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Fall August 1, 2019

JEPonlineAUGUST2019_Gregory Palevo (1).doc

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High Concentrated Beetroot Juice Supplement Improves Cycling Power, VO\(_2\), Time to Exhaustion, Heart Rate and Anaerobic Threshold in Trained Cyclists

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ABSTRACT

Palevo G, Williams N, Harp A, Barring E, Mize LB. High Concentrated Beetroot Juice Supplement Improves Cycling Power, VO\(_2\), Time to Exhaustion, Heart Rate, and Anaerobic Threshold in Trained Cyclists JEPonline 2019;22(4):39-45. The purpose of the study was to determine the effects of a single dose of a high concentrate dietary nitric oxide (NO\(_3^-\)) on cycling power, VO\(_2\), time to exhaustion, heart rate, and anaerobic threshold in trained cyclists. Twenty-one male and female cyclists (16 males and 5 females) participated in a double-blind, randomized study in which the subjects consumed either a single-dose (5 ounces) of a low dose organic beetroot juice (placebo) or a highly concentrated beetroot endurance superfood 2 hrs before performing a volitional maximal cycling test on a stationary trainer. The subjects performed a baseline cycling test to volitional fatigue following a ramped protocol. Compared to the placebo group, the intervention group increased power in watts 5.97%; VO\(_2\) peak 3.57%; time to exhaustion 3.23%; heart rate threshold at 210 watts 3.77%; and anaerobic threshold 6.63%. The outcomes from this study are clear. A single-dose of a highly concentrated nitric oxide dietary supplement 2 hrs before intensive cycling improved peak power (watts), increased time to exhaustion, increased VO\(_2\) peak, higher anaerobic threshold, and a reduced heart rate at sub-anaerobic threshold.

Key Words: Beetroot juice, Cycling power, VO\(_2\) peak
INTRODUCTION

It is well established that ingested nitrate (NO$_3^-$) is rapidly converted to nitric oxide (NO) (6). Foods such as beets, spinach and specific dietary supplements are good sources of nitrates (NO$_3^-$). Nitric oxide is also produced through the classic method described by Larson et al. (6) through the oxidation of L-arginine, a reaction catalyzed by NO synthase. Dietary supplements are now available in the form of beetroot concentrated powders (Bee Elite, Beet Essence) that increase the amount of circulating nitrite levels, thus making it easier to consume a high enough content to elicit performance benefits.

Lundberg et al. (7) found that NO decreases whole body oxygen cost during exercise and may enhance maximal performance. Also, Biswas et al. (2) reported that supplementation in the form of oral an NO lozenge improved physiological responses in the human body, which included a decrease in blood pressure in people with prehypertension.

Competitive cyclists use a wide array of sports supplements to improve cycling performance. Lane et al. (4) demonstrated that a combination of caffeine and beetroot juice significantly increased cycling power when compared to controls. Lansley and colleagues (5), in a crossover design study, demonstrated that 0.5 L of beetroot juice taken 2.5 hrs before a 4.0 and 16.1 km time trial (TT) increased power output in the 4.0 km TT (P<0.05) compared to placebo (5). Beetroot juice also improved both 4.0 and 16.1 km TT overall performance by 2.8% and 2.7%, respectively. In regards to longer TT studies, Wilkerson et al. (10) studied 8 well trained male cyclists in a laboratory based 50 mile TT. The subjects consumed 0.5 L nitrate-rich beetroot juice 2.5 hrs before the 50-mile TT.

Another scientific approach is NO loading. McQuillan and colleagues (8) studied 9 well-trained endurance male cyclists. The subjects consumed 70 mL of either a placebo or NO$_3^-$-rich beetroot juice for 8 consecutive days and on the day of testing they consumed their 8th and final dose 2 hrs before their scheduled laboratory appointment. Although unclear, effects were found regarding VO$_2$ peak and trivial effects were found for ventilatory threshold (VT) and exercise economy. However, the study did find that the TT performance time and power were beneficial and would most likely improve 4.0 km TT performance.

Dietary NO$_3^-$ supplementation has been shown to significantly reduce oxygen consumption (VO$_2$) during sub-maximal exercise in trained cyclists (1,3). Suzuki and colleagues (9) studied oral L-citrulline supplementation on cycling time trial performance. L-citrulline is a precursor of L-arginine, a substrate for nitric oxide synthase, leading to nitric oxide formation. Their findings indicated that L-citrulline significantly increased L-arginine plasma levels and subsequently had the same effect as nitric oxide supplementation, which resulted in a 1.5% improvement in cycling TT performance (P<0.05) compared to the placebo.

