Effects of Energy Drinks on Economy and Cardiovascular Measures

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Abstract

Peveler, WW, Sanders, GJ, Marczinski, CA, and Holmer, B. Effects of energy drinks on economy and cardiovascular measures. *J Strength Cond Res* 31(4): 882–887, 2017—The use of energy drinks among athletes has risen greatly. Caffeine and taurine are the 2 primary performance enhancing ingredients found in energy drinks. The number of emergency department visits involving energy drinks doubled over the past 5 years. Reviews of the health complications have highlighted adverse cardiovascular events. The literature reveals that caffeine is known to moderately increase blood pressure (BP) and heart rate (HR). The purpose of this study was to determine the effect of 3 different energy drinks on cardiovascular and performance measures. Fifteen recreational runners completed 5 trials. The first trial consisted of a graded exercise protocol. The 4 remaining trials consisted of 15-minute economy trials at a treadmill speed consistent with 70% of subject's $\dot{V}O_2$max. An hour before subjects ingested 1 of the 3 energy drinks or a placebo. HR, BP, $\dot{V}O_2$, and rating of perceived exertion (RPE) were recorded during the 15-minute trial. Mean values for dependent measures were compared using repeated-measures analysis of variance. Fifteen-minute systolic BP readings were significantly lower in the placebo trials (156.93 ± 15.50) in relation to the 3 energy drink trials (163.87 ± 13.30, 166.47 ± 13.71, and 165.00 ± 15.23). There were no significant differences in diastolic BP and HR. There were no significant differences found in $\dot{V}O_2$ or RPE measures. Ingestion of energy drinks demonstrated no change in $\dot{V}O_2$ or RPE during the economy trials. The findings show no performance benefits under the conditions of this study. However, there does appear to be a significant increase in systolic BP.

Key Words red bull, monster, 5 hour, caffeine, taurine

Introduction

Use of energy drinks to promote improved athletic performance has become common among athletes in recent history (11,19). A potential reason athletes use energy drinks may, in part, be due to the manufacturers of these products targeting their advertising directly toward athletes by claiming improved sport performance. Hoyte et al. (2013)found that more than 80% of college athletes reported using energy drinks to potentially enhance their performance and Froiland et al. (2003) found that 73% of collegiate athletes use energy drinks to enhance performance. Energy drink sales have increased substantially since their introduction in the United States and most of the growth in the soft drink market share is attributable to sales of energy drinks (16).

The significant rise in the use energy drinks for sport performance has led to increased scrutiny as physicians and scientists have identified health concerns associated with these products (2,12,37). The Drug Abuse Warning Network (DAWN), a public health surveillance system, has been monitoring the increasing number of negative medical consequences associated with consuming energy drinks. The number of U.S. emergency department visits involving energy drinks doubled over the past 5 years (39). It was reported in 2011 that there were 20,783 emergency room visits involving energy drinks, with 58% of those visits (12,054) due to energy drinks alone (39). However, the details of these visits are not given. It is unclear as to what caused the visits (i.e., allergic reaction, cardiovascular event, etc.) and the number of energy drinks ingested per incident was also not reported. Although caffeine is known to moderately increase blood pressure (BP) and heart rate (HR), energy drinks contain other substances and the underlying reasons for these emergency room visits have yet to be fully elucidated (24,28,36). It is also unknown how many of these visits are related to the use of energy drinks in an athletic context. Although some countries regulate advertising of energy drinks for sport performance and other countries ban energy drinks out right due to adverse effects, the United States has done neither (3,16). The paucity of scientific evidence regarding the effectiveness and safety of the use of energy drinks to improve athletic performance is problematic for communicating with the general public regarding the appropriate use of energy drinks during performance (23).

