# Effect of Sugar-Free Red Bull Energy Drink on High-Intensity Run Time-to-Exhaustion in Young Adults

**Darren G. Candow,[1] Amanda K. Kleisinger,[1] Stephanie Grenier,[2] and Kim D. Dorsch[1]**

[1]*Faculty of Kinesiology and Health Studies, University of Regina, Regina, Saskatchewan, Canada; and* [2]*School of Human Kinetics, Laurentian University, Sudbury, Ontario, Canada*

## Abstract

Candow, DG, Kleisinger, AK, Grenier, S, and Dorsch, KD. Effect of sugar-free Red Bull energy drink on high-intensity run time-to-exhaustion in young adults. *J Strength Cond Res* 23(4): 1271–1275, 2009—Consuming sugar-free Red Bull energy drink before exercise has become increasingly popular among exercising individuals. The main purported active ingredient in sugar-free Red Bull is caffeine, which has been shown to increase aerobic exercise performance. The purpose of this study was to determine the effects of sugar-free Red Bull energy drink on high-intensity run time-to-exhaustion in young adults. Physically active university students ($n = 17$, 9 men, 8 woman; 21 ± 4 years, 73.4 ± 3.1 kg, 175.1 ± 3.2 cm) participated in a double-blind, crossover, repeated-measures study where they were randomized to supplement with sugar-free Red Bull (2 mg·kg$^{-1}$ body mass caffeine or ~147 mg caffeine; 4 kcal/250 mL) and noncaffeinated, sugar-free placebo (lemon-lime flavored soft drink, tonic water, lime juice; 4 kcal/250 mL) separated by 7 days. Exercise capacity was assessed by a run time-to-exhaustion test at 80% $\dot{V}O_2$max, perceived exertion was assessed immediately after exercise, and blood lactate was measured before and after exercise. There were no differences in run time-to-exhaustion (Red Bull: 12.6 ± 3.8 minutes, placebo: 11.8 ± 3.4 minutes), perceived exertion (Red Bull: 17.1 ± 2.0, placebo: 16.6 ± 1.8), or blood lactate between groups. In conclusion, sugar-free Red Bull energy drink did not influence high-intensity run time-to-exhaustion in young adults.

**Key Words** caffeine, ergogenic aids, athletes

Address correspondence to Darren G. Candow, darren.candow@uregina.ca.

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## Introduction

Since 2002, the popularity of commercially available energy drinks has increased substantially, with sales estimated at ≥$ 5 billion with industry leader Red Bull commanding more than 50% of all revenues (8). In recent years, consumption of sugar-free energy drinks has increased possibly because of the low-calorie, refined sugar content. The main active ingredient in sugar-free Red Bull is caffeine. Caffeine is one of the most widely used ergogenic aids, with acute caffeine ingestion increasing aerobic exercise endurance and reducing fatigue (10,14,26). When consumed at least 60 minutes before exercise, caffeine is reported to increase aerobic exercise performance (9,15,20,22,31) and decrease rating of perceived exertion (RPE) (14,21), usually in a dose-dependent manner (11). Plausible theories for the beneficial effects of caffeine include an increase in central nervous system activity (7,18,21,33), acting as an adenosine receptor antagonist (11,12), increasing calcium release and uptake to the sarcoplasmic reticulum (28), and enhancing plasma epinephrine concentrations (30).

Concern regarding the safety of commercially available energy drinks has been prompted by the potential adverse effects of caffeine (32). It has been found that large doses of caffeine (>3 mg·kg$^{-1}$) may lead to negative health consequences such as impaired glucose tolerance (3), gastrointestinal irritation (24), anxiety (32), irritability and nausea (18), and tachycardia (32), suggesting that a lower dose of caffeine should be investigated. However, only a few studies have investigated the potential effects of low-dose caffeine (<3 mg·kg$^{-1}$) on exercise performance. When Cox et al. (10) replaced a sports drink with a commercially available caffeinated soft drink (Coke: 1.3–1.9 mg·kg$^{-1}$ caffeine), cycling performance (time trial) was enhanced over placebo by 3.3%. Recently, Forbes et al. (16) found that 2 mg·kg$^{-1}$ caffeine ingestion (regular Red Bull energy drink) increased total bench press repetitions over 3 sets (Red Bull = 34 ± 9 vs. placebo = 32 ± 8, $p < 0.05$) in young adults. Results across studies suggest that a solution containing low-dose caffeine and sugar is effective for increasing exercise performance in young adults. However, the effects of a caffeinated, sugar-free solution on exercise performance are unknown.

