

Energy Drinks: Ergolytic or Ergogenic?

JOE SILLIVENT[†], JENNIFER BLEVINS[‡], and KAYLA PEAK[‡]

Kinesiology Wellness Lab, Tarleton State University, Stephenville, TX, USA

[‡]Denotes professional author, [†]Denotes graduate student author

ABSTRACT

International Journal of Exercise Science 5(3) : 214-222, 2012. Despite the growing popularity of energy drinks, many do not realize the negative effects on the cardiovascular system. The purpose of this study was to examine the effects of energy drink ingestion on estimated VO_2max , heart rate (HR), systolic and diastolic BP (SBP and DBP, respectively), rate pressure product (RPP), and RPE at rest and during exercise. Seven healthy adults (age: 24.3 ± 3.5 yrs; body mass: $= 66.0 \pm 2.2$ kg) participated in this randomized double blind, crossover study. Subjects ingested a placebo (PL) or Redline (RL) energy drink (240ml; 250 mg caffeine) 40 minutes before maximal graded exercise test (GXT). Estimated maximal oxygen consumption (VO_2max) was lower in the RL trial (37.9 ± 5.7 ml·kg⁻¹·min⁻¹) compared to the PL trial (39.7 ± 6.5 ml·kg⁻¹·min⁻¹; $P= 0.02$). Although no significant differences were noted for the number of ectopic beats (ETB) between the trials, a five to one ratio for the RL and PL existed (RL = 106 total ectopic beats; PL = 21 total ectopic beats). Sub-maximal exercise heart demand (RPP: systolic BP × HR) at the same workload was considerably higher in the RL trial (224.9 ± 39.9 mmHg·bts·min⁻¹; $P=0.04$) compared to PL (195.8 ± 22.9 mmHg·bts·min⁻¹). Recovery DBP was significantly higher at one min. in the RL trial (51.6 ± 25.1 mmHg) compared to PL (25.4 ± 33.8 mmHg; $P=0.05$). Based on the results of this study, it was determined that energy drinks lowered estimated VO_2max while elevating RPP and recovery DBP.

KEY WORDS: Ergogenic aid, electrocardiography, pre-workout drink, cardiovascular effects

INTRODUCTION

Energy drinks are becoming more and more popular throughout the United States. Last year Americans spent more than \$4 billion on various brands of energy drinks (12). Recent studies have shown that these drinks are the most popular supplement in young adults. Thirty percent of American male and female adolescents and young adults consume energy drinks on a regular basis (6, 8). The primary reason for energy

drink consumption are purported to be for alertness and energy, as well as sports performance (1). Despite the growing popularity of energy drinks, many do not realize the potentially negative effects on the cardiovascular system. Most energy drinks contain between 80 and 170 milligrams (mg) of caffeine per serving. Caffeine is a central and sympathetic nervous system stimulant. Caffeine may have an indirect effect on several neurotransmitters involved in both

stimulation and non-stimulation (9). The most caffeine-rich energy drinks are equal in caffeine to about two eight ounce cups of coffee. Drinking energy drinks in moderation is safe for healthy individuals (8, 9). However, if a person drinks any of these drinks in excess, combines these with other caffeinated beverages, and has high blood pressure or heart problems, there could be adverse effects and possibly death (8, 9, 12).

Energy drinks that contain either carbohydrates or a sugar-free substance, combined with caffeine, have shown differing results relative to time to exhaustion (6, 9, 10, 18). Various combinations of the ingredients in energy drinks such as caffeine, taurine, niacin, and carbohydrate, may explain some of the differential findings (1). Walsh et al. (18) examined the effects of Amino Impact® energy drink on the time to exhaustion during a 70 percent VO_2max treadmill protocol. The supplement improved performance 12.5 percent compared to the placebo protocol (18). In an effort to determine the acute effects of energy drinks on endurance performance, Kazemi et al. (12) conducted a double blind study, with 12 female student athletes, with two different energy drinks (Phantom® and Dragon®), as well as a placebo (12). The researchers found significant differences in time to exhaustion determined using VO_2max and a decrease in post-test RPP in both energy drinks when compared to the placebo. In addition, post-test HR was significantly increased in the Dragon® energy drink compared to the Phantom® energy drink and the placebo. Rahnama et al. (16) found that VO_2max was significantly higher after Red Bull® and

