Effect of Acute Beetroot Juice Supplementation on Bench Press Power, Velocity, and Repetition Volume

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Abstract

Williams, TD, Martin, MP, Mintz, JA, Rogers, RR, and Ballmann, CG. Effect of acute beetroot juice supplementation on bench press power, velocity, and repetition volume. *J Strength Cond Res* 34(4): 924–928, 2020—The purpose of this study was to examine the effects of acute beetroot juice (BRJ) supplementation on power, velocity, and repetitions to failure (RTF) during bench press exercise. Resistance-trained male subjects ($n = 11$) were recruited for this study. Using a double-blinded, counterbalanced, crossover study design, subjects were supplemented with either 70 ml of BRJ or placebo (PL; black currant juice) 2 hours before exercise. During each exercise trial, subjects began by completing 2 sets × 2 repetitions of bench press at 70% 1 repetition maximum (1RM) with maximum explosive intent. Barbell velocity and power were measured using a linear position transducer. Subjects then completed 3 sets × RTF at 70% 1RM separated by 2 minutes of rest between each set. Maximum mean power, velocity, and repetitions were analyzed. Mean velocity ($p = 0.011$; effect size [ES] = 0.54) and mean power ($p = 0.015$; ES = 0.51) were significantly higher with BRJ when compared with PL. Total RTF ($p = 0.002$; ES = 0.46) was higher during the BRJ condition vs. PL. Results indicate that acute BRJ supplementation positively impacts velocity, power, and total repetitions during free-weight bench press exercise.

Key Words: nitrate, ergogenic aid, resistance training

Introduction

Beetroot juice (BRJ) is a rich source of bioavailable dietary inorganic nitrate (NO_3^-) (30). After ingestion, NO_3^- from BRJ is absorbed and concentrated in the saliva where anaerobic bacteria in the mouth reduce it to nitrite (NO_2^-) through nitrate reductase (34). NO_2^- is then either further broken down to nitric oxide (NO) in the stomach or absorbed into the systemic circulation (21). Circulating NO_2^- can also be further reduced to NO and cause a multitude of physiological changes. Precursors to NO have been shown to cause vasodilation (23), lower blood pressure (28), alter lactate removal (33), and increase muscle blood flow (12). Because of these changes, BRJ has become a popular dietary supplement for use during exercise in efforts to increase performance. However, much of the literature is conflicting, and evidence for how BRJ affects free-weight resistance exercise is lacking.

Beetroot juice supplementation and exercise performance has been primarily studied in endurance-based exercise and has revealed varied results. Hoon et al. (17) showed that BRJ ingestion improved 2,000-m rowing performance in well-trained athletes. Further supporting this, Cermak et al. (9) showed multiple days of BRJ ingestion enhanced 10-km time-trial cycle performance in trained cyclists. Although the exact physiological mechanisms for improvements in performance are not fully clear, it appears that BRJ enhances O_2 uptake kinetics and increases contractile efficiency (3,8). However, multiple other groups have shown that BRJ supplementation does not improve performance. Muggeridge et al. (25) showed that a single bolus of BRJ did not improve time-trial performance of kayakers. Boorsma et al. (7) showed no difference in 1,500-m run time in athletes with acute or chronic BRJ supplementation. Thus, the collective results of BRJ and improvements in exercise performance are equivocal leaving the need for further study.

Compared with endurance-based exercise, the effects of BRJ on strength and resistance exercise performance are comparatively less studied. Bender et al. (6) showed that acute BRJ supplementation increased peak force during an isometric midthigh pull. Flanagan et al. (13) showed that 3 days of supplementation with beetroot extract improved gross motor efficiency but did not improve resistance exercise performance. Bailey et al. (4) reported that 6 days of BRJ supplementation improved knee extension tests and reduced phosphocreatine (ATP-PC) cost during exercise. Further supporting this, Mosher et al. (24) showed that 6 days of BRJ ingestion increased total volume during Smith-machine bench press exercise at 60% of 1 repetition maximum (1RM). Mechanisms underlying these changes in resistance exercise performance may be due to enhanced neuromuscular efficiency (13), reduced ATP-PC cost (4), and changes in calcium handling (16). In addition, previous reports have shown that BRJ preferentially increases blood flow to fast-twitch fibers (12). Taken together, BRJ may mediate force output and fatigue of fast-twitch fibers possibly leading to improved performance in explosive resistance exercise. However, factors such as different dosages, timing of ingestion, and mode of exercise still need to be investigated.

