The Effect of Acute Beetroot Juice Ingestion on Jumping Ability, Upper Body Muscular Strength, and Cardiorespiratory Endurance on Frequently Training High School Athletes: A Double-Blind Randomized Crossover

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Abstract

Ingestion of Beetroot juice (BRJ) has been shown to have improvements on endurance performance and resistance training, but there's scarce evidence of its effectiveness on jumping ability. The purpose of this study was to investigate the effects of BRJ when compared to a placebo (PLA) on cardiorespiratory endurance, upper body muscular strength, and jumping ability. 16 high school athletes, 11 males and 5 females, performed a countermovement jump test (CMJ), 3 medicine ball throws, and a 20m shuttle run (SRT). Each participant had 2 sessions, one where they ingested 70mL of BRJ and another where they ingested 70mL of PLA (Blackcurrant juice). BRJ when compared to PLA showed on average to have a small improvement, but non-significant difference when looking at CMJ (BRJ AVG, 14.63; BCJ AVG, 14.40, $p<0.89$). When looking at medicine ball throw, BRJ showed no improvements, and there was no significant difference (BRJ AVG, 5.30; BCJ AVG, 5.38, $p<0.89$).When looking at the 20mSRT, BRJ shows no improvements and there is no significant difference (BRJ AVG, 4:39; BCJ AVG, 4:50, $p<0.81$). Due to all the p-values >0.80, across 3 different exercises, the supplemental groups data showed no difference and/or no correlation. BRJ shows no improvements in cardiorespiratory endurance, upper body muscular strength, or jumping ability. Future studies should be conducted in order to solidify the results.

1. Introduction

Athletes, trainers, and scientists are always looking for a way they can boost exercise performance, and reach maximal athletic potential to be the best they can in their sport. Natural and dietary supplements have been the healthiest and most effective way to improve exercise performance since the birth of sports. Many supplements have shown to be effective in improving athletic ability, including whey protein, with its benefits in aerobic and anaerobic exercise (Hoffman et al. 2009). Other supplements like creatine, which are naturally produced in the body, have shown to be effective in improving recovery and reducing fatigue (Cribb et al. 2007, Smith et al. 2010). The supplement chosen in this study is beetroot juice, a natural supplement used to increase muscular endurance/tolerance to resistance training (Jurado-Castro et al. 2020). Beetroot juice has also been shown to delay fatigue by improving $VE \bullet VCO_2^{-1}$ slope (Serra-Paya et al. 2021). Beetroot juice improves the $VE \bullet VCO_2^{-1}$ slope by enhancing O_2 intake kinetics and increasing the amount of oxygen going to the muscles (Williams et al. 2020). Beetroot juice in previous studies has been found to show ergogenic effects in exercise performance, mainly when there is a rest period between sets (Jurado-Castro et al. 2020, Serra-Paya et al. 2021). In one study, it was shown that Beetroot juice can increase blood flow to fast twitch fibers (Williams et al. 2020). Research could be done on how Beetroot juice improves endurance on slow-twitch muscle fibers. Beetroot juice contains high levels of NO_3, which NO_3 has shown to reduce oxygen and ATP consumption (Jurado-Castro et al. 2020). NO_3 (Nitrate) enters the body, in this case through beetroot juice, then enters the salivary circulation where it is absorbed and reduced to NO_2 (Nitrite). Then NO_2 breaks down and decomposes in the stomach, where it turns to Nitric oxide(NO) and Nitric oxide, which has shown to have vasodilator effects and can improve blood flow, lactate removal, and lower blood pressure (Jurado-Castro et al. 2020) (Serra-Paya et al. 2021). Beetroot juices' effects on endurance exercise need more research. . Knowing that NO_3 improves ventilatory efficiency, further research could be done on other supplements containing high NO_3 levels to test the effect on ventilatory efficiency during resistance exercise. NO_3 can reduce oxygen consumption by improving ventilatory efficiency and improving the matching of ventilation/perfusion during resistance exercise (Serra-Paya et al. 2021). Since, Beetroot juice has all these ergogenic effects on athletic performance, the purpose of this study was to identify whether Beetroot Juice has ergogenic effects on jumping ability, upper body muscular strength, and cardiovascular fitness.