Hype® energy drinks containing carbohydrates compared to placebo, with no differences in pre or post-test HR for the two drinks. Ivy et al. (11) also determined that a Red Bull energy drink significantly increased cycling time trial performance compared to placebo in trained cyclists (11). However, Candow et al. (6) determined that a sugar-free Red Bull energy drink did not influence run time to exhaustion in a group of 17 young adults (6). Hunter et al. (10) also found that a caffeine tablet with carbohydrate ingestion did not alter peripheral fatigue in a 100-km cycling time trial compared to placebo (10). Possible mechanisms for differences in performance and cardiovascular responses may include caffeine content in the beverages, carbohydrate versus sugar-free solutions, whether subjects were caffeine habituated, and submaximal vs. maximal exercise bouts.

Consuming caffeine drinks has been shown to increase HR and blood pressure during exercise (5, 15). Caffeine has been shown to increase in systolic blood pressure (SBP) 1 hour after ingestion with lesser effects on DBP during activities of daily living (5). Recently, Steinke et al. (15) found that HR and SBP were significantly elevated within two hours of consumption of an energy drink at rest. However, cardiovascular changes were not measured during exercise.

Only two studies have investigated the electrocardiography effects of energy drinks (7). Both studies report increased resting HR, SBP, and report two episodes of atrial fibrillation after the ingestion of (RedBull® and Sugar Free RedBull®, both 80 mg caffeine). In a study of 15 healthy

adults, no significant ECG changes were found after drinking 500 mL of an energy drink containing caffeine (100 mg) from day 1 to day 7 (17). No research has been conducted on the electrocardiography responses to energy drinks during intense exercise.

The purpose of this study was to examine the effects of RedLine® energy drink ingestion on cardiovascular responses (VO₂max, SBP, DBP, RPP, ectopic beats, HR, and RPP) at rest and during exercise. We hypothesized that Redline® drink would significantly increase estimated VO₂max. Consistent with previous literature, we also hypothesized that following strenuous exercise, recovery HR and blood pressure would be elevated. Finally, due to the quantity of caffeine in the drink (250 mg of caffeine anhydrous), we hypothesized that subjects may have a higher incidence of irregular ectopic beats at rest and during exercise.

METHODS

Participants

Junior and senior kinesiology students from Tarleton State University between the ages of 18-30 were asked to participate in this study. Seven subjects were asked to complete a brief physical activity readiness questionnaire (PAR-Q) to pre-screen them before exercise. Potential clients were screened prior to any evaluation via medical and health history questionnaire in order to exclude those with a physician diagnoses for any of the following: coronary artery disease, congestive heart failure, valvular heart disease, post coronary artery bypass graft or angioplasty, uncontrolled hypertension, moderate to

severe chronic obstructive pulmonary disease, carotid or peripheral vascular disease, uncontrolled diabetes mellitus, orthopedic and musculoskeletal limitations that preclude moderate-vigorous exercise.

Protocol

Baseline descriptive measures including height, weight, and resting 12-lead ECG and blood pressure were taken on all subjects. Blood pressure was taken using a standard stethoscope sphygmomanometer after 5 minutes rest in a supine position. All subjects completed two maximal aerobic Bruce stress tests on a treadmill. The exercise tests were conducted at the same time of day and within one week of each other. Heart rate (every minute), blood pressure (each stage), and overall effort (RPE) were monitored continuously during the test. The total time commitment for the subject was approximately three hours. Subjects were asked to report after a 10 to 12 hour fast overnight. Subjects were instructed to have the same dietary intake and activity during the 24-hour period before the first and second exercise test, and they were instructed to fast from caffeine for a minimum of 24 hours before testing. Subjects were considered to be occasional users of caffeine and energy drinks defined as less than two cups of coffee per day and less than three energy drinks per week.