To date, all studies investigating BRJ and dynamic resistance exercise performance have used multiple day dosage protocols

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leaving the effects of a 1-time acute dose on resistance exercise performance unknown. Furthermore, no investigations have examined BRJ supplementation and free-weight exercise performance at loads typically used to induce hypertrophy (23). Given that loads of 67–85% of 1RM are recommended for hypertrophy and most athletes will use free weights to train (14,24), knowledge of whether BRJ can enhance performance during these conditions is of practical importance. Finally, no studies to date have investigated how BRJ influences power and velocity during barbell movement. Thus, the purpose of this study was to investigate the effects of acute BRJ supplementation on power, velocity, and repetitions completed during free-weight resistance exercise. Owing to previous reports of increased neuromuscular efficiency and calcium sensitivity, we hypothesized that BRJ supplementation would increase power output, velocity, and repetitions performed during free-weight bench press exercise at 70% 1RM.

Methods

Experimental Approach to the Problem

The following investigation used a double-blinded, counterbalanced, crossover study design to investigate the effects of acute BRJ ingestion on velocity, power, and bench press volume. Resistance-trained men volunteered to participate and participated in 2 randomized experimental trials: supplementation with BRJ or placebo (PL; black currant juice). After ingestion, subjects completed a series of bench press exercises. Comparisons were drawn between BRJ and PL for mean velocity, power, and total volume performed during bench press exercise. Trials were separated by a 72-hour washout period.

Subjects

Resistance-trained men ($n = 11$), performing the barbell bench press at least once per week, were recruited for this investigation. Descriptive characteristics of subjects are presented in (Table 1). Resistance-trained was defined as participating in resistance exercise training a minimum of 2–3 days a week (24). Subject aptness for exercise was assessed using a modified physical activity readiness questionnaire (PAR-Q) which excluded subjects who reported upper-body injuries in the past 6 months, metabolic disease, cardiovascular disease, musculoskeletal disease, or other health problems. Subjects were asked to refrain from caffeine, nicotine, alcohol, and strenuous activity 24 hours before each trial. Time of all trials was standardized to where trials were completed within ±1 hour of the same time of day. Written informed consent was obtained from each subject before data collection, and all experimental procedures were approved by the Samford University Institutional Review Board (IRB).

Table 1
Descriptive characteristics of subjects.*†

Characteristic	Mean ± *SD*
Age (y)	22.1 ± 2.4
Height (cm)	170.8 ± 32.6
Body mass (kg)	89.3 ± 10.3
Resistance training experience (y)	7.0 ± 2.8
Bench press 1RM (kg)	127.5 ± 20.6
Relative strength [1RM (kg)/BM (kg)]	1.4 ± 0.2

*1RM = 1 repetition maximum.
†Data are presented as mean ± *SD*.

Procedures

Supplementation. Subjects supplemented with either 70 ml of BRJ (Sport shot, Beet It, United Kingdom) or PL (black currant juice; R.W. Knudsen, Chico, CA) 2 hours before each exercise trial (11). The BRJ was standardized to provide approximately 400 mg of nitrate per dose while the PL provided negligible to no nitrate. Subjects were instructed to consume the entirety of the supplement within 5 minutes. In addition, all subjects were asked to replicate their diet each day of the exercise trials. Subjects were not aware of any experimental hypotheses. Supplements were distributed by an independent researcher not involved in testing, and distribution order was only divulged to researchers on completion of data collection.

One Repetition Maximum Testing and Familiarization. For the first session, subjects completed a warm-up consisting of 5 repetitions at 50% and 3 repetitions at 70% of their perceived 1RM for bench press. Each set was separated by a 2-minute rest period. The barbell load was then increased by 2.0–20.0 kg for each 1RM attempt until the subject could not complete the lift. The 1RM weight was determined within 4 attempts with 3- to 5-minute rest periods between each attempt (24). After 1RM testing, subjects were familiarized with the protocol of lifting with maximum explosive intent in the bench press. Subjects lifted a standard 20-kg Olympic barbell as fast and explosively as possible for a total of 3 repetitions and correction for form were given if needed.