Energy drinks contain various amounts of caffeine, taurine, and vitamins. Of all the ingredients found in energy drinks, only caffeine and taurine have been shown to consistently produce a positive effect on performance (16). The other ingredients found in energy drinks have not been shown to significantly impact performance, or that the quantity of the

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substance in the energy drink is not large enough to elicit a physiological response (16). Caffeine is the primary ingredient found within energy drinks that may alter performance and cardiovascular measures. Caffeine is a psychoactive drug known to allay fatigue and improve endurance performance and is one of the most widely used drugs in the world (6,8,10,15,21,22,25,27,34). In previous research, caffeine has been shown to improve performance (8,10,15,21,22,25,34). The amount of caffeine contained in each energy drink varies greatly. Taurine has also been shown to increase performance (4,21,40). Taurine is an amino acid that acts as a neurotransmitter (5,20,35). Although taurine acts as a neurotransmitter, it is also thought to have an antihypertensive effect (5,20).

To our knowledge, there is currently no published research examining the effect of multiple energy drink brands on economy and cardiovascular measures in one study. Therefore, the purpose of this study was to compare the effects of 3 different commercially available energy drinks on economy and cardiovascular response during rest and exercise. As the number of energy drinks ingested in a given time is unknown, this study will examine one drink per session to examine response under responsible use conditions. It was hypothesized that energy drinks would affect cardiovascular measures and rating of perceived exertion (RPE), but would not impact $\dot{V}O_2$ measures.

Methods

Experimental Approach to the Problem

A within-subjects design was chosen so that the subjects would act as their own control. Economy trials were chosen to determine if energy drinks had a significant effect on performance. Because the resistance was fixed (speed and grade) between trials, any change in $\dot{V}O_2$ or HR would reflect alterations to economy because of the effects of the ingestion of energy drinks. A lower $\dot{V}O_2$ or HR would reflect improved economy where a higher $\dot{V}O_2$ would indicate poorer economy. This methodology has been used successfully in previous studies to detect changes in economy (30,31). Ratings of perceived exertion (is a common measure of effort during exercise and is often used during research studies) (8,14). If economy improves due to intervention, then RPE will be lower (30,31).

Squirt was chosen as the placebo as it tastes similar to energy drinks, contains no ergogenic ingredients commonly found in energy drinks, and is commonly used as a placebo in energy drink studies (18). Squirt does contain 38 g of sugar, which would have no effect on economy trials 1 hour after ingestion. Although carbohydrates have been shown to be beneficial during prolonged exercise where glycogen stores may be a limiting factor, it would not affect stores during a 15-minute economy trial at 70% of maximum (16). The 3 energy drinks (248.42 ml Red Bull, 473.18 ml Monster, and 27.50 ml 5-Hour Energy) were chosen because they are currently the most popular energy drinks on the market. Caffeine content varied between drinks (Red Bull = 80 mg of caffeine, Monster = 163 mg of caffeine and 5-hour drink = 207 mg of caffeine). Taurine content also varied between drinks (Red Bull = 1,000 mg of taurine, Monster = 1,000 mg of taurine, and 5-Hour Energy = 479.9 mg of taurine). Drinks were ingested 60 minutes before exercise as this has been shown to be the optimal time for caffeine to peak in the system (7,10,15,22).

Subjects

Fifteen recreationally active individuals (men = 12 and women = 3) volunteered for participation in this study. All subjects were capable of running for periods of time longer than the 15 minutes required for the study. Descriptive statistics can be found in Table 1.

Approval for this study was obtained through the university institutional review board and all subjects completed an informed consent before participation. A physical activity readiness questionnaire and a health status questionnaire were used to screen for individuals who may be placed at increased risk during strenuous exercise. Those found at an increased risk were excluded from the study per American College of Sports Medicine guidelines (1).

Subjects reported to the laboratory in appropriate running attire. To promote optimal performance and ensure accurate measurements, subjects were instructed to abstain from training at least 1 day before each performance trial. Subjects were also instructed to refrain from taking any other form of ergogenic aid, to avoid caffeine on the day of trials, and to maintain their normal diet and exercise between trials.