Subjects drank 240 ml of either a placebo (Wild Berry Crystal Light®) drink or a sugar-free energy drink (ED) (Redline® 250 mg caffeine anhydrous, Vit-C, Ascorbic Acid, Potassium, Beta-Alanine) 40 minutes before the exercise test. The drink was randomly assigned and blinded to subject and the administrator. Resting HR and blood pressure were monitored in a supine

position and taken before the testing phase began.

Symptom Limited Maximal Exercise Test:

Functional aerobic capacity (estimated VO_2 max) was determined via a symptom limited maximal graded exercise test (GXT) on a motor driven treadmill (Parker Treadmill Co) using the Bruce treadmill protocol, in which the subjects were asked to give an exercise effort level equivalent to vigorous (maximal effort) exercise. However, the subjects were instructed that they could stop the test at any time. Maximum oxygen consumption was estimated based on time on treadmill using the following equation; $\text{VO}_2\text{max (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 14.8 - 1.379 (\text{time in min}) + 0.451 (\text{time}^2) - 0.012 (\text{time}^3)$ (8). During the GXT, 12-lead ECG (to monitor heart rate, rhythm, and ischemia) (CardioPerfect® software) (WelshAllyn®, Louisiana, MO), blood pressure, RPP, and subjective ratings of discomfort were measured at the end of each stage. Heart rate was recorded every minute. All subjects were given a four to six minute passive cool down in a supine position on a mat immediately following the completion of the maximal exercise test. Recovery 12-lead ECGs, blood pressures, HR, and RPP were recorded immediate post exercise (~one min), 3 min, and every two minutes after until HR and blood pressure returned to within 10 percent of resting values.

Additionally, the number of ectopic beats (ETB) was recorded as the number of premature atrial, junctional, or ventricular complexes as measured and reported by CardioPerfect® software (Welsh-Allyn®). The software records and stores every beat from test start to end. Each complex was

verified by the principle investigator as being an ectopic beat, by reviewing the entire 12-lead recording from the exercise test through recovery.

Statistical Analysis

Differences in estimated VO_2max , HR, ectopic beats, blood pressure, RPP, and RPE between the two conditions were evaluated using a dependent t-test. Results were reported using means and standard deviations. Significance was set at ≤ 0.05 level.

RESULTS

Cardiovascular responses at rest and during exercise are reported in table 1. Maximal oxygen consumption was significantly lower in the Redline® (RL) trial ($37.9 \pm 5.7 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) compared to the placebo (PL) trial ($39.7 \pm 6.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; $P= 0.02$). In other words, subjects' maximal time on treadmill was blunted after the consumption of the RL compared to the PL (see table 1).

Sub-maximal RPP taken at the end of stage two of the Bruce protocol (6 min; 7 METs) was significantly higher in the RL trial ($224.9 \pm 39.9 \text{ mmHg}\cdot\text{bts}\cdot\text{min}^{-1}$; $P=0.04$) compared to PL ($195.8 \pm 22.9 \text{ mmHg}\cdot\text{bts}\cdot\text{min}^{-1}$) (see table 1).

Recovery diastolic blood pressure (DBP) was significantly higher after one minute of rest in the RL trial ($51.6 \pm 25.1 \text{ mmHg}$) compared to PL ($25.4 \pm 33.8 \text{ mmHg}$; $P=0.05$) (Figure 1). No other differences were found for any of the other cardiovascular measures at the three minute recovery period or subsequent recovery periods.

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Table 1. Cardiovascular responses at rest and during exercise in PL and RL trials