2. Methods

2.1. Design

The study involved an experimental double-blind crossover randomized trial. The study was designed following the Consolidated Standards of Reporting Trials (CONSORT). The experimental procedure consisted of two visits, separated from one another by one week. Before testing began, athletes were interviewed on body composition and instructed on how and what exercises would be used during the experiment. During the 2 trials, the participants carried out the experimental protocol, after ingesting either a BRJ supplement or a placebo (PLA). In line with previous studies on diurnal variation in strength and muscle power (Lopez-Samanes et al. 2017) and a study on the different effects of BRJ based on the time of day (Dumar et al. 2021), the experimental measurements were taken in the morning, at the same time of day (±0.5 h) for each individual, to standardize the influence of the circadian rhythm, at a temperature of 54°F (± 20°F).

2.2. Participants

To assess the eligibility of high school athletes (males and females) that lift and exercise regularly, the following inclusion/exclusion criteria were considered: i) age, between 14-18 years; ii) more than 2 years doing sport training programs; iii) no consumption of any type of nutritional supplement in the preceding three months or during the study period itself; iv) no musculoskeletal injuries that could interfere with the exercise protocol during the research. These criteria were verified through personal interviews. The study was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2001), and the project protocol was approved by the Hudson Falls SRC/IRB. All participants were required to fill out an Informed Consent Form with parental approval and all tests were under guidance and monitoring of a Physical Education teacher. All risks were deemed minimal by the IRB on account of the physical activity was not greater than those ordinarily encountered during daily Physical Education classes and the drinks are commonly available beverages. Before familiarization was completed, a warm-up was completed, the participants performed a 2 min jog and/or were playing basketball for >10 min. They performed different warm-ups of the different exercises to

be evaluated. Participants were given nutritional guidelines to follow 48 hours before each session.

2.3. Anthropometry and body composition

The anthropometric measurements and body composition of all the participants were recorded during their first visit. They were surveyed on their height and weight and were asked to be honest with their given answers.

2.4. Study Interventions

2.4.1. Test familiarization and study protocol

Due to time constraints, before each session, the participants familiarized themselves with the test protocol proposed for this study. Before attempting the physical test, the participants first completed a warm-up, composed by 2 minutes of jogging or an extended period of basketball, due to most participants having gym before the experiment, and then, they performed a warm-up test of the different exercises, where they performed the exercise and stretched if need be. Their technique was evaluated and corrected whenever necessary for all the exercises.

2.4.2. Supplement protocol

The Beetroot juice and placebo (Blackcurrant juice) were presented in opaque jars. Moreover, adequate transport and storage conditions for the products were ensured. One of the drinks, 70 mL of the BRJ (400 mg NO_3 , BEET It Sport ® ; James White Drinks Ltd., Ipswich, UK), or 70 mL of the PLA, a blackcurrant beverage that depletes NO_3 , unlike BRJ (Nature Goodness, 100% Black Currant Juice, Mekor LLC, Russia), was taken 120 min before each visit (Ranchal-Sanchez et al. 2020). As an individual's diet could affect energy metabolism during exercise, the participants were given nutritional guidelines to ensure that 48 h before each of the test sessions. The nutritional guidelines included avoiding foods with a high or moderate NO_3 content (beetroot, celery, arugula, lettuce, spinach, turnip, endives, leek, parsley, cabbage) (Lopez-Samanes et al. 2020). In the 24 h prior to each experimental session, the participants were instructed to avoid any products that contain caffeine, due to its ergogenic effect. In addition, in the 24 h preceding the test sessions the participants were asked to refrain from

brushing their teeth with toothpaste or using a mouthwash, chewing gum, or eating any sweets that could contain a bactericidal substance such as chlorhexidine or xylitol.