METHODS

Subjects
The present study was approved by the Institutional Review Board (IRB) at the University of North Georgia, Dahlonega Georgia. The subjects consisted of 21 highly trained male and female cyclists (16 males, 5 females). Refer to Table 1 for demographics.
Procedures
The subjects participated in a double-blind, randomized study in which they consumed either a single-dose 5 ounces of a low dose organic beetroot juice powder (placebo) or a highly concentrated beetroot superfood 2 hrs before performing a volitional cycling test to fatigue on a Wahoo KICKR trainer using their own bicycle (Wahoo Fitness, KICKR). All the subjects performed a baseline cycling test to volitional fatigue following a ramped protocol. The men started at 150 watts for 10 min and thereafter increased 20 watts per minute. The women started at 100 watts for 10 min and thereafter increased 15 watts per minute. Test termination was volitional fatigue that was determined by each individual subject.

Experiment Trial Procedures. Each subject performed a baseline test to determine his or her maximal cycling power, peak VO₂ in mL·kg⁻¹·min⁻¹, anaerobic threshold in mL·kg⁻¹·min⁻¹, RPE, and maximal heart rate. After the baseline test, the subjects were randomized into the placebo group (PG) or the intervention group (IVG). The subjects were then retested within 7 to 10 days of the baseline test by performing a second cycling test (intervention test) to volitional fatigue. Performance data were measured on both groups prior to the administration of either the placebo or the supplement. The test protocol was a ramped protocol designed to gradually increase resistance (watts) until the subject reached volitional fatigue. Time to exhaustion, VO₂ (CosMed, Quark CPET), heart rate (Wahoo TICKR), anaerobic threshold (CosMed, Quark CPET), cycling power in watts (Wahoo Fitness, KICKR), and rate of perceived exertion (RPE, Borg Scale 6-20) were collected throughout the study.

Dietary Control. The PG received an inorganic beet juice powder and the IVG received a high concentrate superfood (Nitric Oxide Activator). The dose for both supplements was 2 teaspoons mixed with 5 ounces of water that was given 2 hrs before the second test. Each subject used their personal bike, which was connected to the Wahoo KICKR (Wahoo Fitness).

Table 1. Anthropometric and Clinical Variables Baseline Data.

<table>
<thead>
<tr>
<th></th>
<th>Placebo (n = 8)</th>
<th>Intervention (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>36.6 ± 13.6</td>
<td>36.7 ± 9.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.7 ± 8.4</td>
<td>74.2 ± 7.9</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>20.2 ± 9.6</td>
<td>15.97 ± 8.2</td>
</tr>
<tr>
<td>VO₂ Peak (mL·kg⁻¹·min⁻¹)</td>
<td>50.65 ± 7.81</td>
<td>55.82 ± 9.45</td>
</tr>
<tr>
<td>Max HR (beats·min⁻¹)</td>
<td>188.9 ± 17.2</td>
<td>183.5 ± 12.0</td>
</tr>
<tr>
<td>Max Power (watts)</td>
<td>313.1 ± 46.4</td>
<td>327.7 ± 57.6</td>
</tr>
<tr>
<td>Time to Exhaustion (sec)</td>
<td>1172 ± 160</td>
<td>1228 ± 134</td>
</tr>
<tr>
<td>RPE</td>
<td>19.13 ± 1.1</td>
<td>19.7 ± 0.6</td>
</tr>
</tbody>
</table>

RPE = Rate of Perceived Exertion
Statistical Analyses

Repeated measure ANOVA was used to determine whether there was a statistically significant difference between the groups. A 95% dependent sample t interval was calculated to determine the size of effect. The data were checked for normality assumptions and sphericity. The following variables resulted in post treatment difference that were significant at P<0.05 and P<0.01 (Table 2).

Table 2. Pre- and Post-Test Means for Max Power, VO₂ Peak, Time to Exhaustion, 210 Watt HR Threshold and Anaerobic Threshold.

<table>
<thead>
<tr>
<th></th>
<th>Placebo Group (n = 8)</th>
<th>Intervention Group (n = 13)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Pre-test</td>
</tr>
<tr>
<td>Max Power (watts)</td>
<td>313.1 ± 46.4</td>
<td>292.5 ± 45.7</td>
<td>327.7 ± 57.6</td>
</tr>
<tr>
<td>VO₂ Peak (mL·kg⁻¹·min⁻¹)</td>
<td>50.65 ± 7.81</td>
<td>51.39 ± 6.81</td>
<td>55.82 ± 9.45</td>
</tr>
<tr>
<td>Time to Exhaustion (sec)</td>
<td>1172 ± 160</td>
<td>1183 ± 173</td>
<td>1228 ± 134</td>
</tr>
<tr>
<td>210 Watt HR (beats·min⁻¹)</td>
<td>158.25 ± 20.9</td>
<td>155.0 ± 21</td>
<td>153.7 ± 15.7</td>
</tr>
<tr>
<td>AT (mL·kg⁻¹·min⁻¹)</td>
<td>45.31 ± 6.8</td>
<td>44.35 ± 6.5</td>
<td>45.22 ± 9.6</td>
</tr>
</tbody>
</table>

AT = Anaerobic Threshold; * = P<0.05; ** = P<0.01

RESULTS

Three subjects only completed the pre-assessment and their data were removed from statistical analysis. All other subjects (21 in total) completed all aspects of the research study.