Therefore, the purpose of this study was to determine the effects of sugar-free Red Bull energy drink on high-intensity run time-to-exhaustion in young adults. To increase applicability, we chose to test sugar-free Red Bull energy drink because many exercising individuals routinely choose low-calorie, sugar-free caffeinated energy drinks (27). Furthermore, ingesting carbohydrate shortly before aerobic exercise may increase plasma insulin concentration and subsequently cause a decline in blood glucose due to suppression of liver glucose output (18). The run time-to-exhaustion test was chosen as this type of exercise demand may have application for sporting events, which involve acute bursts of speed to the finish line such as cross-country skiing and triathlons. Based on the potential ergogenic properties of caffeine, it was hypothesized that sugar-free Red Bull supplementation would increase high-intensity run time-to-exhaustion over placebo.

## Methods

### Experimental Approach to the Problem

The study implemented a double-blind, crossover, repeated measures design where subjects were randomized to supplement with sugar-free Red Bull or placebo 60 minutes before exercise, separated by a 7-day period. Exercise testing sessions were separated by 7 days to ensure adequate recovery between subsequent tests and to allow adaptation to caffeine withdrawal before the next exercise bout. Each subject underwent 3 days of testing. Exercise testing occurred at the same time each day (2–4 PM) at room temperature (19–21°C). During the first visit to the laboratory, subjects performed an incremental $\dot{V}O_2$max test to exhaustion on a motorized treadmill. At least 3 days after the $\dot{V}O_2$max trial, subjects were randomly assigned to supplement with sugar-free Red Bull (2 $mg \cdot kg^{-1}$ caffeine or ~147 mg of caffeine) or decaffeinated, sugar-free placebo (lemon-lime flavored soft drink, tonic water, lime juice) 60 minutes before performing a run time-to-exhaustion at 80% $\dot{V}O_2$max. One week after this initial supplementation and testing trial, subjects returned to the laboratory and ingested the opposite supplement drink and performed the same test. Variables measured were (a) run time-to-exhaustion, (b) RPE, and (c) blood lactate.

### Subjects

Seventeen university students (9 men, 8 women; age: 21 $\pm$ 4 years, body mass: 73.4 $\pm$ 3.1 kg, stature: 175.1 $\pm$ 3.2 cm, $\dot{V}O_2$max: 45.41 $\pm$ 6.3 $ml \cdot kg^{-1} \cdot min^{-1}$) who were performing regular physical activity (i.e., running, cycling, weightlifting; 2–5 times a week) before the study were recruited. All subjects were familiar with running on a motorized treadmill and were low to moderate caffeine consumers (~50–200 mg/d). Subjects were instructed to refrain from caffeine and alcohol for 48 hours, physical activity for 24 hours, and food and drink for 3 hours before each exercise test. Water was permitted *ad libitum*. Subjects were instructed not to change their diet during or engage in additional physical activity during the duration of the study. Subjects were screened for health problems using the Physical Activity Readiness Questionnaire (PAR-Q), which assesses an individual's readiness for participation in exercise training programs and includes questions related to heart conditions, angina at rest or during physical exercise, balance and bone or joint problems that may affect exercise performance. The PAR-Q was designed by the Canadian Society for Exercise Physiology and endorsed by Health Canada. All subjects were informed of the possible participation risks before providing their written informed consent. The study was approved by the University of Regina and Laurentian University Ethics Review Board for research with human subjects.

