**Do the Noncaffeine Ingredients of Energy Drinks Affect Metabolic Responses to Heavy Exercise?**

ROBERT W. PETTITT, JOLYNNE D. NIEMEYER, PATRICK J. SEXTON, AMANDA LIPETZKY, AND STEVEN R. MURRAY

*Department of Human Performance, Minnesota State University, Mankato, Minnesota*

**ABSTRACT**

Pettitt, RW, Niemeyer, JD, Sexton, PJ, Lipetzky, A, and Murray, SR. Do the noncaffeine ingredients of energy drinks affect metabolic responses to heavy exercise? J Strength Cond Res 27(7): 1994–1999, 2013—Energy drinks (EDs) such as Red Bull (RB) are marketed to enhance metabolism. Secondary ingredients of EDs (e.g., taurine) have been purported to improve time trial performance; however, little research exists on how such secondary ingredients affect aerobic metabolism during heavy exercise. The purpose of this study was to investigate the effect of the secondary ingredients of RB on aerobic metabolism during and subsequent to heavy exercise. In double-blind, counterbalanced, and crossover fashion, 8 recreationally trained individuals completed a graded exercise test to determine the gas exchange threshold (GET). Subjects returned on 2 separate occasions and ingested either a 245 ml serving of RB or a control (CTRL) drink with the equivalent caffeine before engaging in two 10-minute constant-load cycling bouts, at an intensity equivalent to GET, with 3 minutes of rest between bouts. Accumulated liters of \( \text{O}_2 \) (10 minutes) were higher for the first bout (17.1 ± 3.5 L) vs. the second bout (16.7 ± 3.5 L) but did not differ between drinks. Similarly, excess postexercise oxygen consumption was higher after the initial bout (RB mean, 2.6 ± 0.85 L; CTRL mean, 2.9 ± 0.90 L) vs. the second bout (RB mean, 1.5 ± 0.85 L; CTRL mean, 1.9 ± 0.87 L) but did not differ between drinks. No differences occurred between drinks for measures of heart rate or rating of perceived exertion. These results indicate that the secondary ingredients contained in a single serving of RB do not augment aerobic metabolism during or subsequent to heavy exercise.

**KEY WORDS** EPOC, gas exchange threshold, oxygen uptake, taurine

**INTRODUCTION**

Despite the lack of scientific evidence for the performance-enhancing effects of energy drinks (EDs), their popularity is impressive, with Red Bull (RB) reporting sales exceeding 500 million cases in a single year (16). Energy drinks are marketed to boost energy or metabolism, and such marketing is persuasive among competitive athletes (16). For instance, one group (10) reported that 72.9% of the 203 athletes surveyed consumed EDs with the primary reason being to enhance “energy during practice.” Thus, sales and survey findings indicate that EDs are used for a performance-enhancing benefit.

The claims for the ergogenic effects of the secondary (i.e., noncaffeine) ingredients of EDs, such as taurine and B vitamins, by manufacturers are ambiguous. For instance, Red Bull markets that its secondary ingredients boost energy (16). Such a claim would imply RB ingestion would positively affect aerobic metabolism. To date, the literature on these secondary ingredients and exercising metabolism is limited. The isolated effects of taurine can reportedly enhance vascular reactivity (20) along with muscular contractility (1,13,26), whereas B vitamins may support aerobic metabolism directly (25). Furthermore, when these secondary ingredients are studied in combination, investigators have reported enhanced cycling time trial performances (12,17); however, noncaffeinated RB has been reported not to enhance exhaustive performance (7). There is simply a paucity of research demonstrating any positive metabolic effects of the secondary ingredients during submaximal exercise.

