MUSCLE FATIGUE RESISTANCE VIA ENERGY DRINK CONSUMPTION – ASSESSMENT OF PRE- AND POST- EXPERIMENT PARTICIPANT FEEDBACK

by
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ABSTRACT

Energy drink consumption poses a health risk among college students, and long-term health implications are unclear. Because energy drinks are classified as dietary supplements, the FDA is not responsible for proving consumption is safe for the consumer. This research project studies the consumption of an energy drink and an energy bean's effect on muscle fatigue using a grip force transducer, subjective perceptions of the participants after consumption across the two trials, and subjects' opinion of energy drinks after the conclusion of the experiment. All subjects, ages 18-24 and regular users of caffeine, were recruited through email at the University of Mississippi to participate in this blind study where the investigator was aware of whether the subject consumes the caffeine-containing energy drink/bean or the placebo, but the subject was not. Grip strength (MVC), time-to-fatigue, heart rate, and pulse rate before and after consumption of the energy drink, or energy bean, were measured. Subjects consumed 8 ounces of an energy drink (containing 80 mg of caffeine or placebo) or 42.5 g of energy beans (containing 75 mg of caffeine or placebo). 10 minutes after consumption the subject was asked to squeeze a grip force for as long and hard as possible until fatigued. After measuring the physiological time-to-fatigue, grip strength, heart rate, and pulse rate, each subject completed a survey assessing his or her alertness and energy levels. One week later, subjects returned for participation in the second trial of the

study. In the second trial, baseline measurement of grip strength (MVC) and heart rate were also measured. If the subject consumed the caffeinated energy drink or bean in the first trial, he or she consumed the placebo drink or bean in the second trial, and vice versa. The second part of the experiment measured the same values as the first part (physiological time-to-fatigue, grip strength, heart rate, and the subjective assessment). When all data were collected, subjects were provided with the post-experiment results, as well as information on the effects of energy drinks. After reviewing the results, subjects completed the free response exit survey. Significant physiological changes (MVC, time-to-fatigue, and heart rate) after consumption of the energy bean were not found. There was a significant decrease in maximum voluntary contraction after consumption of the energy drink, but no other significant physiological changes. Subjects who consumed the placebo and caffeinated version of the solid-form and the placebo version of the liquid-form did report a significant increase in mental focus. While previous studies have found physiological differences, such as increased heart rate, muscular strength, and time-to-fatigue from the ingestion of caffeine in energy drinks and energy beans, the present study did not find the same results.. This could have been due to subjects ingesting a too little dosage of caffeine, and variances in subjects activity levels, habitual dietary intake of caffeine, and the timing of the experiment. By increasing the amount of caffeine consumed, the subjective perceptions of mental focus, energy levels, and degree of fatigue may have clearer results. In the future, the mg of caffeine consumed should be increased or tailor-made to the subjects' body weight to induce physiological results.

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INTRODUCTION

Overview

Energy drink consumption has increased in recent years, particularly among college-aged students, but the nutritional label of an energy drink does not provide clear or useful details of what ingredients have been added (Bello, 2008). While caffeine is the predominant ingredient in energy drinks and has been shown to delay fatigue and increase the time until exhaustion during endurance exercises (Campbell et al., 2013), the benefit of consuming an energy drink over a more natural form of caffeine, such as coffee or tea, is unknown. Most energy drinks claim their products increase cognitive and physical performance, but there is not much evidence that any ingredients other than caffeine contribute to the effects (McLellan & Lieberman, 2012). Caffeine can act as an adenosine-receptor antagonist in the brain, increase plasma epinephrine concentrations, enhance calcium release and reuptake from the sarcoplasmic reticulum, and alter plasma potassium concentrations (Cureton et al., 2007). While these effects are not dangerous in the short-term, the long-term health implications are unclear. In 2011, McIlvain surveyed college students' caffeine consumption patterns. The students' mean caffeine consumed per day was 849.86 mg, nearly 5 times the recommended amount (McIlvain et al., 2011). Because caffeine has been shown to increase alertness, three questions were asked pertaining to the students' reasons for consuming caffeine. More than 72% of respondents in McIlvain's study did not believe that caffeine would help them concentrate, while 76% and approximately 59% believed that caffeine would keep them awake or wake them up in the morning, respectively. McIlvain et al., (2011) supported the findings of Kristiansen et al. (2005) that caffeine was consumed to counteract tiredness, but more than 81% of the respondents did not believe that caffeine would enhance their athletic, academic, or artistic performances. Pettit (2011) also conducted a study on college students' stress, energy drink consumption, and academic performance. It was found that the relationship between energy drink consumption and academic performance was negative. As energy drink consumption on any occasion decreased, academic performance increased (Pettit et al., 2011).

Energy drinks also contain ingredients such as taurine, guarana, ginseng, glucuronolactone, B-vitamins, and other compounds (McLellen and Lieberman, 2012), but the amounts of these ingredients are not always listed on the nutritional labels, and their purpose as an ingredient in energy drinks is debated. It is uncertain whether caffeine alone has the same effects as caffeine in conjunction with these added ingredients in the energy drinks (McLellen & Lieberman, 2012). The nutritional labels of energy drinks are vague, and include ingredients that are unfamiliar to the consumers. Because energy drinks are classified as a dietary supplements, the Food and Drug Administration (FDA) does not require manufacturers to demonstrate that the product is safe for purchase and consumption (Rath, 2010). Furthermore, scientific research has not been able to demonstrate that these ingredients are necessary, beneficial, or harmful to human health. In particular, the long-term effects have not been determined.