Protocol. After the ingestion of the supplement, subjects began with a brief warm-up consisting of 5 repetitions at 40% of 1RM and 3 repetitions at 60% of 1RM. Each set was separated by a 2-minute rest period. After the warm-up, subjects completed 2 sets × 2 repetitions of bench press at 70% of 1RM with maximum explosive intent separated by 3 minutes of rest. A linear position transducer (GymAware, Kinetitech Performance Technology, Mitchell, Australia) was attached to the barbell to measure power and velocity of movement. This device has been previously validated for velocity and power measurements (18,27). In addition, our group has previously used this equipment with excellent test-retest reliability in our laboratory (intraclass correlation coefficient [ICC] = 0.932) (5). The device was used according to manufacturer's instructions such that the device was attached to the barbell with an approximate perpendicular angle being achieved throughout the entirety of lifts (15). Mean velocity and mean power measurements were averaged across the 2 repetitions, and the highest value between the 2 sets was used for analysis. After a 5-minute rest period, subjects then completed 3 sets × repetitions to failure (RTF) at 70% of bench press 1RM. Each set of RTF was separated by 2 minutes of rest. Failure was determined by the subject's inability to complete the concentric phase of the lift. Mean velocity, mean power, and total repetitions completed during the 3 sets were recorded for analysis.

Statistical Analyses

All data were analyzed using SPSS 25 (IBM, Armonk, NY). Groups were randomized using Excel (Microsoft, Redmond, WA). Power, velocity, and total repetitions were analyzed using a paired-samples *t*-test. Cohen's *d* effect sizes (ES) were calculated for all performance variables as BRJ minus PL divided by the pooled *SD* with the following interpretation: 0.2—small, 0.5—moderate, and 0.8—large (10). Set-to-set RTF performance was analyzed using a 2 × 3 [condition × set] repeated-measures analysis of variance. Multiple comparisons were analyzed with a Bonferroni adjustment if warranted. *SEM* was calculated with the following formula: $SEM = SD$ [SQRT $(1 - \text{ICC})$] (31). All data are presented as mean ± *SD* or overall mean (bars) and individual performance (lines). Significance was set at $p \leq 0.05$ a priori.

Results

Velocity and power measurements are presented in (Figure 1). Mean velocity ($m \cdot s^{-1}$) (Figure 1A) was significantly higher with BRJ supplementation vs. PL (PL = 0.62 $m \cdot s^{-1}$ ± 0.08, BRJ = 0.66 $m \cdot s^{-1}$ ± 0.08; $p = 0.011$; ES = 0.54). Beetroot juice supplementation resulted in increases in mean velocity above the *SEM* (*SEM* = 0.02 $m \cdot s^{-1}$) of the PL in 72% of individuals. Mean power (watts) (Figure 1B) was significantly increased with BRJ supplementation vs. PL (PL = 508.14 W ±117.55, BRJ = 607.36 W ±112.28; $p = 0.015$; ES = 0.51). For mean power, BRJ supplementation resulted in increases above the *SEM* (*SEM* = 29.9 W) of the PL in 63% of individuals.

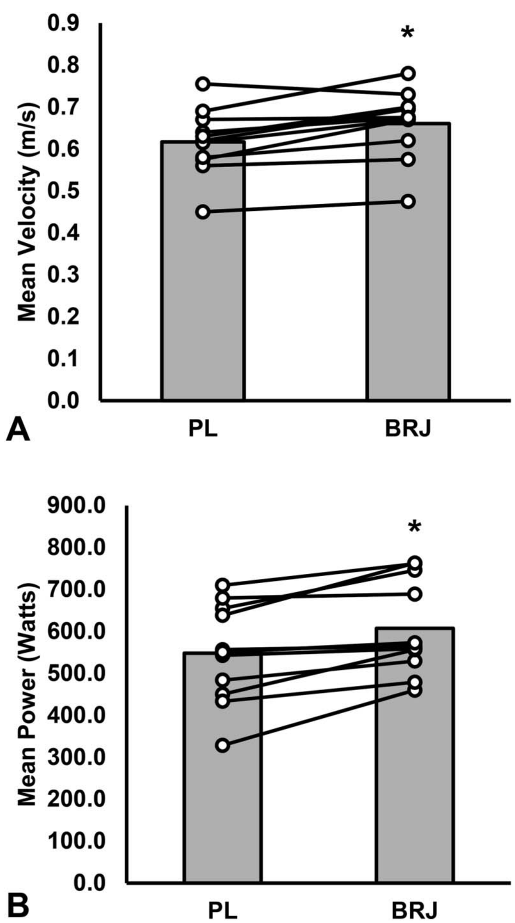

Figure 1. Highest average (A) mean velocity and (B) mean absolute power during 2 reps × 2 sets. Data are presented as overall mean (bars) and individual performance (lines). *Significantly different from placebo ($p < 0.05$).

