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**EXTENDED
ABSTRACT**

The Acute Effects of Beetroot Juice on Muscular Endurance Among Recreationally Active Young Adult Males

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I. INTRODUCTION

Beetroot juice, rich in dietary nitrates, has gained interest for its potential ergogenic effects. While prior studies focus on aerobic and high-intensity performance, few investigate its acute influence on resistance-based endurance. This study examines the immediate effects of diluted beetroot juice on muscular endurance and perceived exertion in recreationally active young adult males, addressing existing gaps by incorporating both objective performance and subjective fatigue measures [1].

II. METHODS

Fourteen recreationally active males (18–35 years) completed a randomized, single-blind, placebo-controlled crossover trial. Participants consumed 250 ml of either beetroot juice or a nitrate-free placebo two hours before performing push-ups and squats for 90 seconds each. Repetitions were counted, and perceived exertion was rated using the Borg RPE scale. A 2-day washout period separated conditions. Eligibility was based on activity level, with strict exclusion criteria applied.

III. RESULTS AND DISCUSSION

A. Immediate Impact of Beetroot Juice on Muscular Endurance

Push-up performance improved significantly after beetroot juice ($M = 9.21$) versus placebo ($M = 4.43$), $p = 0.016$, with a moderate-to-large effect. Squat differences were non-significant. These findings indicate that acute beetroot supplementation enhances upper-body muscular endurance more reliably than lower-body, likely due to oxygen delivery dynamics in smaller muscle groups.

B. Comparison of Performance Between Exercises

Push-ups showed greater performance gains (+4.78 reps) compared to squats. The upper-body response may reflect beetroot juice’s rapid vascular benefits in smaller muscles, whereas larger muscles may require prolonged exposure or higher doses to yield meaningful effects.

C. Comparison of Perceived Exertion Between Conditions

Perceived exertion during push-ups was lower in the beetroot condition, showing a borderline trend ($p = 0.065$), though no RPE difference was found for squats. This suggests beetroot juice may reduce subjective effort in upper-body

exercises, highlighting its potential for improving both performance and exercise tolerance.

TABLE I
DESCRIPTIVE STATISTICS FOR REPETITION AND RPE CHANGE SCORES

	Treatment	Squat_ Change	Pushup_ Change	RPE_Squat_ Change	RPE_Pushup_ Change
N	Beetroot	14	14	14	14
	Placebo	14	14	14	14
Mean	Beetroot	10.4	9.21	1.36	-0.357
	Placebo	6.71	4.43	1.14	0.357
Standard deviation	Beetroot	7.06	7.43	1.45	1.65
	Placebo	12.8	3.76	1.61	1.50
Minimum	Beetroot	0	-3	-1	-4
	Placebo	-15	-1	-2	-3
Maximum	Beetroot	22	25	4	2
	Placebo	43	14	4	2

Participants showed greater improvements in both squat and push-up repetitions in the beetroot condition. RPE changes were minimal.

Table I presents the descriptive statistics for the change scores in squat repetitions, push-up repetitions, and ratings of perceived exertion (RPE) following beetroot juice and placebo treatments. Participants demonstrated greater improvements in both squat and push-up performance in the beetroot condition compared to the placebo. Additionally, a slight reduction in RPE for push-ups was observed in the beetroot condition, while RPE for squats increased marginally under both conditions.

TABLE II
PAIRED SAMPLES T-TEST RESULTS COMPARING BEETROOT AND PLACEBO
CONDITIONS (N = 14)

Measure	t	df	p	Mean Difference	95% CI of Difference	Cohen's d	Interpretation
Squat_Repetition_Change	1.437	13	.174	3.64	[-1.83, 9.12]	0.38	Not significant
Pushup_Repetition_Change	2.772	13	.016	4.79	[1.06, 8.52]	0.74	Significant
RPE_Squat_Change	0.586	13	.568	0.21	[-0.58, 1.00]	0.16	Not significant
RPE_Pushup_Change	-2.016	13	.065	-0.71	[-1.48, 0.05]	-0.54	Borderline (not significant)

Note. $H_0: \mu_{Measure 1} - \mu_{Measure 2} = 0$. CI = Confidence Interval; $p < 0.05$ is considered statistically significant. Cohen's d reflects effect size. A significant improvement was found in push-up repetitions with beetroot ($p = 0.016$, $d = 0.74$), while other variables showed no significant differences.

A paired-samples t-test was conducted to compare the effects of beetroot juice and placebo on muscular endurance and perceived exertion.

Results indicated a statistically significant increase in push-up repetitions under the beetroot condition ($M = 9.21$, $SD = 7.43$) compared to placebo ($M = 4.43$, $SD = 3.76$), $t(13) = 2.772$, $p = 0.016$, $Cohen's d = 0.74$. This reflects a moderate-to-large effect size.

Squat repetitions did not differ significantly between treatments ($t(13) = 1.437$, $p = 0.174$, $d = 0.38$). Likewise, RPE changes for squats ($t(13) = 0.586$, $p = 0.568$, $d = 0.16$) and push-ups ($t(13) = -2.016$, $p = 0.065$, $d = -0.54$) were not significant, although the push-up RPE approached significance.

TABLE III
NORMALITY TEST (SHAPIRO-WILK)

	W	p
Squat_Change_Beetroot - Squat_Change_Placebo	0.882	0.062
Pushup_Change_Beetroot - Pushup_Change_Placebo	0.968	0.842
RPE_Squat_Change_Beetroot - RPE_Squat_Change_Placebo	0.916	0.190
RPE_Pushup_Change_Beetroot - RPE_Pushup_Change_Placebo	0.863	0.034

Note. A p-value < 0.05 suggests a violation of the assumption of normality.

Normality of the difference scores was assessed using the Shapiro-Wilk test. As shown in Table III, the assumption of normality was met for all comparisons ($p > 0.05$), except for RPE push-up change, which showed a slight violation ($p = 0.034$). Visual inspection of Q-Q plots showed approximate normality for all variables, except for RPE push-up change, which slightly deviated from the line.

IV. CONCLUSIONS

Acute beetroot juice supplementation significantly improves upper-body muscular endurance and may reduce perceived exertion during push-ups in recreationally active

males [2]. However, no significant effects were observed for lower-body performance [3]. These findings support beetroot juice as a practical ergogenic aid for enhancing upper-body resistance training outcomes in this population [4].

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