Forbes et al. (2007) sought to examine the effects that Red Bull® energy drinks have on anaerobic functions and muscle endurance of the upper body, and Walsh et al. (2010) explored the effects of Amino Impact®, a pre-exercise energy supplement, on time to exhaustion, as well as the effects on focus, energy, and fatigue. The fifteen volunteers for Forbes' (2007) study (12 men, 4 women) consumed Red Bull® or a placebo 60-minutes before performing repetitive spurts of high-intensity exercises. Seven days later, each participant repeated the trial with the opposite treatment. Walsh et al. (2010) had fifteen participants (9 men, 6 women) complete two sessions of a double-blind, randomized study where the participants consumed either the energy drink or the placebo 10 minutes before running on a treadmill at 70% of their VO_2 max. Forbes et al. (2007) found that Red Bull® increased muscle endurance in the upper body, but did not affect anaerobic performance during repeated stationary bike cycling tests. Walsh et al. (2010) determined that participants who consumed energy supplements had a significantly greater time to exhaustion (12.5% longer). Participants who consumed the energy supplement also reported more focus and energy, and less fatigue (Walsh et al., 2010). Hogervorst et al. (2008) writes that caffeine has been shown to be an effective ergogenic agent by delaying fatigue and increasing time to exhaustion during endurance exercise, but both Forbes et al. (2007) and Walsh et al. (2010) could not determine that the caffeine supplementation in their respective energy drinks was the only reason for increased muscle endurance. Forbes et al. (2007) mentioned that these ingredients are controversial, because there are no known effects on muscle endurance, and it is questioned whether their addition as an ingredient is necessary. Caffeine is a mild central nervous system stimulator, and other ingredients are added to create a synergistic effect with the caffeine (Walsh et al., 2010). There is no evidence of the other ingredients added to the Red Bull® energy drinks, such as carnitine, B-vitamins, and taurine, contributing to increased muscle endurance, but it cannot be ruled out (Forbes et al., 2007). Walsh et al. (2010) came to the same conclusion because Amino Impact® contains caffeine as well as taurine, glucuonolactone, creatine, beta-alanine, and the amino acids leucine, isoleucine, valine, glutamine and arginine.

In an examination of dose response effects of a caffeine-containing energy drink on muscle performance, Coso et al. (2012) studied two different doses of caffeine from an energy drink, and their effects on muscle performance for the upper and lower body. The 12 participants consumed either 0, 1, or 3 mg of caffeine per kg of body weight, and then performed half-squats and bench-presses 60 minutes after ingestion. The caffeinated drinks increased heart rate and mean arterial pressure, but not metabolic rate (Coso et al., 2012). The researchers concluded that at least 3mg of caffeine per kg of body weight will significantly increase muscular performance of the half-squat and bench-press while 1 mg of caffeine per kg of body weight does not provide enough caffeine to increase muscular performance. However, participants who consumed 3 mg of caffeine per kg of body weight experienced negative side effects such as anxiety, headaches, elevated heart rate and blood pressure, increased sweating and urine production or insomnia. While it is necessary to consume at least 3 mg of caffeine per kg of body weight of caffeine for increased muscle performance, ingestion can produce negative side effects in the hours after consumption (Coso et al., 2012).

Cureton et al. (2007) studied the specific effects caffeinated sports drinks have on cyclists. Sixteen participants either consumed a caffeinated sports drink, a carbohydrate-electrolyte sports drink, or a placebo. The subjects consumed half of the drink 10 minutes before exercise, and the remaining half immediately before the exercise. After 135 minutes of intense cycling, the maximal voluntary contraction (MVC) of the knee extensors was measured and compared to the original MVC of the participant before the performance. Participants who consumed the caffeinated sports drink completed 15-23% more work, and had less MVC strength loss due to less muscle fatigue (Cureton et al., 2007). The caffeinated energy drink used in this study also contained vitamins B3, B6, and B12, taurine, carnitine, and sucralose. The vitamin carnitine is not known to increase work capacity, but taurine has been attributed with increasing performance, yet the mechanism is still unclear (Geiss et al., 1994). Cureton et al. (2007) states that there can be differing results in the effects of caffeine based on the dose, the form in which the caffeine is ingested, the timing and pattern of administration, habitual dietary caffeine consumption by subjects, period of withdrawal of caffeine before testing, environment, and nature of the performance test.

There is little evidence that the added ingredients, such as taurine, guarana, ginseng, glucuronolactone, and B-vitamins are necessary for increased muscle performance. Through McLellan and Lieberman's literature review, it was concluded that only caffeine has been shown to improve mental and physical performance and is the only ingredient essential to energy drinks, but more studies should be conducted. The marketing claims promoting these components are not supported by evidence. Guarana seeds, a natural caffeine extract from the guarana plant native to Brazil, contain caffeine at concentrations of either 2% to 15% of their dry weight, and has some evidence of increased cognitive performance (McLellan and Liberman, 2012). While it was found that cognitive performance was increased in rats, there is no experimental evidence showing that guarana can be attributed to increased cognitive performance in humans (McLellan and Lieberman, 2012).

In a meta-analysis, Burrows et al. (2013) researched 15 other studies to gather information about cardiorespiratory effects, physiological and pathological measures, and body composition to determine whether or not energy drinks pose a health risk for consumers, but long-term effects were difficult to find. It was concluded that there is not enough information to estimate a safe level of consumption of energy drinks, and that while energy drinks do increase performance, they should be used cautiously because long-term effects are still unknown (Burrows et al., 2013).

Purpose

This research project studies the effect of consumption of an energy drink or energy bean on muscle fatigue using a grip force transducer. It was hypothesized that the consumption of the energy drink or energy bean would produce physiological changes such as, an increase in time-to-fatigue, the maximum voluntary contraction, and heart rate. It was also hypothesized that there would be an increase in the subject's self-assessment of mental focus, energy levels, and degree of fatigue after the consumption of the caffeinated energy drink or energy bean, and would be able to perceive a difference in ability to focus, energy, and fatigue after consumption of the caffeine or placebo treatment.

MATERIALS AND METHODS

The study began by recruiting college-aged students enrolled at the University of Mississippi, that were male or female with no history of adverse reactions to caffeine and between the ages 18-24. The experiment was reviewed and approved by the Institutional Review Board (#15-038) at the University of Mississippi. After confirming that potential participants were regular users of caffeine, they were asked to read a brief paragraph explaining the experiment. If participants were interested in volunteering, informed consent was obtained and an intake survey was given to the potential participants (Appendix A).

In brief, the intake survey examined the participant's current knowledge of energy drinks and their effects on physical and mental performance, as well as the health implications associated with consumption of energy drinks. Participants were asked to indicate which side effects, from a list provided, they believed were associated with energy drink consumption. The participant marked whether he or she consumed energy drinks, and if so, how frequently. A list of foods and drinks that contain caffeine were provided,and subjects were instructed to indicate the foods or drinks included in his or her normal diet. Lastly, the participant was asked to provide information about his or her weekly amount of physical activity, considering time spent doing cardiovascular activities and/or strength training activities. After the intake survey, the participants were asked if they wanted to continue into the experimental portion of the experiment. There was no penalty for students who did not want to continue their participation.