Repetitions from each set and total repetitions are shown in (Figure 2). For set to set (Figure 2A), there was a main effect for set ($p < 0.001$) with no effect for condition ($p = 0.290$) and no interaction for set and condition ($p = 0.643$). Analysis of multiple comparisons for set showed that set 1 (PL = 14.09 reps ±2.50, BRJ = 14.82 reps ±1.88) was significantly higher than set 2 (PL = 8.36 reps ±1.96, BRJ = 9.55 reps ±2.50; $p < 0.001$) and set 3 (PL = 5.55 reps ±1.63, BRJ = 6.27 reps ±1.67; $p < 0.001$). Set 2 was also significantly higher than set 3 ($p < 0.001$). For total repetitions (Figure 2B), repetitions during the BRJ condition were significantly higher than the PL condition (PL = 28.00 reps ±5.60, BRJ = 30.63 reps ±5.76; $p = 0.002$; ES = 0.46). Beetroot juice supplementation resulted in increases in total repetitions above the *SEM* (*SEM* = 1.46 reps) of the PL in 63% of individuals.

Discussion

Previous investigations have shown that acute BRJ improves isometric force production and multiday supplementation increases number of repetitions completed during Smith-machine bench press (6,24). However, no studies to date have examined the effects of acute BRJ supplementation on power output, velocity, and total volume during free-weight resistance exercise. Thus, the current study sought to investigate whether acute BRJ supplementation improves power output, velocity, and total volume of exercise using free-weight bench press. Our results indicate that acute BRJ supplementation increased mean velocity and mean power output during free-weight bench press. Furthermore, BRJ supplementation increases the total number of repetitions completed across 3 sets to failure. The physiological mechanisms responsible for the changes in performance are unclear based on the current data set, but these results hold important implications for enhancing free-weight resistance exercise performance using BRJ.

A previous investigation has shown that BRJ ingestion increases the total volume and weight lifted during Smith-machine bench press exercise (24). Our results of increased total repetitions during free-weight bench press agree with these findings albeit at a higher load. Unlike our findings, Mosher et al. (24) reported that over 3 sets of RTF, BRJ supplementation resulted in higher repetitions performed over all 3 sets vs. this study which only saw total repetition improvements. Differences in results may be due to exercise equipment and supplementation period. Mosher et al. used a Smith-machine bench press while the current study used a free-weight bench press, which is more practical for athletic preparation. In addition, Mosher et al. used a 6-day supplementation regimen vs. the current acute 1-time dosage. Supporting longer supplementation periods, Bailey et al. (4) showed that a supplementation period of 6 days with BRJ improves knee extension exercise challenges over multiple sets. Thus, a longer supplementation period may have result in greater ergogenic benefits during free-weight resistance exercise. Bolstering this, previous evidence has suggested that longer loading may be needed to maximize benefits of BRJ and nitrate supplementation in trained powerlifters (19). Future studies should seek to elucidate optimal supplement timing and dosage for strength performance.

Currently, acute BRJ supplementation increased dynamic resistance exercise performance. Previous research by Bender et al. (6) demonstrated that acute BRJ supplementation increased peak isometric force output in adolescent men. In

