Original Research

Effects of Energy Drinks on Metabolism at Rest and During Submaximal Treadmill Exercise in College Age Males

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ABSTRACT

Int J Exerc Sci 4(1) : 65-76, 2011. Energy drinks are widely available and popular among athletes and non-athletes. However, the effects of energy drinks on resting and exercise energy expenditure and metabolism remain largely unknown. On four separate occasions, baseline measurements of resting metabolic rate (RMR) and Respiratory Exchange Ratio (RER) were obtained in ten healthy males (21.4 ± 1.6 y, 77.60± 7.5 kg, 180.0 ± 7.1 cm). Then, in a randomly assigned cross-over design, the subjects consumed 473 ml of one of three commercially available energy drinks or a placebo and then RMR and RER were measured 1 hour later. The subjects then engaged in 15 minutes of treadmill exercise at 50% of $V0_2$max, during which RER and oxygen consumption (VO_2) were measured. RMR was not changed by placebo, but increased ($P<0.05$, means ± se) above baseline by 10 ± 2.5%, 15.0 ± 2.9%, and 15.3 ± 2.9%, following Energy Drink One, Energy Drink Two, and Energy Drink Three (respectively) with no differences between energy drinks. RER was reduced below baseline ($P<0.05$) by 4.9 ± 1.5% in the placebo and increased ($P<0.05$) above baseline by 12.8 ± 1.8%, 9.6 ± 1.3%, and 9.0 ± 1.3% following Energy Drink One, Energy Drink Two, and Energy Drink Three (respectively) with no differences between energy drinks. Oxygen consumption and RER during submaximal exercise were not different between placebo, Energy Drink One, Energy Drink Two, or Energy Drink Three. These data indicate that energy drink consumption increases RMR and carbohydrate use at rest, but metabolism during submaximal exercise remains unchanged.

KEY WORDS: Oxygen consumption, carbohydrate, fat, caffeine, respiratory exchange ratio

INTRODUCTION

The term "Energy Drink" applies to a number of readily available soft drinks purported to reduce or prevent fatigue, enhance physical performance, improve mood, and enhance cognitive performance (21). In addition to maltodextrin, carbonated water, and sugar, energy drinks frequently include caffeine and other stimulants. Common non-caffeine stimulant ingredients in energy drinks include guarana, yerba mate, ginseng, inositol, carnitine, creatine, glucuronolactone, ginkgo biloba, taurine, and B complex vitamins. While the average eight fluid ounce energy drink has about 80 mg of caffeine, which is similar to eight oz of brewed coffee (6, 16), the amounts of non-caffeine stimulants (e.g. guarana, yerba mate, taurine, etc) in most energy drinks are not known as these are part of "proprietary formulae".

The effects of caffeine on metabolism at rest and during exercise have been extensively studied (16). Overall, when caffeine is consumed in sufficient doses (generally three to six mg caffeine / kg of body mass), there is an increase in energy expenditure and use of fat as a metabolic substrate at rest and during exercise. Caffeine intake in sufficient doses also delays the onset of fatigue, enhances submaximal and maximal power output during exercise, and is considered an ergogenic aid (16). However, given the numerous herbal ingredients in energy drinks, the metabolic response to energy drinks cannot be predicted solely based on their caffeine content (7).

Guarana and Yerba mate are herbs commonly used in South America as stimulants. However, when guarana was combined with green tea and bitter orange extract there were no changes in resting or exercise metabolism (23) and the effects of Yerba mate on metabolism at rest and during exercise have not been evaluated (17). Ginseng is a commonly used Asian herb that may promote a reduction in body mass in older subjects (7), but acute ginseng intake does not appear to alter metabolism during exercise (10). Although long term creatine intake in conjunction with exercise may alter body mass, body composition, and metabolism at rest and during exercise (5, 22), the effects of acute creatine intake on metabolism and substrate utilization are not known. Taurine, carnitine, and B complex vitamins intake do not appear to alter energy expenditure at rest or during endurance exercise (11, 14, 24). The sugars included in energy drinks, usually sucrose and glucose, are simple sugars that are metabolized quickly by the body and produce a quick energy burst, followed by a deep energy deficit (27) often described as a "crash". The effects of inositol, ginkgo biloba, and glucuronolactone on metabolism at rest and during exercise have not been evaluated. Overall, the individual effects of the non-caffeine stimulant ingredients in energy drinks on resting and exercise metabolism are either unknown or appear to have no effects. Therefore, it appears that the main stimulant in energy drinks is caffeine, but the other ingredients may have some type of synergistic effects on metabolism when combined together as in energy drinks.

