retest reliability using intra-class correlation coefficients (ICC Smith Machine = 0.985; ICC bench press = 0.943). Before the 12RM tests, each participant completed 5 minutes of low-intensity aerobic activity (i.e., jogging/walking). Two warm-up sets preceded testing of each exercise at 50% of their perceived

12RM load for 10 repetitions each. After the warm-ups sets were completed, the load was increased progressively to the perceived 12RM, and 1 set was performed to voluntary exhaustion (i.e., muscle failure) which was used to determine 12RM.

Once 12RM was determined, participants were randomized into creatine (n = 21) or placebo (n = 19) groups. Participants in the creatine group ingested 5 g of creatine (powder form; Midway, Santos-SP, Brazil) and 5 g of dextrosol (New Millen Ltda, Cajamar-SP, Brazil) four times per day for 7 days. Analyses from three independent laboratories confirmed that the creatine supplements were 99.9% pure, with no microbiological contaminants [27]. Food intake was assessed by three 24 hr dietary recalls undertaken on separate days (two week days and one weekend day) using a visual aid and photo album of real foods. Energy and macronutrient intake were analyzed by the Brazilian Software Virtual Nutri Plus®.

The 12RM loads established during the initial training period were used to design the subsequent experimental testing sessions. The following testing conditions included (a) constant load for all sets (CON), (b) 5% load reduction after each set (RED 5), and (c) 10% load reduction after each set (RED 10). The conditions were randomized and counter-balanced to control for order effects. Each testing session began with 5 minutes of low-intensity aerobic activity (i.e., jogging/walking). Two warm-up sets at 50% of the 12RM for 15 repetitions. Three minutes after the warm-up sets, 3 consecutive sets were performed to the point of voluntary exhaustion (i.e., full repetition maximums). Participants were allowed exactly 1 minute of rest between sets. Total number of repetitions and ratings of perceived exertion (RPE) [18] were recorded after each set.

Statistical analysis

All data are presented as mean ± standard deviation. Dependent variables were assessed with a two-way mixed model analysis of variance with repeated measures. Multiple comparisons were made according to Bonferroni's method. When sphericity was not verified Greenhouse-Geisser correction was used. Significance level was set at $p \leq 0.05$. Statistical analysis was completed using Jamovi 1.0.4.0 (Jamovi Project).

Results

Anthropometrics

Baseline anthropometric characteristics are shown in table 1. There were no significant differences between creatine and placebo groups at baseline. Following supplementation, there was a significant interaction between groups over time for body mass ($p<0.001$; Cohen's d = 1.0873). Creatine loading significantly increased body mass (1.0 kg; pre: 74.9 ± 13.8 to 75.9 ± 13.6; $p<0.01$), while there were no changes in the placebo condition (-0.1 kg; pre: 74.7 ± 10.3 to post: 74.6 ± 10.5; $p=0.54$).

Table 1 – Baseline subject characteristics.

	Creatine (n=21)	**Placebo (n=19)**	***p-value***
Age (years)	23.2±7.6	23.3±6.9	0.957
Body Mass (kg)	74.9±13.8	74.7±10.3	0.962
Height (cm)	175±7	175±5	0.803
%CHO	54.8±8.4	56.0±5.8	0.601
%FAT	28.4±7.1	27.7±3.7	0.669
%PRO	16.8±2.8	16.4±3.2	0.645
12 RM Bench Press	69.6±17.8	69.2±14.2	0.906
12 RM Smith Machine Squat	67.2±17.8	66.7±15.4	0.910

RM = repetition maximum

Performance

Creatine signficantly increased total bench press repetitions ($p = 0.04$; $\eta^2 = 0.029$), however, there was no group effect for total smith machine squat repetitions ($p = 0.234$; $\eta^2 = 0.021$).

There were no significant group (creatine vs. placebo) by condition (fixed vs. 5 vs. 10% planned load reduction) by set (set 1 vs. set 2 vs. set 3) for repetitions on bench press ($p = 0.203$; $\eta^2 = 0.003$) and smith

machine squats ($p = 0.904$; $\eta^2 = 0.001$) as shown in figures 1 and 2, respectively. As predicted, there was a significant decrease in the number of repetitions performed across sets.