Energy drinks also are marketed to enhance recovery (16); yet, there is little research on if (or how) EDs may influence short-term postexercise metabolism. Caffeine, the primary active ingredient of EDs, may enhance utilization of free fatty acids at lower levels of metabolic demand (22), thereby, augmenting the rate of return to resting postexercise homeostasis. Such an effect from the secondary ingredients is unknown. Therefore, the purpose of this study was to examine if the noncaffeinated ingredients of RB affected heavy exercise and postexercise metabolism using intensities corresponding heavy exercise (i.e., at or exceeding the gas exchange threshold [GET]) (6).
METHODS

Experimental Approach to the Problem

A double-blind, counterbalanced, placebo-controlled, 2-period within-subject, crossover experimental design was used. A convenience sample of apparently healthy adults (N = 8) completed a graded exercise test (GXT) to determine GET and maximum oxygen uptake (VO2max). On 2 additional visits, subjects completed 2 consecutive constant-load cycling bouts at GET for 10 minutes, with 3-minute recovery in between bouts. Heart rate and expired gas exchange were evaluated during exercise and 3 minutes subsequent to each bout. We selected a heavy exercise intensity because previous studies have used longer-duration trials (12,17). Subjects consumed either blinded RB or a control (CTRL) drink while on another day consumed the opposite. The CTRL drink contained identical calories and caffeine to RB; that is, we aimed to investigate any effects of the secondary ingredients, beyond those of caffeine, on metabolism during and subsequent to heavy exercise.

Subjects

A convenience sample of 5 men and 3 women (age = 23 ± 2 years; body mass = 73.6 ± 9.9 kg; height = 177.3 ± 6.4 cm) volunteered for this study. The study's procedures were approved by the host institution review board on human subjects, and informed consent was obtained. Men and women were included for generalizability of results and not for statistical analysis of sex differences. All subjects engaged in at least 150 minutes of aerobic exercise per week. Exclusion criteria included any reported history of serious medical illnesses or orthopedic injuries. Each subject indicated that he or she was not a regular user of EDs. Specifically, each subject noted that he or she previously had tried EDs, but none drank them on a regular basis.

Procedures

Equipment and Metabolic Measurements. As indicated, a GXT was performed to determine GET and the power-evoking GET (WGET) (21). In brief, gradation was estimated to yield a 10-minute GXT from a series of regression equations, and the test was terminated when cadence decreased below preferred cadence for more than 5 seconds (3 subjects selected 60 rpm and 5 subjects selected 70 rpm). Gas exchange threshold was determined using the V-slope method (3), and power was interpolated with the presump-

dion equations, and the test was terminated when cadence decreased below preferred cadence for more than 5 seconds (3 subjects selected 60 rpm and 5 subjects selected 70 rpm). Gas exchange threshold was determined using the V-slope method (3), and power was interpolated with the presumption of a 1-minute delay in gas exchange.

For each constant-load exercise bout, expired air, volumes, and fractional concentrations of O2 and CO2 were sampled, breath-by-breath, and averaged to 15 seconds. Integrated values (sum of 15 seconds averaged values) were used to derive excess postexercise oxygen consumption (EPOC). VCO2 and VO2 data were divided to calculate the respiratory exchange ratio (RER). Ratings of perceived exercise (RPEs), on a 6–20 scale (4), were obtained at the conclusion of each constant-load exercise bout.

Dietary Intake Screenings. Dietary intake can influence expired gas analysis measurements. Because controlling for dietary factors increases the accuracy of indirect calorimetric measurements, the subjects were interviewed about their use of EDs and other supplements and drugs, along with a log of their food intake for 24 hours preceding each exercise bout. Food intake was input into a commercial dietary software program (Diet Analysis Plus, version 7.0; Wadsworth, Inc., New York, NY, USA) to help verify that the macronutrient intake was not different between the RB and CTRL trials.

The subjects were instructed to eat how they normally would for each day of the experiment to reduce disparities of liver and muscle glycogen concentrations (19). The subjects also self-reported their compliance with prior instructions to refrain from consuming food and beverages containing alcohol, caffeine, supplements, prescription, and nonprescription drugs for 48 hours before exercise. In particular, the half-life of caffeine is approximately 4–6 hours (14); therefore, our 48-hour washout period was adequate. Finally, the subjects were asked to refrain from exercising 24 hours before each data collection day.