### Procedures

During the first visit to the laboratory, subject's stature and weight were recorded. Stature was recorded to the nearest 0.5 cm using a wall-mounted Tanita HR-100 stature rod (Tanita Corporation of America Inc., Arlington Heights, IL). Weight, to the nearest 0.5 kg, was recorded using a Health-ometer 349KL electronic weigh scale (Health O Meter Inc., Bridgeview, IL). Subjects performed an incremental run time-to-exhaustion test on a motorized treadmill (SciFit Systems Inc., Tulsa, OK). The treadmill was calibrated before exercise according to the manufacture's instructions. Expired air was collected and analyzed ($O_2$ and $CO_2$) breath-by-breath through a 2-way valve using a calibrated VMax Spectra 229 metabolic cart (Viasys Health, Burlington, Ontario, Canada). Subjects wore a polar heart rate watch (S-8101) and monitor (Polar Electro Oy, Kempele, Finland) during exercise to monitor changes in heart rate. The heart rate monitor was applied to the subject at the level of the xiphoid process to ensure a quality heart rate signal. Before the start of the test, subjects performed a 5-minute warm-up (3–5 mph) on the treadmill to elicit a heart rate $\leq$70% of their age-predicted maximum. Immediately after warm-up, the treadmill speed was increased (9–12 mph) and held constant during the test, and the grade of the treadmill was increased by 2% every 2 minutes until exhaustion. At the end of the test, the highest value recorded during the last 30 seconds of exercise was considered the subject's $\dot{V}O_2$max, which was reached between 8 and 14 minutes.

Three days after the $\dot{V}O_2$max test, subjects were required to return to the laboratory and ingest either sugar-free Red Bull (2 $mg \cdot kg^{-1}$ caffeine) or placebo. One hour after the drink was consumed, subjects ran on the treadmill until exhaustion at a speed and grade corresponding to 80% of their individual $\dot{V}O_2$max. Immediately upon cessation of exercise, subjects estimated their perceived exertion according to the 20-point Borg scale (14). Fingertip blood lactate levels (Accutrend Lactate; Roche Diagnostics, Mannheim, Germany) were recorded immediately before and after exercise and 3 and 6 minutes after exercise. Seven days after the first supplementation, subjects consumed the opposite supplement and repeated testing at the same time as on the previous supplementation day.

#### Supplementation

Sugar-free Red Bull and placebo were similar in energy content, volume, texture, and appearance. Each drink was carbonated and provided 4 kcal/250 mL. Supplements were relative to body mass and ingested in an opaque container by each subject 1 hour before exercise in the presence of a researcher. The caffeine dose of 2 $mg \cdot kg^{-1}$ was chosen for the present study because this dose has been shown to increase exercise performance (10,16,23,26) without resulting in adverse side effects in young adults (16). Ingredients for sugar-free Red Bull are listed in Table 1.

Sugar-free Red Bull energy drink ingestion occurred 60 minutes before exercise because peak plasma caffeine concentrations are maximized at this time (17,18,25), and several studies have shown an ergogenic effect from caffeine ingestion 60 minutes before exercise (16,23,29).

#### Statistical Analyses

A paired sample *t*-test was used to assess differences in run time-to-exhaustion and RPE between groups. A 2 (Red Bull vs. placebo) x 4 (blood lactate at 4 time points) analysis of variance, with repeated measures on the last factor, was used to assess changes in blood lactate concentration over time. Statistical significance was set at $p \leq 0.05$. All results were expressed as means ± *SD*. Data were analyzed using SPSS software (version 13.0; SPSS, Inc., Chicago, IL).

## Results

All subjects completed the study. Nine subjects correctly guessed they were supplementing with sugar-free Red Bull or placebo, 5 subjects incorrectly guessed which drink they were consuming, and 3 subjects did not know. Before testing, 6 subjects were caffeine naive, 8 subjects reported consuming less than 150 mg caffeine/d, and 3 subjects reported consuming >200 mg caffeine/d. There were no differences in performance variables between caffeine-consuming subjects and caffeine-naive subjects or between men and women. There were no side effects reported from the exercise testing or sugar-free Red Bull energy drink or placebo.