Prior to participating in the experimental portion of this project, participants were asked to refrain from consuming caffeine for 4 hours before the experiment. Baseline testing for pulse rate and maximum voluntary contraction was obtained when the subject first arrived for each trial. Grip force and heart rate were measured using PowerLab 26T data acquisition units connected to CPUs running LabChart 8.0.2 software with a sampling rate of 1000 readings per second. Grip force was measured with detection limits of ±1 V using a grip force transducer (MLT004/ST). A pulse transducer (TN1012/ST) was placed on the index finger of the opposing hand to measure heart rate. Raw pulse was measured with detection limits of ±200 mV. The raw pulse data was normalized over each 2-second window of time. Minimum peak heights of ±3.5 standard deviations from the normalized value were detected to calculate momentary pulse rate. Subjects were randomly assigned to either the liquid- or solid-form of the treatment, and then randomly assigned to consume the respective caffeinated treatment during the first or second trial. The liquid-form of the treatment was 236.5 mL of either a Monster® energy drink, or a placebo of caffeine-free Mountain Dew®, which contains approximately the same amount of carbohydrates. The solid-form of the treatment was 42.5 grams of Jelly Belly's Extreme Sports beans with Caffeine®, or a similar-flavored, similar-carbohydrate content, Jelly Belly Extreme Sports bean®, containing no caffeine, acting as the placebo. The liquid-form contained 80 mg of caffeine, and the solid-form contained 75 mg of caffeine.

Approximately 10 minutes after consumption, the participant was asked to squeeze the grip force transducer for as long and as hard as possible until fatigued using his or her dominant hand. Post-consumption MVC, time-to-fatigue, and pulse rate were measured ten minutes after consumption because Walsh (2010) found a greater time to exhaustion in subjects who consumed an energy drink 10 minutes before an endurance exercise, as well as increased focus and energy and less fatigue 10 min after consumption. Prior research indicates that subjects fatigue within 5 minutes of gripping the force transducer (Anderson et al., 2012). After measuring the physiological time-to-fatigue and heart rate, the participant was given a survey to measure his or her subjective perceptions regarding focus, energy levels, and fatigue after consumption and grip testing (Appendix B).

One week later, the participant partook in the second trial of the study. Baseline testing of grip force and heart rate were measured again. If given the caffeinated energy drink or bean in the first trial, he or she was given the placebo drink or bean for the second trial, and vice versa. Ten minutes after consumption, physiological MVC, time-to-fatigue, heart rate, and subjective perceptions were measured with the same procedure as the first trial.

After all data had been collected and analyzed, participants were asked to complete a questionnaire pertaining to their perceptions across the two trials (Appendix C). At this point, the participants were informed of the trial in which they consumed the caffeinated version of the drink or jelly bean and when they consumed the placebo and the results from the physiological data. Participants concluded their involvement in the study by completing an exit survey. This survey presented detailed information on short-term and long-term effects of caffeine consumption, as well as changes in heart rate, grip-strength, and time-to-fatigue. From this experiment, participants were then assessed of their likelihood for future consumption of caffeine containing substances, as well as their reasoning for that decision (Appendix D).

Analytical Methods

Descriptive statistics, such as mean, standard deviation, and standard error, were calculated for the solid and the liquid form of consumption for both the first and second trial. Chi square analyses were used to determine the level of significance for the knowledge based questions in the intake survey (Siegel and Castellan, 1988). The physiological data included: heart rate, maximum voluntary contraction, and the different intervals for time-to-fatigue (time-to- 75%, -50%, -25% of the MVC). This data was analyzed using t-Tests: Paired Two Sample for Means. Analyses were conducted using Microsoft Excel and the level of significance was set at $\alpha = 0.05$ for all tests. The subject's ratings of perceptions across the two trials were also analyzed using chi-square (Siegel & Castellan, 1988).

RESULTS

Intake survey

None of the 20 participants reported consuming energy drinks on a daily basis. Of other caffeine-containing food and drink, thirteen of the participants reported weekly drinking tea, while ten reported regularly eating chocolate. Six participants regularly drink sodas/soft drinks, and four regularly drink coffee. With regards to the frequency of previous energy drink consumption by the subjects, thirteen reported that the question was not applicable, while six participants had previously consumed 1-2 drinks per week, and one participant reported drinking 3-5 drinks per week. None of the participants reported drinking 6-7 energy drinks in a week. Subjects indicated that they participated in cardiovascular activity for one (n=2), two (n=5), three (n=7), four (n=2), or 5+ hours per week (n=4). When asked about strength training, subjects reported zero hours (n=6), one hour (n=2), two hours (n=5), three hours (n=3), four hours (n=1), five + hours (n=3) in week.

Next, the subjects were asked about the extent of their knowledge of the health implications energy drinks can have. Responses to this question were significantly different ($\chi^2 = 19$, $df = 4$, $p<0.05$) from each other with subjects responding by indicating: Very strong (n=1), Strong (n=5), Neutral (n=11), Weak (n=3), or Very weak (n=0). When asked a similar question regarding their knowledge of the physical and mental effect energy drinks can have, student responses were: Very strong (n=1), Strong (n=5), Neutral (n=10), Weak (n=4), or Very weak (n=0). These responses regarding their knowledge of physical and mental effects of energy drink consumption were significantly different between subjects. (χ^2= 15.5, *df*=4, p<0.05).

Participants were asked about their awareness of short-term effects of consuming energy drinks, with most reporting an awareness of restlessness (n=19), and increased heart rate (n=19). Subjects' awareness of other short-term effects included: insomnia (n=12), nervousness (n=10), stomach irritation (n=10), headache (n=10), and anxiety (n=10). Fewer subjects were aware that chest pain (n=6) and nausea/vomiting (n=5) could be a side effect. Subjects could select more than one answer when asked about their awareness of short- and long-term effects. Lastly, the participants were asked about their awareness of long-term effects of consuming energy drinks, with most indicating they were aware of restlessness (n=14), anxiety (n=11), and insomnia (n=10) as long-term effects. Many were also aware of gastrointestinal disturbances (n=8) and fatigue (n=8) as long-term effects. Fewer subjects indicated dizziness (n=5) and confusion (n=2) and hallucinations (n=1) as long-term effects. One subject was not aware of any long-term effects. No subject indicated being aware of paranoia, dyskinesia, or depression as long-term effects of consuming energy drinks. The very last question of the intake survey asked whether the participant regularly consumed caffeine, to which all answered that they consumed caffeine in their normal diet.