Exercise Measures	PL (N = 7)	RL (N = 7)	Mean
			Difference (% difference from PL to RL trial)
Resting			
Heart rate (bpm)	67.3 ± 6.7	69.4 ± 7.2	3 %
Systolic blood pressure (mmHg)	111.1 ± 18.5	111.4 ± 7.6	0 %
Diastolic blood pressure (mmHg)	63.6 ± 8.3	68.3 ± 9.5	7.3 %
Rate Pressure Product (mmHg·bpm/100)	74.1 ± 9.1	76.4 ± 8.2	2.3
Submaximal Exercise (7.1 METs)			
Heart rate (bpm)	139.6 ± 16.2	145.3 ± 15.8	4.1 %
Systolic blood pressure (mmHg)	141.1 ± 16.4	154.3 ± 16.1	9.3 %
Diastolic blood pressure (mmHg)	55.9 ± 26.0	55.1 ± 26.1	1.4 %
Rate Pressure Product (mmHg·bpm/100)	195.8 ± 22.9	224.9 ± 39.9*	14.8 %*
RPE	11.1 ± 1.1	11.3 ± 1.0	0 %
Peak Exercise			
Estimated VO ₂ max (ml kg ⁻¹ min ⁻¹)	39.7 ± 6.5	37.9 ± 5.7*	- 4.5 %*
Heart rate (bpm)	194.4 ± 10.9	193.9 ± 13.4	0
Systolic blood pressure (mmHg)	161.7 ± 16.2	168.7 ± 21.1	4.3 %
Diastolic blood pressure (mmHg)	56.6 ± 27.3	52.1 ± 23.4	-7.9 %
Rate Pressure Product (mmHg·bpm/100)	312.7 ± 35.5	328.1 ± 52.3	4.9 %
RPE	18.4 ± 1.5	18.4 ± 1.1	0 %

* = P<0.05

Although not significant, there was a 5:1 ratio in the number of ectopic beats (ETB) between the RL and PL trials. (RL = 106 total ectopic beats; PL = 21 total ectopic beats; see table 2).

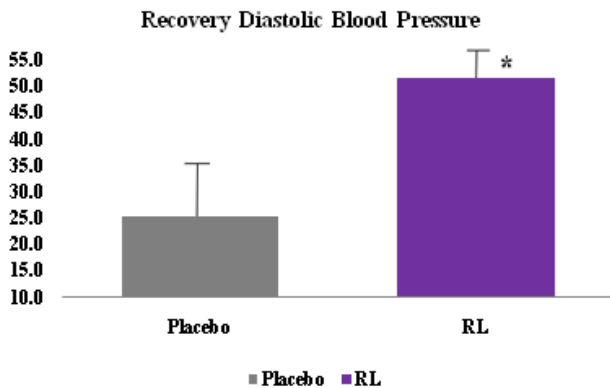


Figure 1. Recovery diastolic blood pressure (DBP) at 1 min post exercise. Values are means \pm SD. *indicates significantly different from the PL ($P=0.05$).

Table 2. Resting and Exercise ECG Ectopy (mean \pm SD).

Exercise	PL (n= 7)	RL (n= 7)	P
Total Resting Ectopic Beats	0	0	NA
Total Exercise Ectopic Beats	21 \pm 3.7	106 \pm 24.9	0.18
Total Recovery Ectopic Beats	60 \pm 20.9	53 \pm 18.7	0.32

DISCUSSION

The purpose of this study was to determine the effects of Redline® energy drinks on the estimated VO₂ max and cardiovascular demands at rest and during exercise. The primary ergogenic ingredient in sugar-free energy drinks is thought to be caffeine. In this study, performance (VO₂max) was

significantly reduced when subjects ingested the RL before exercise testing. In a similar study Candow (6) used sugar-free Red Bull®, researchers found no significant difference in time to exhaustion between the sugar-free Red Bull® and Placebo groups. The lack of carbohydrates in the drink was suggested to be the reason for not finding significant results in run time to exhaustion. In another study using Red Bull®, Astorino et al. (2011) found no significant difference in the sprint time of women athletes (3). The present study, however, looked at differences in VO₂max as a result of ingestion of a sugar-free energy drink. The ergogenic effects of commercially available soft drinks and energy drinks may only be observed when the treatment contains both caffeine and carbohydrates as well as if the exercise bout is submaximal (4,5,11,16). For example, Rahnema et al. (16) found that both Red Bull® and Hype® energy drinks containing fructose significantly increased VO₂max compared to placebo (16). The presence of fructose and caffeine in these drinks may help to provide more carbohydrate fuel to the working muscle. However, metabolic responses may vary widely between individuals. The absence of fructose in the present drink could have contributed to a decreased VO₂max. After a 10 to 12 hour overnight fast, subjects drank Redline® and waited an additional 40 minutes before completing the VO₂max test. The high amount of caffeine in the present drink (250 mg) without fructose may have caused an increased rate of metabolism without providing adequate fuel (carbohydrate) to the muscle. Future research is required to confirm this hypothesis.