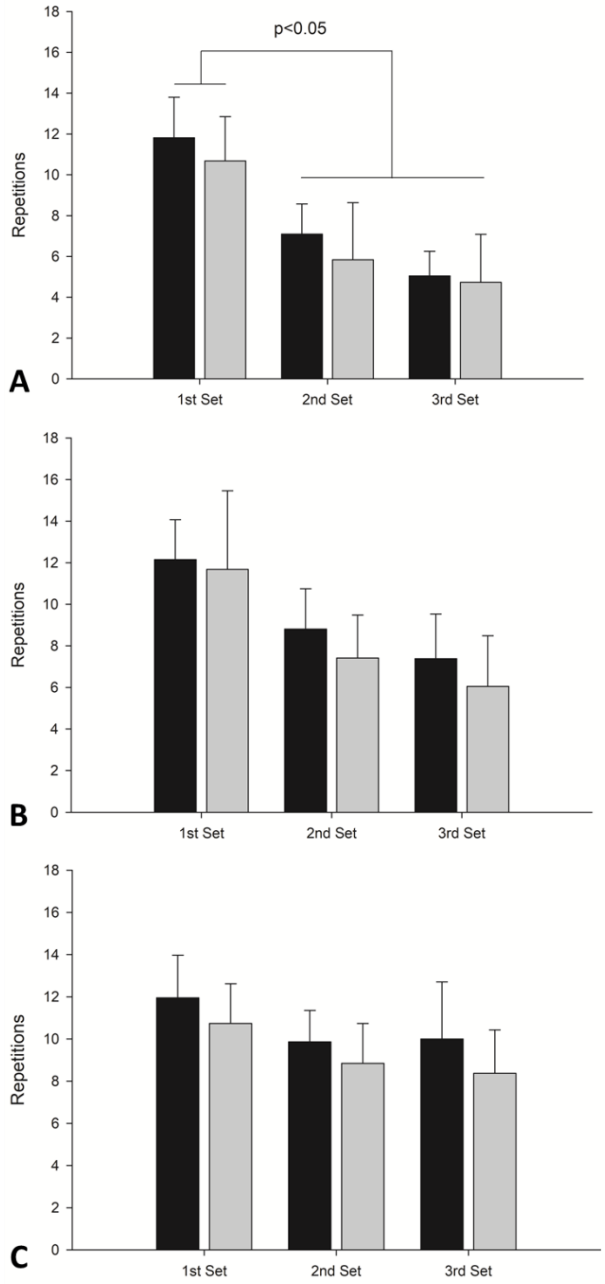

Figure 1 – Repetitions per sets in bench press. Black bars = Creatine Group; grey bars = Placebo group. A – Fixed loading; B – 5% planned load reduction; C – 10% planned load reduction.