Grip-force Tests

For the solid-form caffeine treatment, the maximum voluntary contraction before consumption (MVCpre) and the maximum voluntary contraction for the placebo (MVCplacebo) were not significantly different ($t = -1.07$; *df* =9; $p > 0.05$, Figure 1), nor were the MVCpre vs. the maximum voluntary contraction for the caffeinated jelly bean compared to the placebo (MVCcaffeine) significantly different ($t = -2.06$; *df* =9; $p > 0.05$, Figure 1). The heart rate before consumption (BPMpre) vs. the heart rate for the placebo (BPMplacebo) was not significantly different ($t= 0.54$; *df* = 9, $p>0.05$, Figure 3). The BPMpre vs. the caffeinated jelly bean (BPMcaffeine) also was not significantly different ($t = -1.52$; *df* = 9; $p > 0.05$, Figure 3). There was not a significant difference in the time-to-fatigue at 75%, 50%, or 25% of the maximum voluntary contraction between subjects in the placebo and the caffeine jelly bean conditions ($t =1.07$; *df* =9; $p >0.05$, Figure 2).

For the liquid treatment, the maximum voluntary contraction before consumption (MVCpre) and the maximum voluntary contraction for the placebo (MVCplacebo) were significantly increased ($t = -5.06$; *df* = 9; $p < 0.05$, Figure 4) as were the MVCpre vs. the maximum voluntary contraction for the caffeinated drink (MVCcaffeine) significantly increased ($t = -3.35$; *df* = 9; $p < 0.05$, Figure 4). The heart rate before consumption (BPMpre) vs. the heart rate for the placebo (BPMplacebo) was not significantly different ($t= -0.18$; *df* = 9, $p>0.05$, Figure 5). The BPMpre vs. the caffeinated drink (BPMcaffeine) also was not significantly different ($t = 0.50$; *df* = 9; $p > 0.05$, Figure 5). There was not a significant difference in the time-to-fatigue to 75%, 50%, or 25% of the maximum voluntary contraction between the subjects in the placebo and the caffeinated drink conditions ($t = 0.35$; *df* = 9; $p >0.05$, Figure 6).

Post-consumption survey

After the subject participated in each experiment, he or she was asked to complete the post- test survey of students' perceptions of their degree of mental focus, energy levels, and degree of fatigue. Chi square analyses indicated that there was a significant increase in perceptions of mental focus (χ^2= 12, *df*=4, p<0.05, Table 1) and energy levels (χ^2= 23, *df*=4, p<0.05, Table 2) for the placebo version of the jelly bean. After consumption of the caffeinated jelly bean, there was a significant increase in mental focus (χ^2= 24, *df*=4, p<0.05, Table 1). The participants who drank the placebo version of the drink had a significant increase in mental focus (χ^2= 11, *df*=4, p<0.05, Table 1) and energy levels (χ^2= 13, *df*=4, p<0.05, Table 2). There was a significant increase in energy levels (χ^2= 9.5, *df*=4, p<0.05, Table 2) and degree of fatigue (χ^2= 11, *df*=4, p<0.05, Table 3) for the participants who consumed the caffeinated energy drink.

Post-data Analysis survey

The post-data analysis survey asked the participant if they thought they could guess in which trial they had consumed the caffeinated drink or bean, and if so, which trial, and whether or not they thought their strength and resistance to fatigue improved after the caffeine consumption.

Of the 18 subjects responding (two subjects did not respond to repeated requests to complete this survey), nine did not know which trial they consumed the caffeinated bean or drink, which was not significantly different from the expectation that subjects would be able to perceive a difference between the placebo or caffeinated version of the treatment (χ^2= 0, *df*=1, $p > 0.05$). More subjects (n=6) of the nine believed they consumed the caffeine in the first trial, than the subjects (n=3) who thought they consumed the caffeine in the second trial. Of these assumptions, four of the subjects were right and four were wrong which also was not significantly different than expected (χ^2= 1, *df* = 1, $p > 0.05$). Of these nine, most subjects (n=8) did not think that their strength and resistance to fatigue improved after the caffeine consumption. One of the subjects indicated a perception that his or her strength and resistance to fatigue improved after the consumption of caffeine. There was no significant difference in these responses either (χ^2=2.83, *df* = 1, $p > 0.05$).

After the post-data analysis survey, participants were shown graphs of the data collected during the first and second trials. Subjects were provided information about the effects energy drink can have on consumers. Participants were asked for free-responses (Table 4) to whether they would consume energy drinks in the future, and their reasoning for their decision. Fifteen of the subjects responded that they would not consume energy drinks, but would continue consuming caffeine from a natural source, such as tea or coffee. Three responded that they would continue drinking energy drinks, but in moderation. Two subjects mentioned that they were already aware/ had experience some of the side effects. Seven subjects mentioned that they would continue drinking coffee because it is natural.

DISCUSSION

This experiment provides statistically significant evidence that there was a difference in the subjects' knowledge of the health implications of energy drinks, as well as a significant difference in the students' range of responses in relation to the subjects' knowledge about the physical and mental effects of consuming energy drinks. The lack of significant differences in physiological changes of this study was not expected. From examining the literature, such as Walsh et al. (2010), Forbes et al., (2007), Ivy et al. (2009), and Cureton et al., (2007), it was expected that the caffeine would act as an ergogenic aid for the subjects during the grip test. However, no increases in muscular strength or resistance were measured in this study. In Walsh et al. (2010), the time to exhaustion during moderate-intensity endurance exercises was significantly longer following the ingestion of the energy drink Amino Impact®. Subjects given 26 g of Amino Impact® in 500 mL of water were able to run 12.5% longer after consuming the supplement than when they consumed the placebo (Walsh et al., 2010). It has also been found that 2mg of caffeine per weight of the energy drink, Red bull®, increases upper body muscle endurance, but had no effect on anaerobic power (Forbes et al., 2007). In Ivy et al. (2009), there was a significant improvement in time to complete a cycling time trial when Red Bull® was ingested 40 minutes before the exercise, and 83% of the participant's performance increased with 3-9 mg of caffeine per body weight. Additionally, consumption of an energy drink was shown to affect the active muscles and nervous system to reduce fatigue and perceptions of effort, discomfort, and pain, but did not increase the body's ability to neurally activate muscles. The primary findings of this previous study were that the caffeinated sports drink is more effective in improving cycling performance and attenuating muscle fatigue than the noncaffeinated sports drink (Cureton et al., 2007).