2.5. Study Outcomes

2.5.1. Jumping ability (Countermovement Jump Test, CMJ)

The CMJ test comprised 3 CMJs with a recovery period of 45 seconds between jumps. To ensure that it was performed correctly, the participants were instructed to execute a downward movement followed by complete extension of the legs, and they were free to determine the countermovement amplitude necessary to avoid changes in jumping coordination. The CMJ was performed with the hands on the hips (Lopez-Samanes et al. 2020) During the jump, an evaluator was 1.5 m distant in the frontal plane, to record the jump with a cell phone (Iphone XS Max)) at a frame rate of 170-240 FPS, using the WhatsMyVert app. The maximum height (cm) reached out of the 3 CMJs was recorded.

2.5.2. Upper body muscular strength (Medicine Ball Throws)

To assess the strength of the extensor muscles in the upper limbs, a standing medicine ball throw test was used (weight of ball: 12 lbs). Prior to the start of the test, a two-minute Warm-up was performed using stretching for joint mobility, and performing practice throws (flexion-extension and shoulder circumduction) as well as three ball throws at full effort. For this technique, the participants had to stand behind a line with their feet shoulder-width apart and throw the ball with both hands behind their heads. To perform the throw correctly, they had to bend their legs and extend their trunk to give themselves momentum, as well as extend their heels without taking their feet off the ground. This test was repeated three times, with a 30-second break in between, with the distance achieved (cm) for each throw being noted.

2.5.3. Cardiorespiratory fitness (20m shuttle run test, SRT)

The 20mSRT was performed in a school gymnasium, a school track, or school wrestling room. The participants ran in small groups back and forth between two lines at a measured distance of 20m apart. Following a brief warm-up, the test started at a speed of 8.5 km.h-1 and increased by

0.5km.h-1 every 62 seconds in accordance with audio signals emitted at set intervals from the multi stage pacer test app. Each participant continued until she/he could no longer maintain the pace. The final speed was noted and, with age, converted into predicted peak V ̇O2 using the equation developed by Léger et al. (Léger et al., 1988): Peak VO_2= 31.025 + 3.238 (Speed) − 3.248 (Age) + 0.1536 (Speed) (Age), peak V̇O2 (mL/kg/min); (Speed) is maximal shuttle running speed (km.h-1) and (Age) is how old the participant is during the study.

2.5.4. Rating of perceived exertion (RPE)

As soon as the participants had completed the physical tests, they evaluated their RPE on a scale of 1–10 (Lopez-Samanes et al. 2020).

2.6. Randomization

To ensure the double blinding, an external researcher randomly allocated all the participants' supplements in a counterbalanced fashion; each participant got either BRJ or the placebo (BCJ).

2.7. Statistical Analyses

The data are presented as mean (M) ± standard deviations (SD). To analyze the effect of BRJ vs. PLA a paired-samples t-test was employed. DataClassroom was used for the statistical analysis.

3. Results

All participants had not previously used Beetroot juice or Blackcurrant juice, so they were blind to the supplementation.