Procedures

Subjects participated in 5 separate trials on 5 separate days with at least 24 hours of recovery between bouts. During the first trial, subjects completed a $\dot{V}O_2$max protocol (standard Bruce

Table 1. Physical characteristics of subjects ($n = 15$).

	Mass (kg)	Height (cm)	Age (yrs)	$\dot{V}O_2$max ($mL\cdot kg^{-1}\cdot min^{-1}$)
Males ($n = 12$)	83.99 ± 15.40	179.17 ± 1.64	21.83 ± 2.21	53.05 ± 9.81
Females ($n = 3$)	72.57 ± 6.57	169.90 ± 3.44	24.00 ± 4.36	36.53 ± 7.64

protocol) on a motorized treadmill (Trackmaster Treadmills, Newton, KS). Oxygen consumption was measured using automated indirect calorimetry (TrueOne 2400; ParvoMedics, Sandy, UT). The TrueOne 2400 was calibrated before each testing session per manufacturer's instructions. Heart rate, $\dot{V}O_2$, $\dot{V}CO_2$, and other ventilatory measures were recorded using the automated system. Ratings of perceived exertion were recorded manually during the graded exercise protocol to anchor the scale for later use in the economy trials (14).

The 4 remaining trials consisted of resting measures and 15-minute economy trials. One hour before the start of each economy trial, subjects ingested either a placebo (Squirt, 354.88 ml), or 1 of the 3 energy drinks (248.42 ml Red Bull, 473.18 ml Monster, and 27.50 ml 5-Hour Energy). The trials were conducted in a counterbalanced order and randomized across subjects. The subjects were blinded by placing the energy drinks in plastic cups. However, there was no way to blind for taste or volume. Before ingestion of the trial beverage, resting BP and HR were taken. On completion of the beverage, a timer was started so that BP and HR could be taken at 30 and 60 minutes. Subjects remained seated at a table for the duration of 60 minutes. Subjects were allowed to read but were otherwise required to remain inactive. On completion of the 60-minute measures, the subject immediately started the 15-minute economy trail. The speed and grade of the treadmill was set at the level the subject reached 70% of their $\dot{V}O_2max$ achieved during the graded exercise protocol. Heart rate and $\dot{V}O_2$ were recorded throughout the 15 minutes using the automated indirect calorimetry systems and later averaged for the 15 minutes. Ratings of perceived exertion were manually recorded every minute and later averaged for comparison. Blood pressure was measured every 5 minutes throughout the 15-minutes trial.

Statistical Analyses

Mean values for dependent measures were analyzed using multiple repeated-measures analysis of variance (4 condition $\times$ 3 time) for resting (BP and HR) and exercise (BP, HR, $\dot{V}O_2$, and RPE) measures. A least significant difference follow-up with an alpha of 0.05 was used to determine significance (2 tailed). All statistics were calculated using SPSS 19.0 statistical analysis software (IBM, Armonk, NY).

Results

Resting Measures

Results for resting measure dependent variables are given in Table 2. Placebo predrink systolic measures were significantly higher in relation to 30-minute systolic measures ($p = 0.047$). Red Bull 30-minute systolic measures ($p = 0.001$) and 60-minute systolic measures ($p = 0.001$) were significantly higher than predrink baseline systolic measures. Monster 30-minute systolic measures ($p = 0.003$) and 60-minute systolic measures ($p = 0.001$) were significantly higher in relation to predrink baseline systolic measures. Monster 60-minute systolic measures were significantly higher in relation to 30-minute systolic measures ($p = 0.021$). Five-hour drink 30-minute systolic measures ($p = 0.001$) and 60-minute systolic measure ($p = 0.001$) were significantly higher than predrink baseline systolic measures. Five-hour drink 60-minute systolic measures were significantly higher in relation to 30-minute systolic measures ($p = 0.027$).

Placebo predrink diastolic measures were significantly higher in relation to 30-minute diastolic measures ($p = 0.022$). There were no significant differences found in diastolic measures across time in Red Bull, Monster, and 5-hour drink.