In Forbes' et al. (2007) experiment, the subjects were physically active (moderate physical activity 2-3 times a week) males or females of 21 +/- 5 years of age. They were instructed to refrain from ingesting caffeine for 48 hours, cease physical activity for 24 hours, and not consume food or drink for 3 hours before testing. The 48 hour refrain from caffeine was chosen because the half-life of caffeine is about 4-6 hours (Graham, 2001). Walsh's et al. (2010) subjects were recreationally active men and women of 20.9 +/- 1 years old. Subjects who were pregnant, smokers, taking any medication, had any known metabolic or cardiovascular disease, and/or psychiatric disorder were excluded. Subjects were required to abstain from nutritional supplements or ergogenic aids for 6 weeks before the study. Subjects were also asked to refrain from consuming any products with caffeine on the day of the test and be 3 hours post-absorptive state at the time of their testing session (Walsh et al., 2010). The subjects of Ivy's experiment were 6 male and 6 female competitive cyclists of 27.3 +/- 1.7 years of age. The subjects were instructed to fast for 12 hours before the experiment (Ivy et al., 2009).

A significant increase in time-to-fatigue, % maximum voluntary contraction, and heart rate during the grip test was expected after the consumption of the caffeinated substance. In this study, the participant's caffeinated substance contained either 80 mg of caffeine from the liquid-form of the treatment or 75 mg of caffeine from the solid-form of the treatment. Comparing that to previous studies, this may not have been enough caffeine to show physical effects in the subjects. Coso et al. (2012) concluded that it is necessary to consume at least 3 mg of caffeine per kg of body weight of caffeine for increased muscle performance. The 75 or 80 mg of caffeine the subject's ingested may not have been enough to increase muscle performance. While the subject's body weight was recorded, the mg of caffeine consumed was not altered to be 3 mg of caffeine per subjects' body weight. The subjects' weight ranged from 54.5-115.9 kilograms, with an average weight of 70.84 kg meaning that, predicting from previous results, 163.5-347.7 mg of caffeine, and an average of 212.52 mg of caffeine would have been necessary to increase muscular performance in the subjects, depending on their specific body weight. The amount of energy drink the subjects consumed could have been increased from 8 ounces (226.8 g), but subjects struggled to finish consuming the 1.5 serving size (42.5 g) of energy beans provided. Participants misunderstanding of instructions also could have affected the results. While all subjects were instructed to squeeze for as long as they could and as hard as possible, squeezing for a very long time became many participants main goal, instead of trying to maintain their initial MVC.

No significant differences were found between the time-to-fatigue at 75%, 50%, or 25% of the maximum voluntary contraction comparing the placebo or caffeinated jelly bean or the placebo or caffeinated drink. This was not expected, but could be due to the participants not ingesting enough caffeine or their not being enough time for the caffeine to take an effect. A physiological increase in MVC, time-to-fatigue, and heart rate 10 minutes after consumption of the treatment was expected because Walsh et al. (2010) found significant differences in time to exhaustion 10 minutes after consumption in his trial. Forbes et al. (2007) allowed 60 minutes between ingestion and the trial, while

Cureton et al. (2007) had his subjects consume half of their treatment 10 minutes before their trial, and the other half immediately before their trial. Because Walsh et al. (2010) found significant differences when caffeine was ingested 10 minutes before the trial, it was also expected to find differences in this trial 10 minutes after consumption.

There was a significant decrease between the maximum voluntary contraction (MVC) before consumption and the MVC for the subjects after consuming the placebo beverage. There also was a significant decrease between the MVC before consumption and the MVC of the subjects after consuming the caffeinated beverage. These were not the expected results, and no explanation can be provided by previous studies.

There were no significant differences in the heart rate, whether it was the beats per minute (BPM) before consumption compared to the placebo or caffeinated substance, whether liquid or solid. This could be from the pulse transducer becoming loose during the time of the trials. Because of the pulse transducer becoming loose, very low pulse rates were recorded in some cases and this error could have affected the results.

While there were not any physical changes in muscular strength, there was an influence on the participant's subjective perceptions. In a previous study, participant's subjective perceptions of focus, energy, and fatigue were significantly increased ten minutes after consumption of caffeine, and the study concluded that consumption of the energy drink 10 minutes before the work out increased focus, energy, and reduced fatigue (Walsh et al., 2010). While the present questions about mental focus and energy levels were more general, multiple participants were confused by the question about their degree of fatigue. Many asked whether the question pertained to their overall levels of fatigue, or just the fatigue they felt in the hand that squeezed the grip force transducer.

The questions may have been too vague, and could have had an effect on the results of the participants' subjective perceptions.

From the survey asking about their perceptions during the two separate trials, it was expected to find that the subjects' mentally perceived changes between the placebo and caffeinated treatments. If the subject guessed which trial they had the caffeinated version, then they were asked whether they thought their strength and resistance to fatigue improved after consumption of the caffeine. The results to these questions were not significant, which was not expected based on the results of Walsh et al. (2010). Throughout the trials, some subjects convinced themselves that they had the caffeinated version when they did not. The first question asked the subjects whether they could guess in which trial they consumed the caffeinated treatment. It was expected that more participants would have answered "yes" to this question. Because there were 2-3 months between this survey and the trial, some subjects may not have been able to remember. It could have been more effective to conduct this survey right after the second trials and show the participants the results at a separate time.

While previous studies have found physiological differences, such as increased heart rate, muscular strength, and time-to-fatigue from the ingestion of caffeine in energy drinks and energy beans, the present study did not find the same statistical evidence. This could have been due to too little ingestion of the liquid-form or solid-form of the treatment to cause physiological effects. In the future, an increase in the mg of caffeine in the treatment or tailor-making the treatment to each subject's body weight could induce physiological effects. By increasing the amount of caffeine consumed, the subjective perceptions of mental focus, energy levels, and degree of fatigue may have clearer results.