**Table 1.** Sugar-free Red Bull energy drink ingredients.

| Ingredient | Supplement |
|---|---|
| Nonmedicinal ingredients | |
| Aspartame | 0.01 $mg \cdot kg^{-1}$ |
| Medicinal ingredients | |
| Caffeine | 2.0 $mg \cdot kg^{-1}$ |
| Taurine | 25 $mg \cdot kg^{-1}$ |
| Glucuronolactone | 15 $mg \cdot kg^{-1}$ |
| Niacin | 0.45 $mg \cdot kg^{-1}$ |
| Pantothenic acid | 0.15 $mg \cdot kg^{-1}$ |
| Vitamin $B_6$ | 0.05 $mg \cdot kg^{-1}$ |
| Riboflavin | 0.04 $mg \cdot kg^{-1}$ |
| Vitamin $B_{12}$ | 0.025 $mcg \cdot kg^{-1}$ |

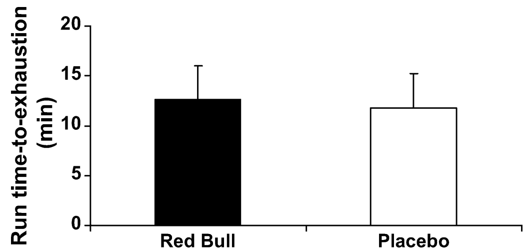


**Figure 1.** Run time-to-exhaustion (minutes) for sugar-free Red Bull and placebo. Values are means ± *SD*.

Twelve subjects ran longer when supplementing with sugar-free Red Bull (average: 1.43 ± 2.1 minutes or 10.1% increase), 3 subjects ran longer on placebo (average: 2.56 ± 1.9 minutes or 6.1% increase), and 2 subjects ran for the same length of time on sugar-free Red Bull and placebo. Of the subjects who ran longer when supplementing with sugar-free Red Bull, 2 subjects reported lower RPE compared with placebo, whereas 15 subjects reported no change between sugar-free Red Bull and placebo. However, there was no significant difference between run time-to-exhaustion (Red Bull: 12.6 ± 3.8 minutes, placebo: 11.8 ± 3.4 minutes; Figure 1) and RPE (Red Bull: 17.1 ± 2.0, placebo: 16.6 ± 1.8) between groups.

As expected, there was a time main effect for blood lactate ($p < 0.05$), with no differences between sugar-free Red Bull and placebo (Red Bull: pre-exercise 3.0 ± 2.0, post-exercise 8.6 ± 2.6, 3 minutes post-exercise 9.1 ± 3.2, 6 minutes post-exercise 7.4 ± 2.6 mmol/L; placebo: pre-exercise 3.0 ± 2.1, post-exercise 8.4 ± 2.6, 3 minutes post-exercise 9.3 ± 3.5, 6 minutes post-exercise 7.3 ± 3.5 mmol/L).

## Discussion

This is the first study to examine the effects of sugar-free Red Bull energy drink on high-intensity run time-to-exhaustion in young healthy adults. Results showed no significant difference in time-to-exhaustion between groups (Figure 1). One possible reason for not finding an effect from sugar-free Red Bull may be due to the lack of carbohydrates in the treatment solution, as a number of studies have shown an ergogenic effect when combining caffeine with carbohydrates (10,26,32). For example, in examining the effects of caffeine (0, 150, 225, 320 mg/L) and carbohydrate (68.8 g/L) containing solutions on exercise performance, Kovacs et al. (26) found that the combination of caffeine and carbohydrates significantly improved cycling exercise performance in young male athletes. Furthermore, the ingestion of a commercially available caffeinated, carbohydrate-containing soft drink (i.e., Coke) improved cycling exercise performance by 3.3% over a carbohydrate-containing solution in young trained male athletes (cyclists, triathletes; (10)). In 2 previous studies investigating the effects of regular Red Bull (i.e., caffeine and carbohydrates) energy drink on exercise performance, it was shown that bench press muscle endurance (defined as the total number of repetitions over 3 sets; (16)) and maximum cycling velocity (65–76% heart rate maximum (1)) increased when Red Bull was consumed compared with a noncaffeinated, carbohydrate-containing placebo (16). Although it is difficult to compare the results across studies, it appears that the ergogenic effects of commercially available soft drinks and energy drinks may only be observed when the treatment contains both caffeine and carbohydrates.