Energy drink consumption causes an increase in resting heart rate and systolic blood pressure (25), yet does not increase the risk of an untoward cardiovascular event in healthy individuals (28). Energy drinks also increase performance on repeated tests of muscular strength but do not alter performance during a 30 second maximal bicycling trial (13) . However, there does not appear to be any published data on the effects of an energy drink on energy expenditure, and use of fat and carbohydrate as energy sources at rest or during submaximal exercise.

Therefore, the purposes of this project were to assess the effects of three commercially available energy drinks on energy expenditure, heart rate, and use of fat and carbohydrate as energy sources at rest and during submaximal exercise.

METHODS

In order to assess the effects of energy drinks on energy expenditure and use of fat and carbohydrate as energy sources at rest and during submaximal exercise, 10 healthy male college students (table 1) were recruited. The participants were first evaluated for aerobic fitness and body composition. Aerobic fitness and body composition were used as subject descriptive data, and aerobic fitness was also used to determine the treadmill speed and grade during submaximal exercise performance. On four other days, after abstaining from caffeine intake and recording their diet and physical activity for 48 hours, and an overnight fast, the subjects reported to the UNK Human Performance Laboratory. The subjects were measured for resting metabolic rate (RMR) and Respiratory Exchange Ratio (RER), then, in a randomly assigned cross-over design, consumed 473 ml (16 ounces) of one of three commercially available energy drinks or a diet caffeine free soft drink and were measured for RMR one hour later. After the post energy drink measurement of RMR and RER, the subjects engaged in 15 minutes of treadmill exercise at 50% of their VO_2max during which oxygen consumption (VO_2; as a measure of energy expenditure), carbon dioxide production, heart rate, were measured and RER was calculated. Baseline and post drink RMR and RER were compared using a two-way (drink X time) repeated measures ANOVA. VO_2, heart rate, and RER during treadmill exercise were compared using a one-way (treatment) ANOVA.

Table 1. Subject descriptive data for 10 college aged males who were measured for RMR and RER before and after consuming three energy drinks or a placebo.

Variable	means ± SEM
Age (y)	21.4 ± 1.6
Body Height (cm)	180.0 ± 7.5
Body Mass (kg)	77.6 ± 7.5
Percent Body Fat	17.5 ± 1.4
VO_2max (ml/kg/min)	45.9 ± 2.1

Values Represent Means ± SEM

Participants

Ten apparently healthy male college students were recruited as study participants. After an initial discussion between the investigators and potential subject in which the goals, purposes, and expectations of the research project were covered, subjects who were still willing to participate signed a document of informed consent and completed a detailed written medical history (as suggested by the American College of Sports Medicine (1)) and lifestyle evaluation. All subjects that completed the document of informed consent completed all of the subsequent aspects of the project. Prior to body composition and exercise testing, subjects were instructed to eat no food for three hours and consume no caffeine for six hours prior to the exercise test, come to the test well hydrated and well rested, and prepared to exercise. This project was approved by the Institutional Review Board for the protection of human subjects at the University of Nebraska at Kearney.

Protocol

Body Composition Assessment

Participants were assessed for body composition for descriptive purposes. First, body mass was measured to the nearest hundredth of a kg using a digital scale (PS6600, Befour Inc, Saukville, WI) and body height was measured to the nearest one-half cm using a stadiometer (Model 707, Seca, Hamburg, Germany). Then body composition was measured using Dual-Energy X-Ray Absorptiometry (DEXA; DPX-IQ, Lunar Corp, Madison W). The subjects were asked to wear comfortable clothing with minimal metal snaps, buttons, or zippers and to remove all jewelry in order to enhance the safety and accuracy of the DEXA measurement.