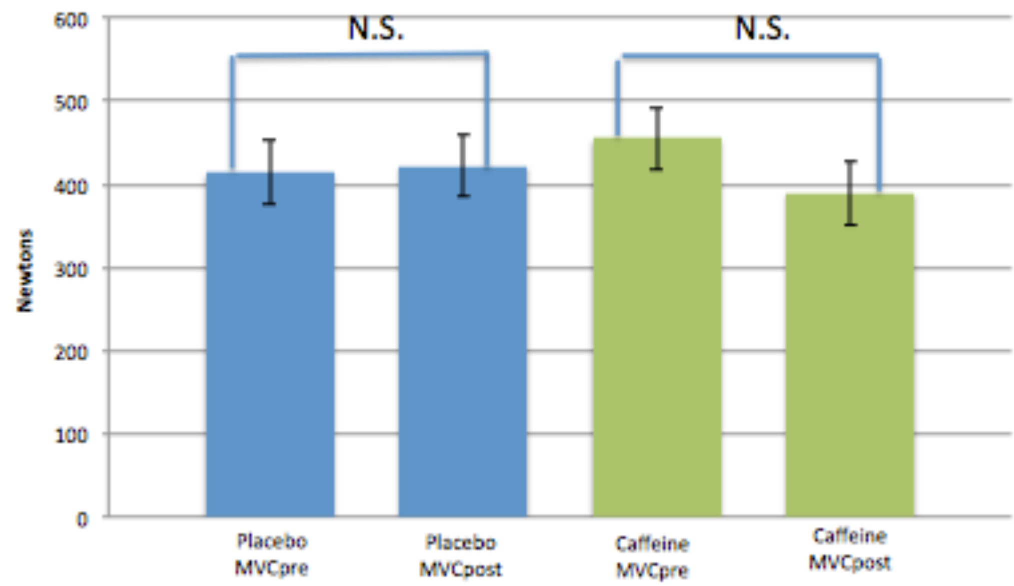

Figure 1. Average maximum voluntary contraction before consumption of the solid placebo and solid caffeine treatment compared to average maximum voluntary contraction after consumption of the solid placebo and the solid caffeine treatment. Error bars represent one standard deviation from the mean.

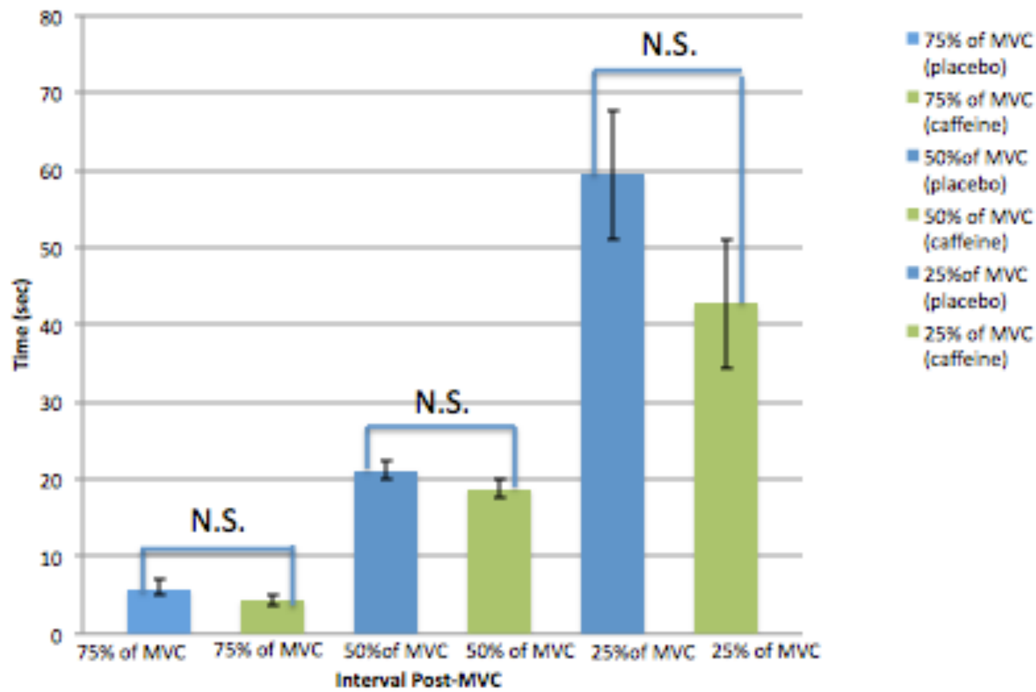

Figure 2. Interval time-to-fatigue between the solid placebo treatment and solid caffeinated treatment at 75%, 50%, and 25% of the maximum voluntary contraction. Error bars represent one standard deviation from the mean.

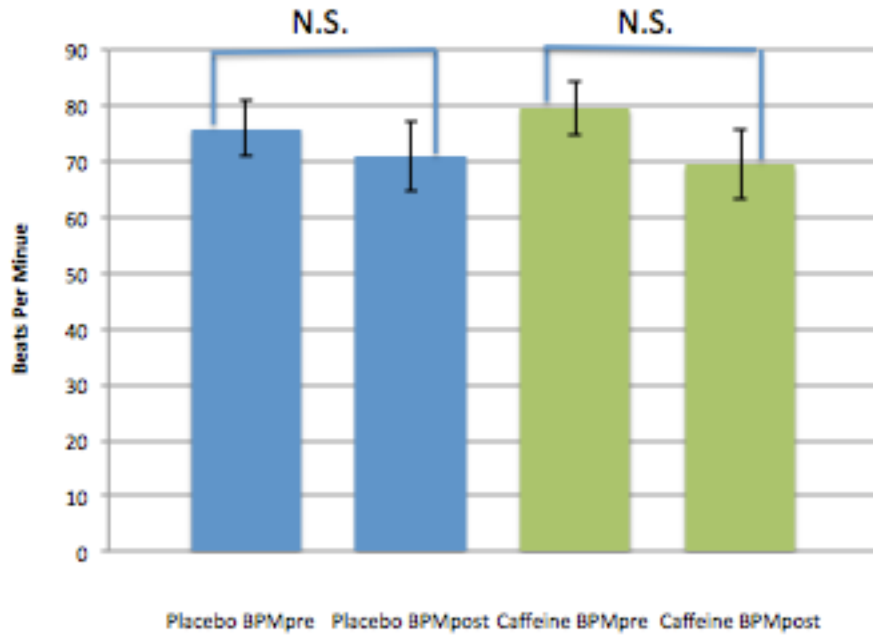

Figure 3. Average heart rate in beats per minute before consumption of the solid placebo and solid caffeine treatment compared to average beats per minute after consumption of the solid placebo and solid caffeine treatment. Error bars represent one standard deviation from the mean.