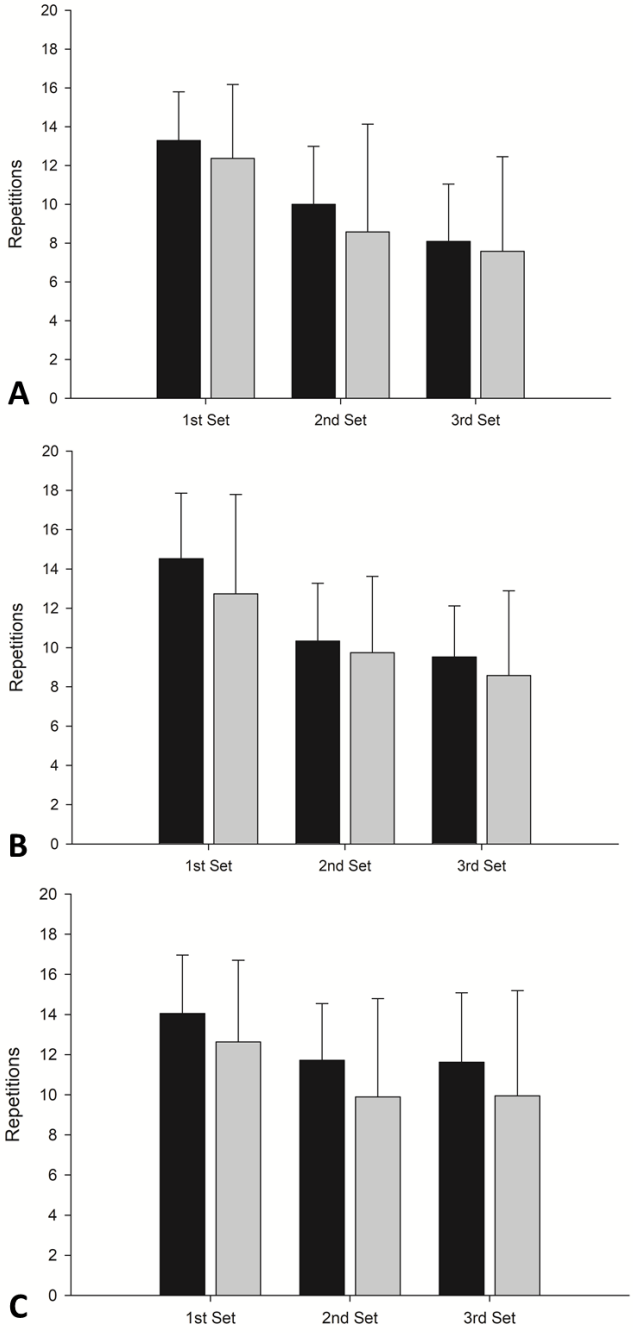

Figure 2 - Repetitions per sets in Smith Machine Squat. Black bars = Creatine Group; grey bars = Placebo group. A – Fixed loading; B – 5% planned load reduction; C – 10% planned load reduction.

Ratings of Perceived Exertion

Despite the creatine groups performing more total repetitions on bench press, there was no significant difference in ratings of perceived exertion (Bench Press: $p = 0.834$; $\eta^2 = 0.000$) when compared to placebo. There was also no significant difference between groups for smith machine squat post set RPE. There was no significant (creatine vs. placebo) by condition (fixed vs. 5 vs. 10% planned load reduction)

by set (set 1 vs. set 2 vs. set 3) for post set RPE following both bench press ($p = 0.667$; $\eta^2 = 0.001$) and smith machine squat ($p = 0.966$; $\eta^2 = 0.000$) as shown in figure 3 and 4, respectively.