Aerobic Fitness Assessment

After assessment for body composition, the participants were assessed for aerobic fitness (VO_2max) for descriptive purposes and to determine the treadmill speed and grade for the submaximal exercise portion of the study. In order to evaluate the participants for VO_2max, a Bruce Ramp Protocol (30) and treadmill (425C, Trackmaster Treadmills, Newton, KS) were used. Oxygen consumption was measured using a metabolic cart (True One, Parvomedics, Sandy, UT) and heart rate was monitored with a heart rate monitor (610, Polar Electro, Oy, Finland). Data for VO_2 and heart rate were measured continuously and then averaged over 20 second intervals. The assessment of VO_2max ceased when the subject reached volitional fatigue.

Diet and Energy Intake

For the 48 hours prior to each drink intervention (placebo, Energy Drink One,Energy Drink Two, Energy Drink Three), the subjects were asked to abstain from caffeine intake, restrict themselves to moderate alcohol consumption (no more than two drinks in a 24 h period), and complete a 48 hour dietary record. Subjects were instructed to eat their normal diet within these parameters and were given written and verbal instructions on how to record dietary intake. When the subjects returned for the measurement of metabolism, an investigator reviewed the diet record with the subjects to make sure quantities and items were clearly and accurately described and no known caffeine containing foods had been consumed. Dietary composition was assessed for energy, carbohydrate, protein, and fat content via commercial software (Diet Analysis Plus, Wadsworth, Indianapolis, IN).

Energy Drink Consumption

Table 2. Listing of ingredients of the three energy drinks used for assessment of the effects of energy drink on resting and submaximal exercise metabolism. Ingredient lists were obtained from the ingredient labels, product websites, and published research (8).

Ingredient	Energy Drink One	Energy Drink Two	Energy Drink Three	Placebo
Serving Size	8.4 fl. ounces	8.0 fl. ounces	8.0 fl. ounces	12.0 fl oz
Calories	110	140	100	0
Sodium	200 mg	40 mg	180 mg	35 mg
Carbohydrates	28 g	31 g	27 g	0
Sugars	27 g	31 g	27 g	0
Protein	1.1 g	N/A	N/A	N/A
Niacin	20 mg	20 mg	20 mg	N/A
Vitamin B12	4.8 mcg	6 mcg	6 mcg	N/A
Vitamin B6	5 mg	2 mg	2 mg	N/A
Pantothenic Acid	5 mg	10 mg	N/A	N/A
Other Ingredients	Carbonated water, sucrose, Glucose, Sodium Citrate, Taurine (1250 mg), Glucuronolactone (750 mg), Caffeine (100 mg), Inositol, Niacinamide, Calcium-pantothenate, Pyridoxine HC1, natural and artificial flavors (8).	Vitamin B2 (3.4 mg), Energy Blend (1.35 g): Taurine (1000 mg), Ginkgo Biloba Leaf Extract (150 mg), Caffeine (80 mg), Guarana Seed Extract (25 mg), Inositol (25 mg), L-Carnitine (25 mg), Panax Ginseng Extract (25 mg), Milk Thistle Extract (20 mg)	Taurine (1000 mg), Panax Ginseng (200 mg), Energy Blend (2500 mg): L-carnitine, glucose, caffeine, guarana, inositol, glucuronolactone, maltodextrin	Cirtric Acid, Concentrated Grapefruit Juice, Potassium Citrate, Potassium Benzoate, EDTA, Aspartame, Acelsulfame Potassium, Acacia, Natural Flavors, Glycerol Ester of Rosin, Brominated Vegetable Oil, Carob Bean Gum

The energy drinks used for this project were Red Bull (Energy Drink One), Rockstar (Energy Drink Two), and Monster (Energy Drink Three). The placebo was Fresca, a sugar-free, caffeine-free beverage. This product was selected as a placebo because it was considered to be unlikely that the subjects would regularly consume this soft drink due to its flavor and not being available on-campus, and thus the subjects would hopefully not easily identify the placebo compared to the energy drinks. On four different occasions, the subjects consumed 473 ml (16 ounces) of one of these drinks in a randomized, cross-over manner after an initial assessment of RMR. These energy drinks were chosen based on a recent survey of the top-selling energy drinks in the United States (2). The volume of drink consumed was based on the typical volume in a can of Energy Drink Two and Energy Drink Three, even though the ingredient labels indicate that a 16 ounce can contains two servings. The ingredients of the energy drinks and placebo (table 2) were gleaned from the manufacturer websites and a recent evaluation of the effect of an energy drink during exercise (8). Unfortunately, a more detailed and specific analysis of the ingredients for these products is not available at this time.