Based on the results of the present study, energy drinks lowered estimated VO_2 max values while elevating RPP and recovery DBP. The results further suggest that these drinks have the potential to produce more ectopic beats and exercise intolerance. However, caution is warranted since there was no statistical significance. While RPP normally increases with exertion in any exercise or sporting event, the added energy drink in this study exacerbated that response during submaximal exercise. Rate pressure product was 14.8 percent higher at the same submaximal workload after the RL trial. Previous research utilizing epinephrine demonstrated similar findings (5). While catecholamines were not measured in the present study, it is presumable that RL caused an increase in circulating epinephrine and thus contributed to elevated RPP.

Woolsey et al. (20) and Loeb et al. (14) suggest that high demand on the heart can be dangerous, especially for an athlete with any kind of heart disease or defect. While others found significantly elevated SBP at rest and during exercise with caffeine ingestion, in the present study only recovery DBP was significantly elevated compared to the placebo trial (17). To our knowledge, no other studies have reported on recovery cardiovascular responses to exercise with caffeine ingestion; in the present study only recovery DBP was significantly elevated compared to placebo trial. This could be detrimental to not only young recreationally active adults, but also athletes that have one event after another or in sports with multiple exertion bouts separated by short rest periods. Furthermore, in an at risk population, the risk of heart attack, stroke, and other

cardiovascular events during acute recovery from exercise is equivalent to that during exercise (2). The additional consumption of excessive amounts of caffeine before exercise may potentially exacerbate this risk.

Of special note, this study focused also on ectopic beats after RL consumption compared to placebo. Two studies have focused on ECG changes after energy drink consumption (17, 19). The present study found no statistically significant difference in ECG changes during exercise recovery. Wiklund et al. (19) found that an energy drink similar in content to the present study caused recovery HR to stay elevated longer compared to control, but no changes in any other ECG parameters. One of the seven subjects tested regularly consumed caffeine with the exception of the day of the testing trials, and had resting premature ventricular complexes and premature atrial complexes that increased during exercise after RL consumption. None of the maximal exercise tests needed to be stopped due to ectopic beats. The highest percentage of exercise ectopic beats noted after the RL trial did not exceed 15 percent.

The number of ectopic beats that resulted after the RL trial brings up the question of safety of this drink, especially during intense exercise or competitive athletic events when sympathetic drive is predominant. Three of the seven subjects had adverse reactions in the RL trial during recovery from the maximal exercise test. Reactions included light-headedness, extreme nausea, and pale skin. These subjects recovered after about 30 minutes after the onset and were provided a small amount of food (~300 kcals). While risk of

myocardial infarction and death has largely been coincidental, Worthley et al. recently (2010) found that consumption of 250 mL of a sugar-free energy drink caused a significant increase in platelet aggregation in 15 healthy volunteers (21). While platelet aggregation was not measured in the present study, future investigations examining both exercise arrhythmias and platelet aggregation would shed more light on the overall cardiovascular risk of energy drinks.

Future research should be conducted on this topic to include, use of gas exchange, carbonated placebo, and a flavoring to mask the taste of each drink. The use of a gas exchange system would allow more accurate VO_2 max measurement. Most college-age subjects have previously used energy drinks and can tell them apart easily from another drink, even when unmarked. Adding something such as tonic water to simulate the carbonation of the energy drink would create similar texture and mask the placebo. Finally, future investigations should focus on other adverse health outcomes related to sugar-free energy drinks, including exercise tolerance and electrocardiographic effects.

Based on the results of this study, it was determined that energy drinks lowered estimated fitness levels while elevating heart demand and recovery BP. Consuming a calorie free energy drink before an endurance race, sport, or event, may be ergolytic rather than ergogenic.

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