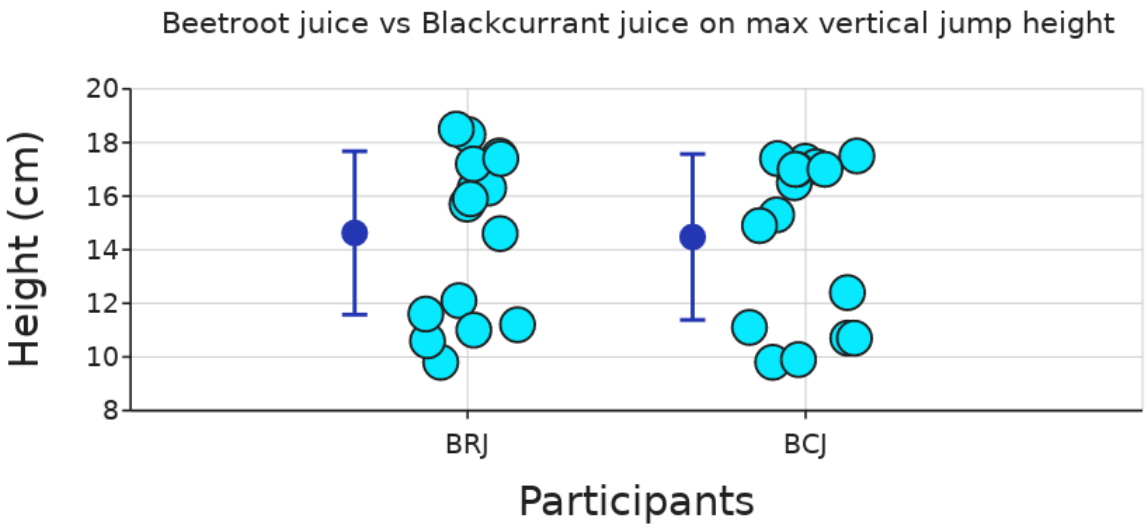

Figure 1: Beetroot juice vs Blackcurrant juice on participants highest counter-movement jump test, BRJ: Beetroot juice, BCJ: Blackcurrant juice, Error bars show the standard deviation of each of the supplemental groups. Dot shows the mean for each group.

Degrees of Freedom (df)	**T-Score**	**P-value**	**Interpretation of P**
30	0.14	0.89	A P-value of 0.89 means no evidence that the groups might be different.

Figure 1 shows the difference between Beetroot juice vs Blackcurrant juice on participants' highest countermovement jump tests across 3 different jumps. Figure 1 shows a small improvement when using Beetroot juice compared to the placebo, but this difference turned out to have a non-significant difference (BRJ AVG, 14.63; BCJ AVG, 14.40). The p-value (0.89) in Figure 1 shows that the supplemental groups have no difference and/or the data has no correlation to each other.

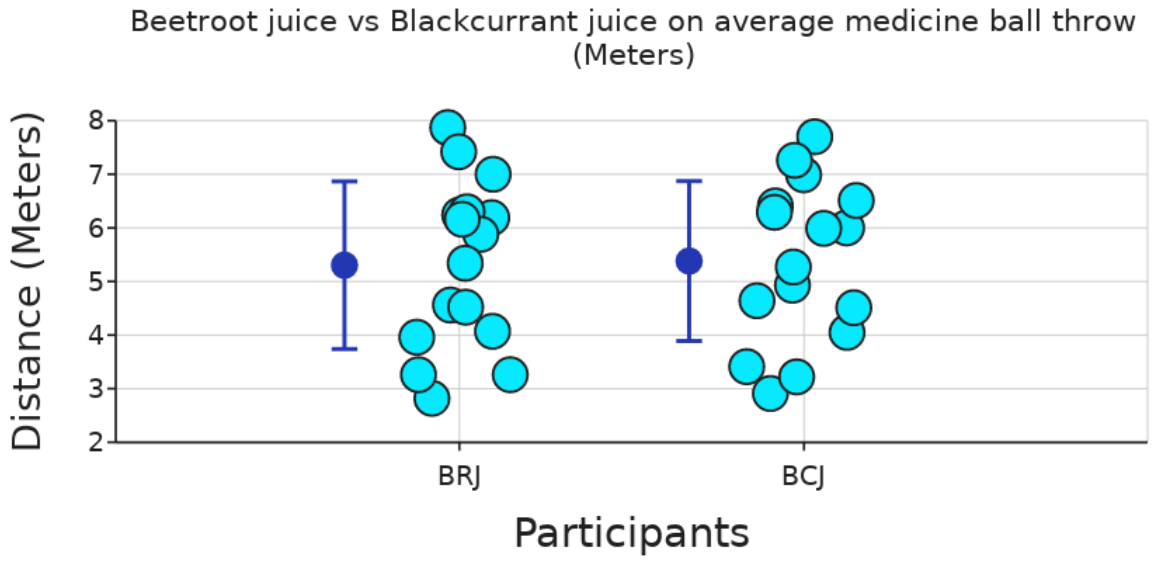

Figure 2: Beetroot juice vs Blackcurrant juice on average medicine ball throw distance. BRJ: Beetroot juice; BCJ: Blackcurrant juice. Error bars show the standard deviation for each supplemental groups, Dots show the mean of each group.