Resting Metabolic Rate

Following the previously mentioned dietary restrictions, after an overnight fast, and before engaging in any physical activity, the subjects were measured for RMR and RER. During the four trials, the subjects were measured for resting RMR and RER and then consumed the drink as rapidly as possible. The subjects then sat and watched TV or read quietly for one hour and then RMR and RER were again measured. RMR and RER were measured by gas analysis through indirect calorimetry. During this procedure, the subjects were instructed to lie supine on a cot in a dimly lit, thermoneutral (21-26 ^{o}C, ~60% humidity) room for 20 minutes. A clear plastic hood (Model 7900, Hans Rudolph, Kansas City, MO) was placed over the subject's head and shoulders, which directed all expired gasses to the metabolic cart (True One, Parvomedics, Sandy, UT) through two inch diameter tubing and used a low pressure air pump to help circulate the expired air through the tubing. Heart rate was also measured during RMR assessment using a heart rate monitor (610, Polar Electro, Oy, Finland). Mean steady state RMR, RER, and Heart Rate were used for all data analysis, and steady state was operationally defined as at least 10 minutes with less than 10% variation in minute ventilation (VE) and VO_2 and less than five percent variation in RER .

Submaximal Exercise Metabolism

After the post drink measurement of resting metabolic rate, the subjects engaged in 15 minutes of treadmill exercise at a speed and grade that elicited 50% of maximal aerobic capacity. The treadmill speed and grade for the submaximal exercise were determined by finding the treadmill speed and grade during the aerobic fitness assessment that elicited 50% of the measured VO_2max. During the submaximal exercise test, VO_2, RER, and heart rate were measured using the same techniques and instruments used for the initial aerobic fitness assessment. From the 15 minute exercise trial, the mean of the final 10 minutes of data for HR, VO_2, and RER, were used for statistical analysis.

Statistical Analysis

Data for heart rate, RER, and energy expenditure (RMR) at rest were analyzed using a two-way (drink by time [pre/post]) repeated measures of analysis of variance (Sigma Stat 10, SPSS Inc, Chicago, IL). Significant main effects or interaction effects were identified using a student Newman-Keuls posthoc comparison. Data for heart rate, RER, and oxygen consumption during submaximal exercise were analyzed using a 1-way ANOVA. As part of the one way ANOVA, the data for heart rate, RER, and oxygen consumption during submaximal exercise were analyzed for normality by the software. If the normality test was failed, the data were analyzed using a Friedman repeated measures analysis of variance on ranks. An alpha level of 0.05 was used for all statistical comparisons. Data are presented throughout the manuscript means and standard error (mean ± SEM).

RESULTS

Dietary Intake

There were no differences in the self reported dietary macronutrient composition for the two days prior to the subjects' consumption of any of the energy drinks (table 3).

Effects of Energy Drinks at Rest

Table 3. Analysis of self reported dietary intake for the 48 h prior to ingestion of one of three energy drinks or a placebo drink before measurement of resting metabolic rate in 10 college aged men.

Variable Measured	Placebo	Energy Drink One	Energy Drink Two	Energy Drink Three
Carbohydrate Intake ($g \cdot day^{-1}$)	285.1 ± 49.4	275.4 ± 34.4	241.3 ± 26.9	264.4 ± 24.3
Fat Intake ($g \cdot day^{-1}$)	101.6 ± 15.5	78.2 ± 10.9	87.5 ± 10.1	91.7 ± 13.3
Protein Intake ($g \cdot day^{-1}$)	84.3 ± 8.7	94.5 ± 10.4	87.3 ± 11.0	114.9 ± 16.7
Energy Intake ($kcal \cdot day^{-1}$)	2424.9 ± 362.8	2186.0 ± 220.2	2128.5 ± 230.8	2352.1 ± 200.0

Data represent means ± SEM.