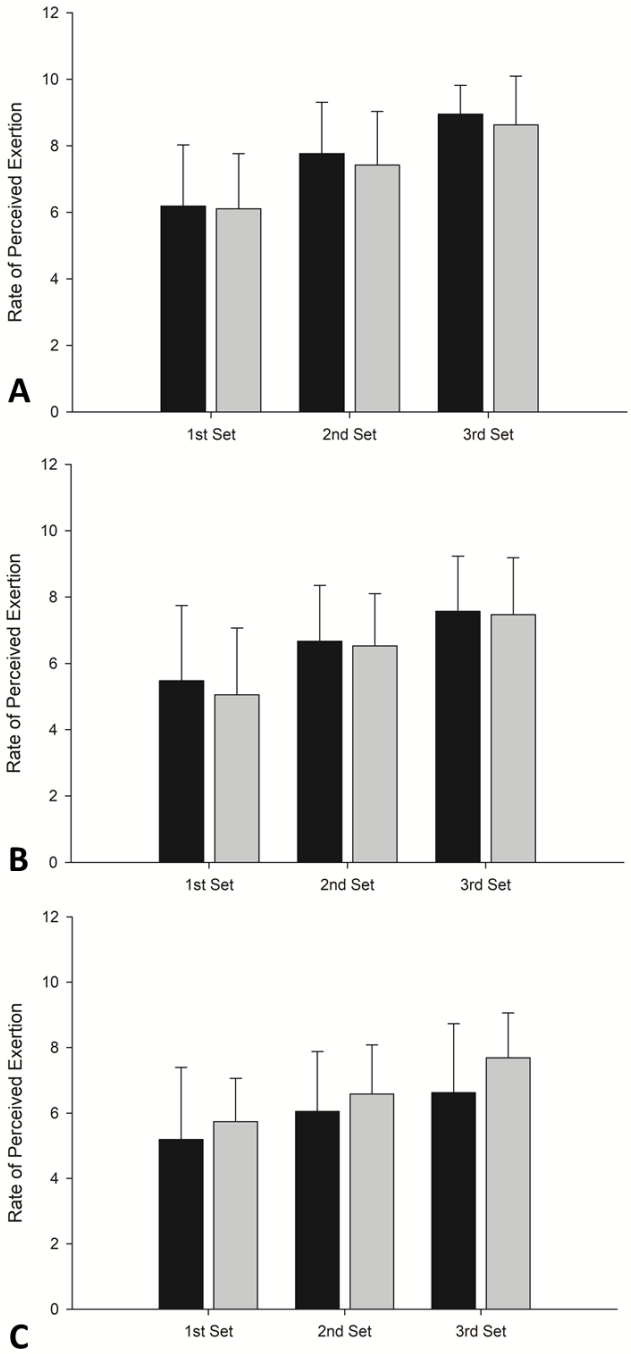

Figure 3 – Rate of Perceived Exertion per sets in Bench Press. Black bars = Creatine Group; grey bars = Placebo group. A – Fixed loading; B – 5% planned load reduction; C – 10% planned load reduction.

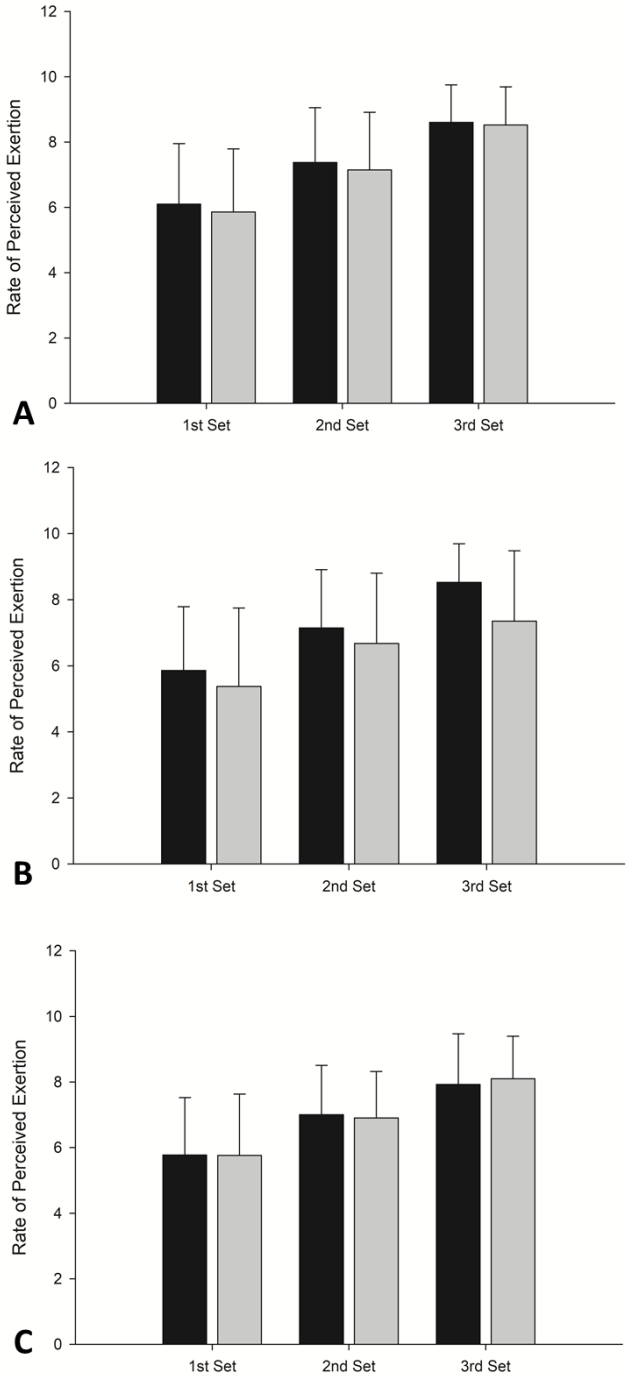

Figure 4 – Rate of Perceived Exertion per sets in Smith Machine Squat. Black bars = Creatine Group; grey bars = Placebo group. A – Fixed loading; B – 5% planned load reduction; C – 10% planned load reduction.

Discussion

Creatine supplementation can increase muscle creatine and phosphocreatine content thereby facilitating a greater capacity for ATP re-synthesis and enhanced high intensity muscular performance [8]. These metabolic changes may influence various forms of training differently and may also influence RPE [16]. This is the first study to directly compare the impact of creatine loading on two resistance training protocols and RPE compared to placebo. Results showed that creatine supplementation regardless of training protocol increased upper body performance compared to placebo, despite no differences in RPE. These results suggest that a greater training stimulus can be achieved with similar perceived exertion following creatine loading. These novel results provide further rationale beyond the well-known mechanistic actions of creatine on skeletal muscle [4]. Despite the impact of creatine on upper body performance, creatine did not augment lower body performance, nor did it differentially influence fixed or planned load reduction protocols.