Handling and Administration of the Experimental Drinks. The volume for both drinks was 245 ml (8.3 oz), the standard single serving size for RB. The control drink (ginger ale) was modified with the addition of dry ingredients to equal 3.1 g of sugar and 76 mg of caffeine (A&C Chemicals LTD, Montreal, Quebec, Australia). Key secondary ingredients of RB include taurine (1,000 mg), glucuronolactone (625 mg), and a volume
of B vitamins exceeding the minimum recommended daily intake. Volume for the CTRL drink was measured with a graduated cylinder, and the dry ingredients were measured with a digital scale (TE212; Sartorius, Goettingen, Germany). We did not officially conduct taste testing under controlled study; however, the additional ingredients to the ginger ale altered the taste profile to where it tasted remarkably similar to RB, as we noted during pilot testing. The trials were double blinded such that neither the subjects nor the investigators associated directly with data collection were aware of the drink consumed. Both drinks were served in a black covered plastic coffee mug. Half of the subjects received RB first and the CTRL drink second, whereas the order was reversed for the other half of the subjects. Both drinks were consumed 35 minutes before a 5-minute cycle ergometer warm-up at an intensity of 50% \( \text{W}_{\text{GET}} \). The time frame for ingestion of the drinks was determined as optimum for maximizing bioavailability of caffeine (14), an ingredient purported to enhance the effect of secondary ingredients in EDs (12,17) (N.B., we were unaware of any data on the bioavailability of secondary ingredients at the time of this study). No additional drinks were permitted during the exercise trials.

**Statistical Analyses**

Separate 2-way analyses of variance (ANOVA) with repeated measures were used to test for differences between the independent variable of the drink (2 levels: RB vs. CTRL) and the independent variable of time. A 2 × 2 model was used to test accumulated \( \dot{V}_{O_2} \) for bout 1 and bout 2 and the EPOC values subsequent to these bouts, respectively. A 2 × 4 model was used to evaluate heart rate at 2 time points during exercise (5 and 10 minutes). A similar 2 × 6 model was used for RER values (see Results for justification of time period). Paired \( t \)-tests were used to compare 24-hour recall values of the RB with the CTRL trials for total kilocalories, fat, carbohydrate, and protein intake, respectively. The Mann-Whitney \( U \)-test was used to compare between-trial RPEs for each bout. Level of significance for rejecting the null hypothesis was set at \( p < .05 \). Data are expressed in mean \( \pm SD \).

**RESULTS**

A \( \dot{V}_{O_2} \) slow component with a delayed steady state was observed for the RB and CTRL trials (Figure 1). These data indicate that the subjects achieved the desired heavy exercise domain (i.e., intensities exceeded the GET) (18). Dietary recall records indicated no differences \( (p > .05) \) existed in the total energy intake and proportion of macronutrients (Table 1); thus, diet was unlikely a confounding factor for the following results.

Summary statistics for accumulated exercising oxygen uptake and EPOC appear in Table 2. Accumulated oxygen uptake was higher for the first bout (17.1 \( \pm \) 3.5 L) compared with the second bout (16.7 \( \pm \) 3.5 L) \( (F = 5.91, p < .05) \); however, no differences were observed between the RB and CTRL trials \( (F = 0.00, p > .05) \). Similarly, EPOC was higher after the initial bout (RB mean, 2.6 \( \pm \) 0.85 L; CTRL mean, 2.9 \( \pm \) 0.90 L) compared with the second bout (RB mean, 1.5 \( \pm \) 0.85 L; CTRL mean, 1.9 \( \pm \) 0.87 L) \( (F = 5.98, p = .04) \); however, no differences were observed between the RB and CTRL trials \( (F = 0.57, p > .05) \).