Heart rate

There were no differences in heart rate between rest (58 ± 3 beats·minute^{-1}) or post drink intake (58 ± 2 beats·minute^{-1}) for all drinks combined. Furthermore, there were no differences in heart rate due to Energy Drink One (61 ± 3 beats·minute^{-1}), Energy Drink Two (58 ± 2 beats·minute^{-1}), Energy Drink Three (61 ± 2 beats·minute^{-1}), or placebo (55 ± 2 beats·minute^{-1}).

RMR

There were no differences in baseline RMR in any condition (figure 1). There were no changes in RMR due to the placebo. RMR was increased similarly (P<0.05) above baseline (1,989.5 ± 19.5 kcal·day^{-1}, for all drinks combined) after Energy Drink One (2,237.3 ± 55.8 kcal·day $^{-1}$), Energy Drink Two (2,230.5 ± 60.1 kcal·day $^{-1}$), and Energy Drink Three (2,221.4 ± 58.0 kcal·day $^{-1}$).

RER

There were no differences in RER at baseline in any condition (figure 2). However, RER at rest was increased (P<0.05) similarly above baseline (0.81 ± 0.01, for all drinks combined) after consumption of Energy Drink One (0.88 ± 0.02), Energy Drink Two (0.87 ± 0.02), and Energy Drink Three (0.90 ± 0.02) and was decreased (P<0.05) after consumption of the placebo (0.78 ± 0.02).

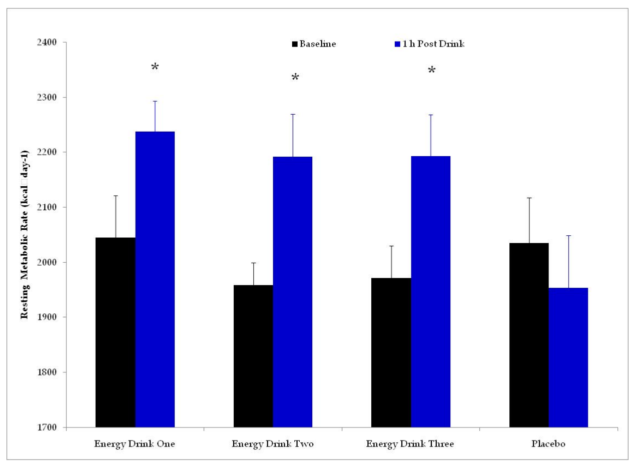

Figure 1. Resting metabolic rate measured by gas analysis through indirect calorimetry in male subjects at baseline and one hour after consuming 473 ml of either a placebo or energy drink. * indicates difference in resting metabolic rate between baseline and post-drink consumption ($p < 0.05$; main effect).

Effects of Energy Drinks During Submaximal Exercise

Heart rate

The data for heart rate during submaximal exercise met the criteria for normality (P=0.250) and equal variance (P=0.251). There were no differences (P=0.786) in heart rate during submaximal exercise after consumption of any of the drinks. The heart rates during the submaximal exercise were 149 ± 7 beats·minute^{-1} for Energy Drink One, 151 ± 7 beats·minute^{-1} for Energy Drink Two, 147 ± 5 beats·minute^{-1} for Energy Drink Three, and 149 ± 6 beats·minute^{-1} for the placebo.

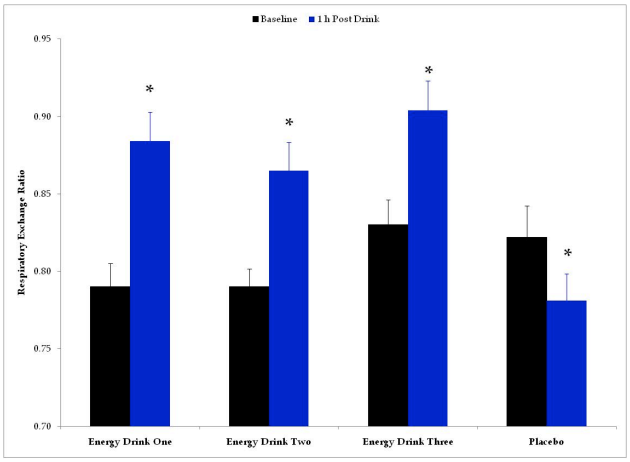

Figure 2. Respiratory exchange ratio during measurement of resting metabolic rate in male subjects at baseline and one hour after consuming 473 ml of either a placebo or energy drink. * indicates difference in respiratory exchange ratio between baseline and post-drink consumption ($p < 0.05$; main effect).