There were no significant differences found in HR measures across time for placebo and Red Bull. Monster 30-minute HR measures ($p = 0.020$) and 60-minute HR measure ($p = 0.004$) were significantly higher in relation to predrink baseline HR measures. Monster 60-minute HR measures were significantly higher in relation to 30-minute HR measures ($p = 0.013$). Five-hour drink 30-minute HR measures ($p = 0.006$) were significantly higher in relation to predrink baseline HR measures. Five-hour drink HR measures at 60-minute time mark approached significance with predrink measures at 0.071 (2 tailed).

Table 2. Dependent variables for resting ($n = 15$).

	Placebo	Red Bull	Monster	5-Hour Drink
Predrink systolic (mm Hg)	117.87 ± 6.83	113.53 ± 7.70	115.40 ± 7.89	114.00 ± 7.40
30-min systolic (mm Hg)	116.13 ± 7.02*	118.20 ± 8.56*	120.87 ± 9.98*	118.40 ± 8.85*
60-min systolic (mm Hg)	117.13 ± 8.36	119.27 ± 8.26*	123.07 ± 9.56*†	121.20 ± 9.16*†
Predrink diastolic (mm Hg)	75.53 ± 5.90	75.00 ± 7.32	75.00 ± 5.46	74.80 ± 6.96
30-min diastolic (mm Hg)	74.43 ± 5.70*	74.80 ± 7.36	74.93 ± 6.77	75.00 ± 6.63
60-min diastolic (mm Hg)	74.80 ± 5.97	75.73 ± 7.72	75.73 ± 6.88	75.87 ± 6.94
Predrink heart rate ($b\cdot min^{-1}$)	69.93 ± 10.73	66.80 ± 10.82	63.73 ± 11.80	65.07 ± 8.95
30-min heart rate ($b\cdot min^{-1}$)	67.07 ± 10.17	68.33 ± 11.37	67.53 ± 8.18*	68.07 ± 8.77*
60-min heart rate ($b\cdot min^{-1}$)	68.27 ± 10.02	67.87 ± 12.21	71.87 ± 10.74*†	69.40 ± 10.15

*A significant difference in relation to predrink ($p \le 0.05$).
†A significant difference between 30-minute and 60-minute measures.

TABLE 3. Dependent variables for running economy measures ($n = 15$).

	Placebo	Red Bull	Monster	5-Hour Drink
$\dot{V}O_2$ (mL·kg^{-1}·min^{-1})	35.76 ± 8.91	35.38 ± 8.73	35.82 ± 8.54	36.55 ± 9.46
Heart rate (b·min^{-1})	162.75 ± 11.23	160.62 ± 13.57	161.96 ± 12.73	161.31 ± 13.72
Ratings or perceived exertion	12.30 ± 2.34	12.60 ± 2.09	12.00 ± 1.99	11.70 ± 2.10
5-min systolic (mm Hg)	157.00 ± 18.19	161.13 ± 16.18	164.73 ± 15.30	160.07 ± 17.65
10-min systolic (mm Hg)	157.27 ± 17.62	163.13 ± 14.12	166.3 ± 15.05	164.40 ± 15.93*
15-min systolic (mm Hg)	156.93 ± 15.50	163.87 ± 13.30*†	166.47 ± 13.71*	165.00 ± 15.23*†
5-min diastolic (mm Hg)	73.60 ± 6.20	74.53 ± 7.67	74.67 ± 6.77	75.00 ± 6.81
10-min diastolic (mm Hg)	73.60 ± 6.53	73.13 ± 8.24	74.67 ± 6.44	74.60 ± 6.58
15-min diastolic (b·min^{-1})	73.00 ± 6.49	73.67 ± 6.94	74.33 ± 6.60	74.33 ± 5.94

*A significant difference in relation to placebo.
†A significant difference from 5-minute measures ($p \leq 0.05$).