Accumulated oxygen measurements between the first and second bouts were remarkably consistent for the RB and CTRL trials, respectively (Table 2). Conversely, EPOC was more variable in comparison with exercising \( \dot{V}_{O_2} \). Ingestion of RB did not seem to alter the individual EPOC responses.

For both trials, RER decreased abruptly at the onset of exercise reaching steady

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**Table 1.** Dietary intake for the Red Bull (RB) and control drink trials, mean \( \pm SD \).

<table>
<thead>
<tr>
<th>Variable</th>
<th>RB</th>
<th>Control</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily expenditure (kcal)</td>
<td>1,957 ± 425</td>
<td>1,862 ± 600</td>
<td>0.38</td>
<td>0.72</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>70 ± 31</td>
<td>64 ± 27</td>
<td>0.54</td>
<td>0.61</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>232 ± 73</td>
<td>246 ± 81</td>
<td>0.43</td>
<td>0.68</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>109 ± 38</td>
<td>82 ± 36</td>
<td>1.48</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**Table 2.** Stability of exercising and postexercising oxygen uptake measurements.\(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Bout 1 (L)</th>
<th>Bout 2 (L)</th>
<th>ICC (( \alpha ))</th>
<th>SEM (L)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercising ( \dot{V}_{O_2} ) (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTRL</td>
<td>17.0 ± 3.8</td>
<td>16.8 ± 4.0</td>
<td>0.99</td>
<td>0.35</td>
<td>2.5</td>
</tr>
<tr>
<td>RB</td>
<td>17.1 ± 3.5</td>
<td>16.7 ± 3.2</td>
<td>0.97</td>
<td>0.83</td>
<td>2.7</td>
</tr>
<tr>
<td>EPOC</td>
<td>2.95 ± 0.90</td>
<td>1.90 ± 0.87</td>
<td>0.77</td>
<td>0.43</td>
<td>22.4</td>
</tr>
<tr>
<td>CTRL</td>
<td>2.65 ± 0.85</td>
<td>1.46 ± 0.85</td>
<td>0.85</td>
<td>0.33</td>
<td>25.0</td>
</tr>
</tbody>
</table>

\(^a\)ICC = intraclass correlation coefficient; CV = coefficient variance; RB = Red Bull.
state at approximately 3 minutes of exercise (Figure 2). Peak values of RER occurred at 2 minutes postexercise for each bout; therefore, time points at 5 and 10 minutes during exercise and 2 minutes postexercise were selected for the ANOVA (2 x 6 model). On average (i.e., main effect), RER was higher \( (F = 7.97, p = 0.03) \) during the RB trial in comparison with the CTRL trial.

Heart rate, relative to exercise time, increased linearly for both constant-load exercise trials (Figure 3). Neither main effects \( (F = 0.00, p = 0.95) \) between trials nor main effects for time \( (F = 0.73, p = 0.58) \) were observed for heart rate. Similarly, no differences in RPE occurred between the first bouts \( (z = 1.12, p = 0.26) \) or the second bouts \( (z = 1.57, p = 0.12) \) (Figure 4).

**DISCUSSION**

Investigators using animal models have reported that taurine, a main secondary ingredient in EDs, can augment the sustainability of force during repetitive skeletal muscle contractions (1,13,26). Research on humans, engaged in rigorous exercise, has supported such claims, with 2 independent laboratories observing improved time trial cycling performances after subjects ingesting taurine-containing EDs (12,17). Athletes, however, also consume EDs for "energy during practice" (10); yet, little research is available to support the efficacy of EDs to augment metabolism during heavy exercise. The primary finding of this study was that a single serving of the secondary ingredients found in RB, one of the more popular EDs (16), does not augment aerobic metabolism during heavy exercise.