RER

The data for RER during submaximal exercise met the criteria for normality (P=0.145) and equal variance (P=0.976). There were no differences (P=0.160) in RER during submaximal exercise after consumption of any of the drinks. RER during the submaximal exercise was 0.92 ± 0.01 for Energy Drink One, 0.92 ± 0.01 for Energy Drink Two, 0.92 ± 0.01 for Energy Drink Three, and 0.91 ± 0.01 for the placebo.

VO_2 (L·min-^{1})

The data for VO_2 (liters·minute^{-1}) during submaximal exercise failed the criteria for normality (P<0.050) and were subsequently analyzed using a Friedman repeated measures analysis of variance on ranks. There were no differences (P=0.696) in VO_2 (liters·minute^{-1}) during submaximal exercise after consumption of any of the drinks. The VO_2 (liters·minute^{-1}) during submaximal exercise was 2.27 ± 0.15 liters·minute^{-1} for Energy Drink One, 2.25 ± 0.15 liters·minute^{-1} for Energy Drink Two, 2.20 ± 0.21 liters·minute^{-1} for Energy Drink Three, and 2.33 ± 0.11 liters·minute^{-1} for the placebo.

VO_2 (ml·kg^{-1}·min-^{1})

The data for VO_2 (ml·kg^{-1}·minute^{-1}) during submaximal exercise failed the criteria for normality (P<0.050) and were subsequently analyzed using a Friedman repeated measures analysis of variance on ranks. There were no differences (P=0.696) in VO_2 (ml·kg^{-1}·min^{-1}) during submaximal exercise after consumption of any of the drinks. The VO_2 (ml·kg^{-1}·min^{-1}) during submaximal exercise was 29.1 ± 1.47 ml·kg^{-1}·min^{-1} for Energy Drink One, 28.9 ± 1.72 ml·kg^{-1}·min^{-1} for Energy Drink Two, 28.1 ± 2.34 ml·kg^{-1}·min^{-1} for Energy Drink Three, and 30.0 ± 1.22 ml·kg^{-1}·min^{-1} for the placebo.

DISCUSSION

The primary findings of this study are that consuming 473 ml of three popular energy drinks increases RMR and RER at rest, but does not alter heart rate at rest. Furthermore, energy drink consumption does not alter oxygen consumption, substrate utilization, or heart rate during short term submaximal exercise. These findings are noteworthy because previous studies involving caffeinated beverages have reported similar results related to heart rate, RMR, RER, and oxygen consumption during rest and exercise (8, 19, 26), suggesting that the additional stimulants included in energy drinks do not alter these physiologic responses beyond the effects of caffeine.

The present data indicate that resting heart rate is not affected one hour after energy drink consumption, in spite of the stimulants contained in the energy drinks. Even though caffeine is a widely known stimulant, the effects of caffeine on resting heart rate are widely variable. For instance, Flinn et al. (12) found no changes in resting heart rate during the three hours after caffeine naïve participants ingested 10 $mg \cdot kg^{-1}$ caffeine. On the other hand, it has been reported that heart rate slows for about an hour after caffeine consumption, and then increases for two to three hours thereafter (9). Yet another study found that, in comparison with regular coffee, an "extreme functional coffee" with added energy enhancing ingredients did not change resting heart rate during the three hours following ingestion (26). The individual effects of the non-caffeine stimulants in energy drinks are not known, but Steinke (25) observed a five-to-seven $beat \cdot min^{-1}$ increase in resting heart rate following consumption of 500 ml of an energy drink. So, while the present data may be surprising regarding to the lack of change in resting heart rate following energy drink intake, the findings are in agreement with previous observations regarding the effects of caffeine on resting heart rate.