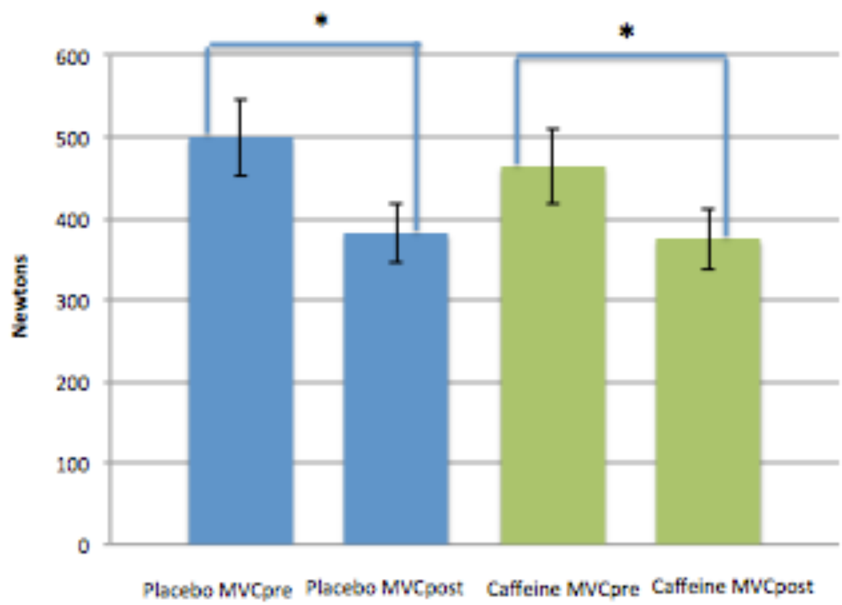

Figure 4: Average maximum voluntary contraction before consumption of the liquid placebo and liquid caffeine treatment compared to average maximum voluntary contraction after consumption of the liquid placebo and liquid caffeine treatment. Error bars represent one standard deviation from the mean. An "*" represents a significant difference at the p=0.05 level.

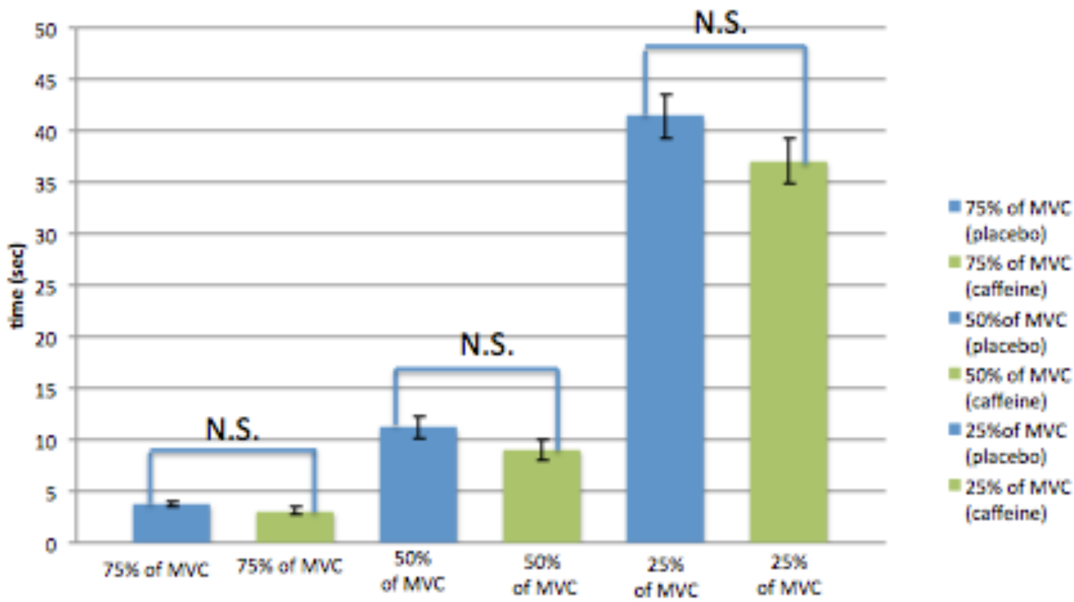

Figure 5. Interval time-to-fatigue between the liquid placebo treatment and liquid caffeinated treatment at 75%, 50%, and 25% of the maximum voluntary contraction. Error bars represent one standard deviation from the mean.

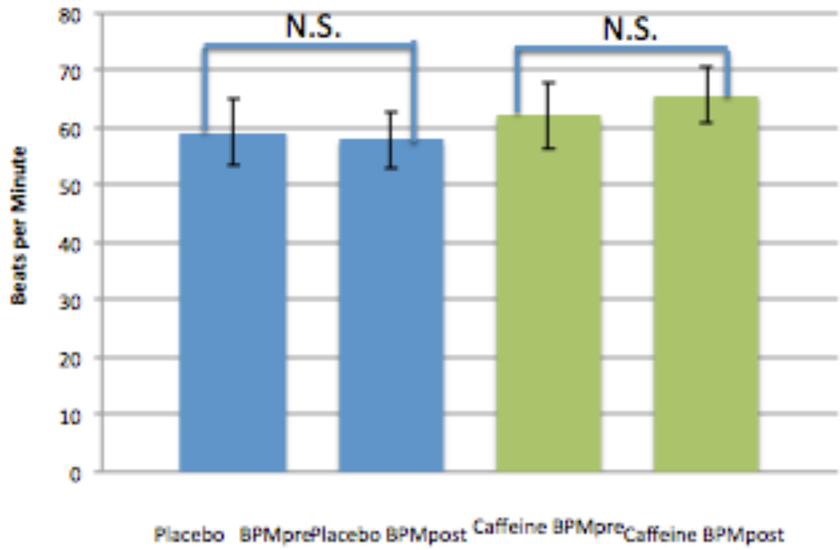

Figure 6: Average heart rate in beats per minute before consumption of the liquid placebo and liquid caffeine treatment compared to average beats per minute after consumption of the liquid placebo and liquid caffeine treatment. Error bars represent one standard deviation from the mean.

Table 1: Student perceptions of mental focus across all treatments rated on a scale of 1-5 (1= low mental focus, 5= high mental focus). χ^2 values were calculated using *df*=4, $p<0.05$ for all χ^2 tests. Significant χ^2 values are bolded.