Degrees of Freedom (df)	**T-Score**	**P-value**	**Interpretation of P**
30	0.14	0.89	A P-value of 0.89 means no evidence that the groups might be different.

Figure 2 shows the difference between beetroot juice and blackcurrant juice on the average distance between the 3 medicine ball throws for each participant. According to Figure 2, it shows a small improvement when the placebo was ingested compared to Beetroot juice, although the difference was non-significant when comparing supplements during the medicine ball throw (BRJ AVG, 5.30; BCJ AVG, 5.38). The p-value (0.89) shown in Figure 2 shows no evidence that the supplemental groups have any difference or that the data has any correlation to each other.

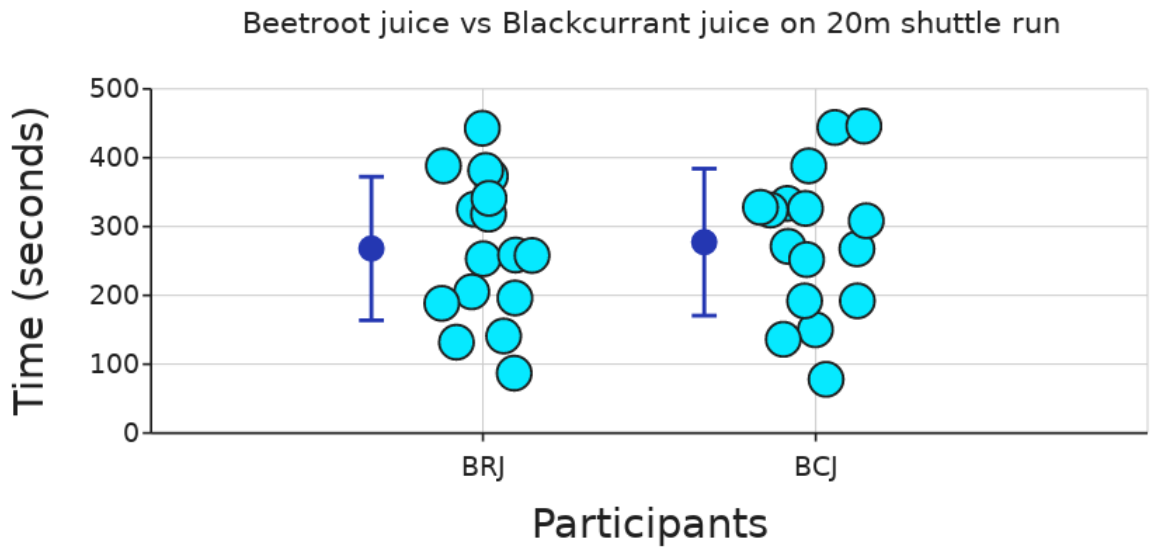

Figure 3: Beetroot juice vs Blackcurrant juice on 20m shuttle run time. BRJ: Beetroot juice, BCJ: Blackcurrant juice. Error bars show the standard deviation of each supplemental group, Dots show the mean for each group.

Degrees of Freedom (df)	**T-Score**	**P-value**	**Interpretation of P**
30	0.25	0.81	A P-value of 0.81 means no evidence that the groups might be different.

Figure 3 shows the difference between Beetroot juice and Blackcurrant juice on how long the participants went before stopping the 20m shuttle run. Figure 3 shows a small improvement when using the placebo compared to Beetroot juice, but there was a non-significant difference when comparing Beetroot juice to the placebo during the 20m shuttle run (BRJ AVG, 4:39; BCJ AVG, 4:50). The p-value (0.81) shown in Figure 3 shows that there is no evidence that the groups are different or the data correlates.