Another possible reason for not finding an effect from sugar-free Red Bull energy drink in the present study may involve the caffeine dose used. We chose the caffeine dose of 2 $mg\cdot kg^{-1}$ because this dose has previously been used to improve exercise performance (5,10,23,26), and specifically this dose of caffeine in Red Bull supplementation increased upper-body muscle endurance in young adults (16). Caffeine has been theorized to have a beneficial effect on aerobic exercise performance by acting as an adenosine receptor antagonist (11), increasing calcium release and uptake from the sarcoplasmic reticulum (28), and enhancing plasma epinephrine concentrations (30). Based on the results of the present study, these potential mechanistic actions of caffeine during high-intensity run time-to-exhaustion may only be observed when larger doses of caffeine are administered. For example, Graham and Spriet (19) showed that caffeine supplementation (3 and 6 $mg\cdot kg^{-1}$) consumed 60 minutes before running at 85% $\dot{V}O_2max$ significantly improved run time-to-exhaustion (increases of 22 $\pm$ 9 and 22 $\pm$ 7%, respectively) over the placebo time (49.4 $\pm$ 4.2 minutes). In addition, caffeine ingestion (6 $mg\cdot kg^{-1}$) 90 minutes before cycling exercise at 80% $\dot{V}O_2max$ increased exercise time-to-exhaustion compared with placebo (caffeine: 41.2 $\pm$ 4.8 minutes, placebo: 32.6 $\pm$ 3.4 minutes) (18). These findings across studies indirectly suggest that a caffeine dose of $\geq$3 $mg\cdot kg^{-1}$ may be necessary to increase high-intensity endurance exercise performance, whereas a lower dose of caffeine (~2 $mg\cdot kg^{-1}$) may be effective for increasing upper-body muscle endurance (16), strength (5) and moderate-intensity endurance exercise performance (10,26). These results may have application for the design of effective caffeine strategies for athletes and exercising individuals to increase exercise performance of various modalities.

Although caffeine is the main purported ergogenic ingredient in sugar-free Red Bull, this commercially available energy drink also contains other potential ergogenic ingredients (Table 1). For example, taurine supplementation has been shown to increase exercise time-to-exhaustion in both humans and rats (35), possibly by increasing muscle hyperexcitability and calcium availability (2,13,35). Research suggests that taurine doses of 2–6 g are required to be beneficial (4,35). For the present study, the amount of taurine administered was 1.0–1.9 g, which may have been too low to elicit an improvement in run time-to-exhaustion. Other ingredients such as the B vitamins have not been proven to have an effect on acute, high-intensity exercise performance (34).

There was no significant difference between RPEs when supplementing with sugar-free Red Bull or placebo. A recent meta-analysis critiquing the effects of caffeine and RPE suggests that there is no difference in RPE between caffeine and placebo after exhaustive exercise (14). However, previous research has shown a reduction in RPE with much higher doses of caffeine (5 $mg\cdot kg^{-1}$) after treadmill running at 70% $\dot{V}O_2max$ (7) and cycling at 80% $\dot{V}O_2max$ (6), suggesting that our caffeine dose may have been too low to see a meaningful effect. We feel confident that all subjects provided a maximum effort during each testing trial. All subjects were accustomed with treadmill running exercise, and because run time-to-exhaustion was relatively the same between sugar-free Red Bull and placebo, we conclude that sugar-free Red Bull supplementation has no effect on RPE.

There was a significant increase in blood lactate over time, which was expected. However, there were no differences between groups at each time point. These results are in agreement with that of Forbes et al. (16) who also found no differences in blood lactate from Red Bull or placebo before and after exercise in young healthy adults. Our results suggest that sugar-free Red Bull did not affect carbohydrate metabolism over placebo.

## Practical Applications

The ingestion of commercially available energy drinks before performing exercise is increasing. Results of this study suggest that young, physically active, healthy adults do not experience benefits from sugar-free Red Bull supplementation when consumed 60 minutes before performing high-intensity short-term intense exercise. These results may have application for altering pre-exercise strategies in athletes and exercising individuals. Future research should compare the effects of regular and sugar-free Red Bull energy drinks, at various caffeine dosages, on exercise performance.

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