Cycling Power

Cycling power was measured in watts using the Wahoo KICKR. Each subject followed the designed protocol precisely (described earlier). The PG average pre-test cycling power was 313.1 ± 46.4 and the post-test cycling power of 292.5 ± 45.7. The IV group pre-test cycling power was 327.7 ± 57.6 and the post-test cycling power was 348.5 ± 57.8, which was significantly higher (P=0.013).

VO₂ Peak

The subjects’ VO₂ was measured continuously throughout each test. The highest VO₂ value was identified as the subjects’ peak VO₂. A CosMed Quark CPET metabolic cart was employed to gather oxygen consumption data. The mean VO₂ values for the PG and the IVG are presented Table 2. While there was no statistical difference in VO₂ peak in the PG (pre-test, 50.65 ± 7.81 vs. post-test, 51.39 ± 6.81), there was a significant difference in VO₂ peak in the IVG (55.82 ± 9.45 vs. 57.89 ± 9.36, P=0.018).
Time to Exhaustion
Each test was timed from the beginning until the subject reached volitional fatigue, which was identified as the "time to exhaustion". Time was recorded in seconds. The PG had no significant difference (1172 ± 160 vs. 1183 ± 173) while the IVG demonstrated a significant improvement (1228 ± 134 vs. 1269 ± 119, P=0.019).

Heart Rate 210 Watt Threshold
The researchers chose the 210 watt threshold (below anaerobic threshold) to assess any differences between the PG and the IVG. The HR for the PG at the 210 threshold was 158.25 ± 20.9 vs. 155.0 ± 6.5. The HR for the IVG was significantly less (153.7 ± 15.7 vs. 147.8 ± 15.5, P=0.000).

Anaerobic Threshold
Anaerobic threshold (AT) was determined by assessing the nonlinear ventilatory anaerobic threshold and the nonlinear increase in carbon dioxide (CO₂). At this deflection point, anaerobic threshold was determined for each subject. In the PG, there was no significant change in anaerobic threshold (45.31 ± 6.8 vs. 44.35 ± 6.5). But, in the IVG, there was a significant change (45.22 ± 9.6 vs. 48.43 ± 8.6, P=0.002).

DISCUSSION
The findings from the present study indicate that dietary NO₃⁻ supplementation improved cycling power by 5.97%, VO₂ peak improved by 3.57%, time to exhaustion increased by 3.23%, heart rate threshold at 210 watts improved by 3.77%, and anaerobic threshold improved 6.63%.

Power
Our findings are similar to those found by Lansley et al. (5) where they demonstrated a 4.3% improvement (P<0.05) in cycling power compared to placebo. Any increase in cycling power in the competitive cyclists is important, which can easily translate into making a breakaway or getting dropped.

VO₂ Peak
The increase in VO₂ has important implications. In fact, even a small increase (3.57%) can translate into a big gain for the competitive cyclist. Larsen et al. (6) demonstrated an increase in VO₂ max that was statistically significant while increasing time to exhaustion. Our study revealed similar findings.

Time to Exhaustion
The IVG group increased their time to exhaustion by 3.23% (1228 sec ± 134 vs. 1269 ± 119 sec, P=0.019. Although McQuillen et al. (8) found only a small benefit in TT performance time it is most likely to translate into an improvement in the competitive cyclist. Having the ability to sustain a high intensity for a just a few additional seconds has important value to the competitive cyclist in a TT.

Heart Rate Threshold at 210 Watts
The 210 watt threshold was selected because it was below the anaerobic threshold in both study groups. Heart rate was significantly lower in the IVG versus the PG (153.7 ± 15.7 vs.
147.8 ± 15.5, *P*=0.000). This has important meaning because a reduction in heart rate at the same power output means there is a conservation of energy or oxygen consumption. Both Bailey et al. (1) and Cermak et al. (3) demonstrated this in their respective studies. Larsen et al. (6) also demonstrated a similar result.

**Anaerobic Threshold**
The AT was significantly higher in the IVG (45.22 ± 9.6 vs. 48.43 ± 8.6). This has the same implications as discussed regarding heart rate at 210 watts. By increasing the AT the cyclist is able to sustain a higher workload without the accumulation of lactic acid.

**CONCLUSIONS**
The evidence continues to indicate that the use of dietary nitric oxide supplements is effective in improving many aspects of cycling performance. The gains demonstrated in our study can help any highly trained cyclist improve his or her overall performance.

**ACKNOWLEDGMENTS**
We thank Gregg Velatini, Professor of Math, University of North Georgia for his assistance with statistical analysis.

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