Economy Trials

Results for economy-dependent variables are given in Table 3. There were no significant differences detected in RPE between the placebo trials and energy drink trials. The 5-hour drink trial RPE measures were significantly lower in relation to the Red Bull trial ($p = 0.048$). The 5-hour drink trial approached being significantly lower in relation to the placebo trial at $p = 0.073$ (2 tailed). There were no significant differences in $\dot{V}O_2$ measures or HR measures across trials.

There were no significant differences detected in 5, 10, and 15-minute systolic measures during the placebo trial. The 5-minute systolic measures were significantly lower in relation to the 15-minute systolic measures ($p = 0.034$) during the Red Bull trial. There were no significant differences in systolic measures found between the 5, 10, and 15-minute measures during the Monster trial. The 15-minute systolic measures were found to be significantly higher in relation to the 5-minute systolic measures during the 5-hour drink trial ($p = 0.028$). There were no significant differences in systolic measures detected between placebo, Red Bull, Monster, and 5-hour drink at the 5-minute time mark. At the 10-minute mark, the only difference was found between the placebo systolic measures and the 5-hour drink systolic measures ($p = 0.040$). At the 15-minute mark, systolic BP was significantly higher with Red Bull ($p = 0.027$), Monster ($p = 0.018$), and 5-hour drink ($p = 0.005$) compared with placebo.

There were no significant differences detected in diastolic measures with time (5, 10, and 15 minutes) with 1 exception; Red Bull; 5-minute and 10-minute measures ($p = 0.020$). There were no significant differences found in diastolic BP between placebo, Red Bull, Monster, and 5-hour drink.

DISCUSSION

The purpose of this study was to compare the effects of 3 different commercially available energy drinks on economy and cardiovascular responses during rest and exercise. Results from this study indicate that energy drinks have a significant impact on cardiovascular measures at rest and during exercise. One hour after ingestion of the energy drinks, but before exercise, there was a significant increase in systolic BP. With all 3 energy drinks, systolic BP increased from predrink measures to 30-minute measures and from 30-minute measures to 60-minute measures. There was an average increase from predrink measures to 60-minute measures of 6.87 mm Hg, a 5.3% increase, across all 3 energy drinks (Red Bull average increase = 5.74 mm Hg, Monster average increase = 7.67 mm Hg, and 5-hour drink average increase = 7.20 mm Hg). The increase in systolic BP is supported by previous research (24,26,28,36). Although systolic BP increased, there was no significant increase in diastolic BP detected during resting measures. Research on the affect of energy drinks on diastolic measures has produced mixed results. Some research has demonstrated no increase in resting diastolic BP after ingestion of energy drinks within the first hour (5,13,32). Conversely, other research has demonstrated an increase in diastolic BP (24,26,36). Caffeine is the most likely ingredient that would lead to an increase in BP (24,26,28,36). Caffeine acts as an adenosine receptor antagonist and enhances the sympathetic nervous system, which increases BP (6). As this is a sympathetic response, it may have a greater effect on systolic as opposed to the diastolic. Although it is believed that taurine has an antihypertensive effect, this was not apparent in the current study (5,20). It is plausible that caffeine masked the antihypertensive effect of taurine as they were not tested separately in this study.

Previous research has produced mixed results with regard to the effect of energy drinks on resting HR. Some research has demonstrated increased resting HR with the ingestion of energy drinks (16,26). Other research demonstrated no significant differences in resting HR (17,21,24,29). During the current study, HR increased from predrink measures for Monster and 5 hours, but not for Red Bull. Red Bull had the lowest cardiovascular response of the 3 energy drinks used in this study with no significant differences detected in resting HR. This is similar to the study of Ivy et al. (2009) who found no significant differences in resting HR with the ingestion of Red bull. Marczinski et al. (2014) detected a significant increase in HR when 5-hour energy was ingested. This may be directly related to the volume of caffeine found within each energy drink. An 8.4 oz can of Red Bull contains 80 mg of caffeine, whereas Monster contains 163 mg and 5-hour drink contains 207 mg. The amount of caffeine found in Monster and 5-hour drink are approximately equivalent to 2 cups of brewed coffee (about 190 mg).