According to the data, there were no significant differences or any correlations found in muscular endurance, CMJ, or cardiorespiratory endurance when comparing Beetroot juice to Blackcurrant juice. ($p > 0.80$)

4. Conclusion

Beetroot juice has garnered a lot of attention due to its ergogenic effects on athletic performance. It has shown to improve blood flow, due to its vasodilator effects (Ranchal-Sanchez et al., 2020). Beetroot juice contains nitrate which can decrease oxygen cost during exercise (Whitfield et al., 2015).

The purpose of this study was to investigate the acute effects of Beetroot juice when compared to a placebo on upper body muscular strength using a medicine ball throw, vertical jump using a countermovement jump test, and cardiorespiratory endurance using a 20m shuttle run. The results show no significant improvements in medicine ball throwing performance, vertical jump, or 20m shuttle run. In conclusion, Beetroot juice showed no improvement in upper body muscular strength, vertical jumping ability, and cardiorespiratory endurance when compared to blackcurrant juice. Future research is necessary to find more conclusive results.

Table 1: BRJ vs BCJ on Peak VO^2

Participants	Max speed for BRJ (km.h-1)	Max speed for BCJ (km.h-1)	Age (years)	Peak VO_2 for BRJ (mL/kg/min)	Peak VO_2 for BCJ (mL/kg/min)
Participant 1	10.5	9.5	16	38.8608	33.1652
Participant 2	9	10.5	15	32.183	40.496
Participant 3	9.5	9.5	16	33.1652	33.1652
Participant 4	10	9	16	36.013	30.3174
Participant 5	10	10	16	36.013	36.013
Participant 6	11	11	16	41.7086	41.7086
Participant 7	12	10.5	17	45.9994	37.2256
Participant 8	11.5	11.5	17	43.0748	43.0748
Participant 9	11	11	16	41.7086	41.7086
Participant 10	9.5	10.5	17	31.3764	37.2256

Participant 11	10	10	17	34.301	34.301
Participant 12	11	11	16	41.7086	41.7086
Participant 13	10.5	10.5	18	35.5904	35.5904
Participant 14	11.5	12	18	41.5932	44.5946
Participant 15	11	11.5	15	43.267	46.038
Participant 16	10	11	15	37.725	43.267

Predicted Peak VO^2 was measured to show peak oxygen consumption during the cardiorespiratory endurance part of the study. Higher Peak VO^2 values can indicate a greater delivery of oxygen from the blood to muscle tissue, allowing athletes to compete at a greater intensity for a longer amount of time (Perez et al. 2019). Predicted Peak VO^2 was calculated using max rate of speed during the 20m shuttle run and participants' age. Maximum speed was found using the 20m shuttle run, depending on the level the participant reached, determined their rate of speed.

This study had some limitations and restrictions that if done differently, could have changed the outcome or reliability of the results. When compared to Jurado-Castro et al. (2020), this study lacked a familiarization session, although participants were allowed to practice the exercises they were to perform beforehand. A familiarization session is recommended for future research, so participants have a better understanding of the exercises and can perform the exercise better. Participants also did not follow a macronutrient specific diet, unlike Sarra-Paya et al. (2021). Also, their diets were not recorded weeks or months before the test, therefore metabolism of participants and what they were digesting may have varied. Participants were informed on the nutritional guidelines, however it was not monitored. The proportion of participants' genders varied, so a comparison of boys to girls cannot be statistically accurately done. In future research, more participants should be considered and dietary journals should be implemented to improve reliability of data. In this study a RPE scale was used to assess how much effort the participants exerted during the trail. Lopez-Samanes et al. (2020) also used a RPE scale and they included an equation based on heart rate and the different speeds ran, which allowed for a more accurate assessment of how much effort the participants actually exerted. In future studies,

participants' heart rate should be assessed to give a more accurate analysis of the effort put forth by participants.

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