The optimal training protocol to maximize resistance training adaptive responses [13] or alter ratings of perceived exertion while maintaining similar adaptive responses is currently unknown. In theory, if an exercise protocol can reduce ratings of perceived exertion while achieving similar resistance training adaptations, this may lead to enhanced adherence and compliance over time. Lima and colleagues [14] have recently demonstrated similar hypertrophic responses and strength adaptations with planned load reductions (5% or 10% load reductions) compared to fixed loading when training to voluntary failure over 16 weeks. Despite similar training volume, hypertrophy, and strength gains, the 10% load reduction had a lower average session RPE. The present study examined the acute effects of creatine loading on performance and RPE following fixed and planned load reduction training. Overall, creatine loading was able to enhance total repetitions on bench press compared to placebo with no observable effect on lower body (i.e., smith machine squat) performance. Despite the enhanced upper body training, there was no significant difference on RPE, suggesting that creatine can enhance bench press performance without an increase in RPE. Previous research examining upper and lower body responses to creatine supplementation support our findings [4, 19]. Chilibeck and colleagues [4] performed a meta-analysis in aging adults and found a larger standard mean difference for chest press (upper body) gains in strength (SMD = 0.35; 95% CI: 0.16-0.53) compared to leg press strength (SMD = 0.24; 95% CI: 0.05-0.43). Potentially, these differences may be associated with fiber type differences [20] between upper and lower body muscles. The majority of intramuscular creatine is found in type II muscle fibers, and Syrotuik and Bell [20] showed that individuals with the highest concentration of type II muscle fibers responded more favorably to creatine supplementation. A limitation of the current study was the lack of a muscle biopsy to verify fiber type differences between muscle groups and individuals.

Furthermore, creatine loading did not alter fixed loading or planned load reduction (both 5 and 10%) differently. Due to the metabolic similarities between these protocols, these results were not surprising. However, the selection of the protocols were based on previous research that found differences in RPE with similar adaptive responses [14]. The primary purpose of the study was to confirm these results and to determine if creatine could further alter RPE. Our results did not find a difference between protocols and RPE (i.e. placebo fixed loading vs. planned load reduction RPE) which is contrary to previous findings. These differences may be due to methodological differences (e.g., within-subject vs. between subject design and acute vs. chronic protocols). Interestingly, creatine was able to allow for a greater training performance without a subsequent increase in perceived effort. Theoretically, this decrease in RPE may be associated with lower metabolic disturbances (i.e. lower lactate, H+ ions, and inorganic phosphate) following creatine supplementation. In support of our findings, previous research found a decrease in RPE at the same running speed [15]. It is also possible for creatine to pass the blood brain barrier and influence cognitive processes [21]. Future research examining the impact of creatine on cognition and RPE in a variety of populations and exercise conditions is warranted.

We would like to highlight several limitations of the present study. We did not take muscle biopsies to measure fiber types or muscle creatine content. Furthermore, we only examined the effects of creatine loading on acute exercise performance. Future long term training studies are warranted to confirm these findings. We also did not perform repeated familiarization sessions, thus there is a possibility of a learning effect. Lastly, we only used male participants, future research in females is required.

Contrary to previous research there was no difference in RPE between fixed and planned load reduction training. Despite no differences between training protocols, creatine supplementation was able to augment upper body performance compared to placebo at a similar RPE. With the importance of training volume to stimulate muscle hypertrophy and strength adaptations, and the importance of perceived exertion, these findings may provide a novel rationale to support creatine supplementation beyond its well-known cellular mechanistic impact at the muscle level. These improvements were not found for lower body exercise, potentially associated with fiber type differences. Future research examining the effect of creatine on RPE in a variety of populations and exercise conditions are warranted.

Media-Friendly Summary

Creatine enhanced upper body (i.e. bench press) performance without any increase in ratings of perceived exertion, that is the participants performed more repetitions without a change in subjective feelings of effort. Creatine did not influence lower body (i.e. squat) performance potentially due to fiber type differences between the upper and lower body. Lastly, creatine did not differentially influence nor were there differences between fixed and planned load reduction resistance training protocols.

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