As indicated, subjects in this study cycled at an intensity that was sufficient to evoke a \( V_O_2 \) slow component. The \( V_O_2 \) slow component is a phenomenon attributed largely to the recruitment of inefficient type II muscle fibers (11). An attenuation of the \( V_O_2 \) slow component denotes enhanced mitochondrial efficiency typically brought about by training adaptations (8,9,18). The marketed benefit of secondary ingredients in EDs is to boost metabolism; however, such a claim lacks scientific support. Our results indicate that ingestion of the secondary ingredients, found in a single serving of RB, evoked no discernible benefit on aerobic metabolism during heavy exercise.

With lower energy demands, caffeine has been suggested to enhance free fatty acid utilization (22), although other authors (15) have more recently disputed such claims. The secondary ingredients of EDs, augmented by caffeine, have been marketed to enhance recovery. Our findings indicate
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that the secondary ingredients for a single serving of RB do not augment EPOC subsequent to heavy exercise. The kinetics of the initial bout produced the expected increase on accumulated O₂ and decrease in EPOC for the second bouts (5,23). The ingestion of the secondary ingredients in RB did not seem to influence O₂ kinetic differences between the 2 bouts (Figure 1).

A tendency for greater nonmetabolic CO₂ production during and subsequent to exercise, as evidenced by higher RER values (Figure 2), was observed for the RB trial. Such a change occurred independent of changes in Vo₂ or heart rate (Figure 4). Greater hydrogen ion production and buffering could have occurred presumably during the RB exercise trial, exhibiting a deleterious effect on metabolism. Such differences, although statistically different, were negligible in effect size. An equally plausible explanation for the RER findings may be that carbonation differed between the 2 drinks (i.e., excess carbonation in RB drink could have inflated the expired VCO₂ values). We regret this shortcoming of our procedures and encourage future investigators to standardize carbonation to eliminate this as possible confounding variable. Finally, ingestion of the RB secondary ingredients did not affect RPE (Figure 4), a finding consistent with a recent time trial study (17).

Serving size for the secondary ingredients is acknowledged as a delimitation of our study. For instance, taurine may enhance vascular reactivity (20), thereby improving O₂ delivery to exercising muscle; however, taurine found in a single serving of RB (i.e., 1,000 mg) does not seem to augment O₂ uptake during heavy exercise (Figure 1). Perhaps, higher concentrations of taurine might augment efficiency. The subjects in the time trial studies investigating RB (12,17) ingested 500 ml of RB, more than 2-times the volume consumed by the subjects in our study (i.e., >2,000 mg of taurine). Conversely, it is equally plausible that taurine only exerts an ergogenic effect during exhaustive exercise. For instance, one group (2) having subjects perform an exhaustive GXT reported that RB ingestion, with 1,000 mg of taurine, resulted in higher ventricular contractility before and after exercise, based on electrocardiographic measures of end diastolic volume. Conversely, others (7) have observed no performance enhancement from a constant-speed exhaustive exercise bout. The disparity of results may be explained simply by the unreliability of time trials and times for exhaustive exercise bouts (24).

Practical Applications

Based on the lack of prior scientific evidence, combined with the results of this study, there is no justification to support that a single serving of the secondary ingredients in RB augments aerobic metabolism during or subsequent to heavy exercise. Indeed, athletes seeking a “boost of energy for practice” (10) may obtain such benefits from beverages containing similar amounts of caffeine (e.g., 80-mg caffeine from an 8-oz cup of coffee). Conversely, if the athlete anticipates exercising to fatigue, such as a time trial, EDs may provide an ergogenic effect, although the precise mechanisms for why remain unclear (12,17).

In conclusion, athletes consume EDs not only before major events but also for boosting energy during practice. The present study revealed that the secondary ingredients found in a single serving of RB had no augmenting affects on aerobic metabolism during or subsequent to exercise intensities analogous to day-to-day practice (i.e., heavy exercise). Future research should examine different doses of the secondary ingredients in EDs while controlling for differences in carbonation as a confounding variable possibly influencing expired VCO₂ values.

Acknowledgment

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References