Ingestion of energy drinks impacted cardiovascular measures during the 15-minute economy trials. Systolic BP for all 3 energy drinks was significantly higher in relation to placebo by an average of 8.81 mm Hg, a 4.95% increase, (Red Bull, average increase = 8.18 mm Hg; Monster, average increase = 9.54 mm Hg; and 5-hour drink, average increase = 8.07 mm Hg). When looking at changes in systolic BP along time, both 5-hour drink and Red Bull 5-minute systolic measures were significantly lower in relation to 15-minute systolic measures. There was an average increase of 3.84 mm Hg (Red Bull, average increase = 2.74 mm Hg and 5-hour drink average increase = 4.93 mm Hg). No significant difference was determined in systolic BP between any measures from the 5- to 10-minute mark. The increase in systolic BP is most likely due to the caffeine within the energy drinks (24,26,28,36). Although systolic BP increased during exercise in relation to placebo, there were no significant differences in HR between any trials.

There were no significant differences found when examining $\dot{V}O_2$ measures between all conditions. The average difference in $\dot{V}O_2$ measures between energy drink trials and the placebo trial was 0.41 $ml \cdot kg^{-1} \cdot minute^{-1}$, demonstrating a near constant oxygen uptake rate regardless of energy drink or placebo drink ingested. These findings suggest that the ingestion of energy drinks has no effect on metabolism under these conditions. As the resistance for each trial was fixed at the level subjects reached 70% of $\dot{V}O_2max$, an alteration in $\dot{V}O_2$ during the economy trials was not expected. These findings are similar to those of Phillips et al. (2014) who found no difference in $\dot{V}O_2$ during a cycling time trial. Conversely, Engels et al. (1999) found an increase in $\dot{V}O_2$ when cycling at 30% of $\dot{V}O_2max$. It was believed that the increased metabolism resulting from the ingestion of caffeine increased over all oxygen consumption during light cycling (9). The differences in findings could possibly be explained by intensity as both the current study and that of Phillips et al. (2014) were conducted at a much higher intensity and may have masked the increase in metabolism due to caffeine ingestion alone.

There were no significant differences in RPE between the energy drink trials and the placebo trial. The mean difference between the energy drink trials and the placebo trials was found to be 0.40, which demonstrates a near constant between trials. It was thought that RPE would alter due to the ability of caffeine to suppress fatigue. Previous research has demonstrated caffeine's ability to suppress the feeling of fatigue, which would in turn decrease RPE at a given submaximal resistance (38). Caffeine reduces fatigue as an adenosine receptor antagonist and through a direct analgesic affect on the CNS (21,33,38). Ivey et al. (2009) found no change in RPE measures between trials, but measured a significant improvement in performance. This finding makes sense as the subjects performed at a higher physiological intensity, yet were performing at the same perceived intensity ultimately improving performance. As resistance was fixed in the current study, it was expected that a significant reduction in RPE would occur if the prescribed energy drinks reduced the feeling of fatigue. However, this was not seen. One of the energy drinks, 5-hour drink, did broach significance at $p = 0.073$ (2 tailed) in relation to placebo. As the theory of caffeine lowering RPE is supported by the research, the hypothesis could be directional with regard to RPE. Therefore, it could be addressed as 1 tailed and the p value cut in half resulting in $p = 0.037$, which would be significant. It was also found that 5-hour drink was significantly lower in relation to Red Bull. It is possible that 5-hour drink may have an impact on RPE. The time length of the economy trials could have played a factor. A 15-minute trial at 70% of max may not have been long enough to alter feelings of fatigue and therefore RPE.

Practical Applications

There are 2 key practical applications for this study that should be considered. First, there were no improvements in economy noted in this study. Second, energy drinks impact cardiovascular function at rest and during exercise. The small increase in systolic BP (3.84 mm Hg at rest and 8.81 mm Hg during exercise) may not have a negative health impact. However, it is recommended that individuals be aware of the increase in BP.

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