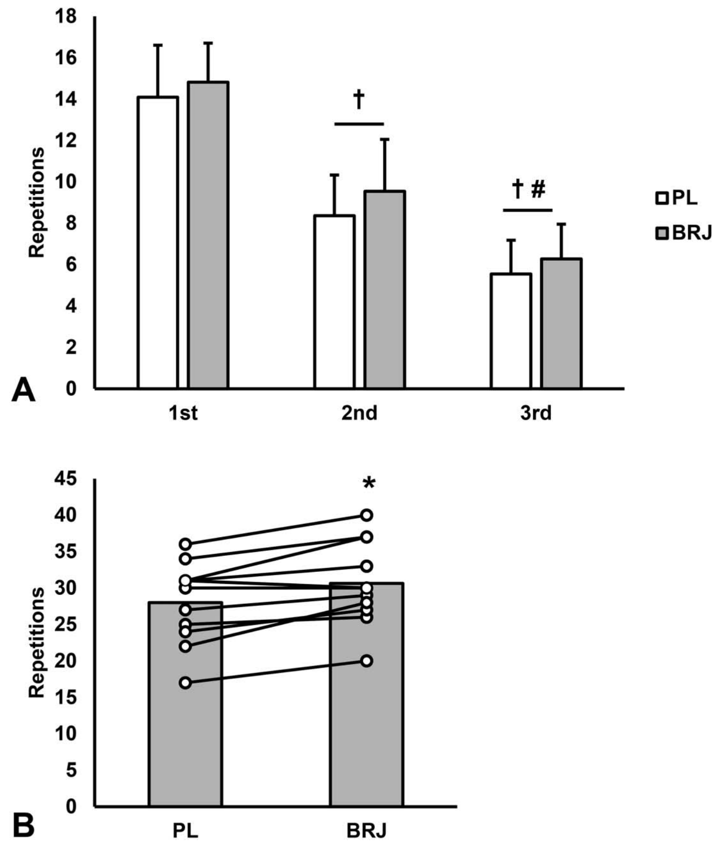

Figure 2. Repetitions to failure from (A) first, second, and third set and (B) total; data are presented as mean ± *SD*. *Significantly different from placebo ($p < 0.05$). †Significantly different from first ($p < 0.05$). #Significantly different from second ($p < 0.05$).

addition to this, Whitfield et al. (32) reported that BRJ supplementation increased force production and peak twitch tension albeit using a multiday dosing protocol. The physiological mechanisms responsible for increases and power and velocity were not currently measured and cannot be identified based off our results alone. However, previous evidence using both human and animal models provides rationale. Hernandez et al. (16) reported that BRJ supplementation increased calcium sensitivity and increased force output of fast-twitch fibers in mice. In regards to the current study, increases in calcium release in fast-twitch fibers may lead to greater cross-bridge formation allowing for greater force production and contraction speed, which would increase power and velocity during exercise. However, changes in calcium handling are not fully supported in humans because previous evidence has shown that multiday BRJ supplementation increases muscle force production despite no changes in calcium handling proteins (32). However, how an acute 1-time dose of BRJ influences calcium handling and sensitivity is unknown and warrants further investigation. Another possible mechanism for increases in velocity and power output may be due to increased neuromuscular efficiency. Flanagan et al. (13) reported that multiday BRJ supplementation altered motor unit firing rate and increased peak electromyography amplitudes during resistance exercise. Furthermore, Bailey et al. (3) reported reduced ATP-PC cost and increased contractile efficiency with BRJ supplementation. Taken together, changes in neuromuscular activation paired with reduced metabolic cost of exercise may have enhanced contractile properties of muscle leading to the increases in power and velocity. Finally, another physiological underpinning for the current results may be due to the fiber-type specific effects of nitrate supplementation (20). Ferguson et al. (12) demonstrated that nitrate supplementation through beetroot juice increased limb and skeletal muscle blood flow preferentially to fast-twitch fibers. Given that O_2 delivery is a limiting factor in resynthesis of ATP-PC and lactate clearance may impact muscle force output (22,29), improved blood flow to fast-twitch fibers in particular may have resulted in improved and sustained muscle force output leading to improved resistance exercise performance.

Although this study provides novel information regarding BRJ supplementation and resistance exercise performance, there were several limitations. Plasma NO_2^- was not quantified in the current study leaving the concentration needed to accompany resistance exercise improvements unknown. However, multiple investigations have confirmed that a dosage of BRJ similar to this study significantly increases plasma NO_2^- (25,26). In addition, only bench press performance at 70% 1RM was investigated. Thus, the effects of acute BRJ supplementation on other free-weight exercises and different relative intensities need to be explored. In conclusion, the present results show that acute BRJ supplementation increases total repetitions performed. Furthermore, BRJ increased velocity and power during free-weight bench press exercise. Future investigations should study how chronic BRJ supplementation influences strength adaptations and what physiological mechanisms are responsible for increases in performance.

Practical Applications

Coaches and athletes alike use dietary ergogenic aids in efforts to improve performance and optimize training results. However, many of them lack scientific support, contain impurities, and can even be harmful. Beetroot juice is a safe, natural, and effective ergogenic aid that has been shown to benefit a wide arrange of populations. Our results suggest that athletes desiring to increase velocity, power, and total repetitions while completing free-weight bench press exercise may consider BRJ as a potential ergogenic aid. The current study may hold important implications for resistance exercise adaptations, and future studies should investigate how chronic BRJ supplementation impacts performance.

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