Student Perceptions of Mental Focus:				
Ratings (1-5)	Solid-form Placebo	Solid-form Caffeine	Liquid-form Placebo	Liquid-form Caffeine
1	0	0	0	0
2	0	0	0	2
3	2	2	5	4
4	6	8	4	4
5	2	0	1	0
χ^2	**12**	**24**	**11**	9.33

Table 2: Student perceptions of energy levels across all treatments rated on a scale of 1-5 (1= low energy, 5= high energy). χ^2 values were calculated using df=4, $p<0.05$ for all χ^2 tests. Significant χ^2 values are bolded.

Student Perceptions of Energy Levels:				
Ratings (1-5)	Solid-form Placebo	Solid-form Caffeine	Liquid-form Placebo	Liquid-form Caffeine
1	0	0	0	0
2	1	0	0	1
3	1	3	3	5
4	8	5	6	3
5	0	2	1	0
χ^2	**23**	9	**13**	**9.5**

Table 3: Student perceptions of their degree of fatigue across all treatments rated on a scale of 1-5 (1= low degree of fatigue, 5= high degree of fatigue). χ^2 values were calculated using *df*=4, $p<0.05$ for all χ^2 tests. Significant χ^2 values are bolded.

Student Perceptions of Degree of Fatigue:				
Ratings (1-5)	Solid-form Placebo	Solid-form Caffeine	Liquid-form Placebo	Liquid-form Caffeine
1	0	0	1	2
2	4	2	2	2
3	4	2	4	3
4	1	5	2	4
5	1	1	1	0
χ^2	7	7	8.5	**11**

Table 4. Typical responses to survey of subjects' free-response opinion of energy drinks after participation

Response:	Number of Subjects:
Will continue caffeine intake through coffee	7
Does not currently consume energy drinks	14
Does not plan to consume energy drinks	15
Plans to continue consumption of energy drinks	3

APPENDICES

Appendix A

Muscle fatigue resistance via energy drink consumption: Assessment of pre- and post-experiment participant feedback

Intake survey

1. What is your body weight? ________________

2. Mark the foods or drinks that are a part of your normal diet. Circle all that apply.

Energy drinks/energy shots	coffee
soft drinks/sodas	chocolate
tea	

3. If you consumed energy drinks previously, how frequently?

Not applicable	1-2 drinks a week	3-5 drinks a week	6-7 drinks a week

4. How often do you participate in cardiovascular physical activity each week?

Never	1 hour	2 hours	3 hours	4 hours	5+ hours

5. How often do you participate in strength training physical activity each week?

Never	1 hour	2 hours	3 hours	4 hours	5+ hours

6. How would you rate your knowledge of energy drinks and the health implications they may cause? Circle the best answer.

Very strong	Strong	Neutral	Weak	Very Weak

7. How would you rate your current knowledge of energy drinks and their effects on physical and mental performance?

Very strong	Strong	Neutral	Weak	Very Weak

Appendix A continued

8. What short-term effects do you believe energy drinks cause? Circle all that apply.

Insomnia	stomach irritation	headache
Nervousness	nausea/vomiting	anxiety
Restlessness	increased heart rate	chest pain

9. Are you aware of any long-term effects that consumption of energy drinks may cause? Circle all that apply.

Dizziness	Confusion	GI disturbances
Insomnia	Paranoia	Fatigue
Restlessness	Hallucination	Depression
Anxiety	Dyskinesias	

10. Please circle whether or not you are a regular user of caffeine.

    Yes, I regularly consume caffeine.

    No, I do not regularly consume caffeine.

Appendix B

Muscle fatigue resistance via energy drink consumption: Assessment of pre- and post-experiment participant feedback

Post consumption and grip test survey

Rate your degree of mental focus 10 minutes after consumption on a scale from 1 to 5 (1=low degree of focus, 5=high degree of focus).

1 2 3 4 5

Rate your energy level 10 minutes after consumption on a scale from 1 to 5 (1=low energy levels, 5=high energy levels).

1 2 3 4 5

Rate your degree of fatigue after the grip test on a scale from 1 to 5 (1=low fatigue, 5=high fatigue).

1 2 3 4 5

Appendix C

Muscle fatigue resistance via energy drink consumption: Assessment of pre- and post-experiment participant feedback

Post-Experiment Survey:

1. Do you think you know when you consumed the caffeine-containing substance and when you consumed the placebo?

    ☐Yes
    ☐No

2. If so, did you consume the caffeine during the first or second trial?

    ☐ 1st
    ☐ 2nd

3. Do you think your strength and resistance to fatigue improved when you consumed caffeine?

    ☐Yes
    ☐No

Appendix D

Muscle fatigue resistance via energy drink consumption: Assessment of pre- and post-experiment participant feedback

Follow up/exit survey

Caffeine is the major ingredient in energy drinks. It's content ranges from 50 mg to 505 mg in each serving. Caffeine enhances alertness and mood, and acts as an ergogenic aid. Side effects include: gastrointestinal upset, nausea, insomnia, spontaneous abortion, and withdrawal symptoms like a headache. Other common ingredients of energy drinks include: taurine, glucuronolactone, guarana. ginseng, and B vitamins. Most of these ingredients are in quantities far above the recommended dietary intake level. There is not a definitive dietary recommendation for safe levels of energy drink consumption. Adverse effects of caffeine include: dizziness, insomnia, agitation, restlessness, anxiety, confusion, paranoia, hallucination, dyskinesias, GI disturbances, heat intolerance, stroke, myocardial infarction, arrhythmia, and death. Fatigue and depression can occur after discontinuing caffeine. Pre-existing conditions, such as heart disease, strokes, high blood pressure, seizure disorders, diabetes, and thyroid disease, are contraindications to caffeine use. Excessive caffeine consumption can result in caffeine intoxication with symptoms of cardiac arrhythmias, seizures, hypokalemia, hyperglycemia, leukocytosis, ketosis, and metabolic acidosis. Chronic caffeine intoxication is demonstrated by irritability, anxiety, emotional disturbances, and chronic abdominal pain. Long-term caffeine consumption has also been linked to cardiovascular disease, and myocardial irritability. Death as a result of caffeine intoxication is very rare, but four deaths have been reported due to dysrhythmias, and seizures.

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With information on what the effects of energy drinks, would you still consume this product? And, why?

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