In this evaluation, in spite of no change in resting heart rate, energy drinks significantly increased RMR one hour after consumption. In earlier studies focusing on caffeine and energy expenditure, a single dose of 100 mg of caffeine significantly increased RMR by three-to-four percent over 150 min, (4, 8, 26). Yet in another study, caffeine ingestion alone increased resting energy expenditure (REE) 13% compared to a placebo (3), which is very similar to the ~12% increase in RMR due to energy drinks in the present investigation. It has also been reported that when comparing regular coffee to a coffee blend with an added energy blend (including extra caffeine), that the drink with the added stimulants showed a significant increase in resting energy expenditure from pre-drink consumption to three-hours post (26). In addition to stimulants, energy drinks contain simple sugars that are broken down quickly and have been reported to provide a quick, but short-lived, burst of energy (27). So, given the present data and the data of previous studies, the increase in RMR can be attributed primarily to the caffeine content, partly to other stimulant ingredients, and partly to the simple carbohydrate content of the energy drinks.

The present data indicate that the consumption of 473 ml of an energy drink causes a significant increase RER, which indicates an increase in carbohydrate utilization, at rest one hour after ingestion. The presently observed increase in RER agrees with a recent investigation of a coffee blend containing additional caffeine, citrus aurantium, and chromium polynicotinate that caused a significant increase in RER (18, 26). However, another study using a coffee blend with added caffeine, green tea extracts, and niacin (similar to energy drink ingredients minus the carbohydrates) found no significant change in on RER three hours later (26). Yet others have reported that caffeine intake reduces RER (12, 15). One very notable difference in many of these studies, including the present investigation, is whether carbohydrate was included with the caffeine. When carbohydrate is included with caffeine, there appears to be a considerable increase in carbohydrate use while without carbohydrate there is an increase in fat use (15). So, while the results of the present data conflict with some studies, they do agree with others regarding the effects of caffeine and stimulants on RER.

As previously stated, the use of energy drinks in a resting state increased RMR similarly in all three drinks and caused a similar increase in RER. Overall, the energy drinks caused a 12.1% increase in RMR and a 9.4% increase in RER. When the increase in RMR is used in conjunction with the change in RER (31), the energy drinks caused an increase of ~686 kcal·day^{-1} in energy coming from carbohydrate and a reduction in energy use from fat of ~445 kcal·day^{-1}.

In the current investigation, no differences in HR were noted between energy drinks and the placebo during 15 minutes of submaximal exercise ~80 minutes after drink consumption. In an earlier study, no significant differences in HR were observed during 105 minutes of steady-state cycling in endurance-trained cyclists who consumed a placebo or a drink containing caffeine and glucose (19). So, as it may be surprising that no differences in heart rate were observed between these stimulant drinks or a placebo during exercise, the current data are in agreement with previous findings regarding heart rate during submaximal exercise and caffeine intake.

No differences in oxygen consumption during submaximal exercise after energy drink consumption or placebo were noted in the present data. Even though caffeine is commonly known as a stimulant, it has no effects on oxygen consumption during exercise. Therefore, while the present data indicate that energy drinks are unlikely to enhance submaximal exercise performance, they are also unlikely to impair performance. However, numerous studies have found that caffeine increases exercise time-to-exhaustion during prolonged, submaximal exercise (20; 29). On the other hand, no significant improvement in run time-to-exhaustion was found after consuming sugar-free Red Bull, suggesting that a lack of carbohydrates may influence the ergogenic effects of a caffeine containing beverage (8).

One weakness to the present investigation is that the energy drinks were not analyzed for content, and so the present findings may apply to the energy drinks only as formulated at the time they were purchased for this project (June 2009). As the energy drink all contained proprietary blends of ingredients, and the manufacturers' ingredient labels are vague regarding many ingredients, it is difficult to determine the efficacy (or lack thereof) for any single ingredient. Furthermore, it is possible that the ingredients in the energy drinks have antagonistic or synergistic physiological effects (7). However, energy drinks remain popular, are readily available, and the present investigation helps elucidate the effects of energy drinks at rest and during submaximal exercise.

These data indicate that energy drink consumption increases RMR and carbohydrate utilization, but not heart rate at rest. However, heart rate, oxygen consumption, and substrate use during submaximal exercise are not changed by energy drink consumption. The present data also indicate that the magnitude of increase in RMR does not compensate for the calories provided by an energy drink. Therefore, energy drinks may contribute to obesity and do not appear to be ergogenic during short-term submaximal exercise.

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