ATRIAL ARRHYTHMIAS

RESEARCH ARTICLE

Evaluation of Hemodynamic and Electrocardiographic Effects of an Energy Drink in Healthy Adults

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ABSTRACT. *Energy drinks have become one of the fastest growing beverages in the United States, and are very popular among teens and young adults. The objective of this prospective study was to determine if consuming 5-hour ENERGY® drinks that contain both caffeine and taurine can cause any hemodynamic and electrocardiogram (ECG) changes on relatively healthy individuals when compared with a caffeine-free control group. We evaluated 15 healthy volunteers and looked at baseline ECG and vitals after consuming energy drinks for 5 days. We performed a survey among our hospital co-workers, peers, and colleagues and found that the 5-hour ENERGY® drink was the number one choice of energy drink. To our knowledge, there are no detailed studies evaluating the arrhythmogenic and hemodynamic effects of this energy drink using several non-invasive modalities.*

KEYWORDS. *Arrhythmia, central aortic blood pressure, QT interval.*

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Introduction

Energy drinks have become one of the fastest growing beverages in the United States, and are very popular among teens and young adults. They were initially introduced in 1997, and their popularity has increased exponentially over the years.¹ The drinks frequently contain relatively high levels of caffeine, taurine, sugar, and variety of vitamins.² Reports have mentioned that people mainly consume energy drinks for their concentration-enhancing properties, to compensate for inadequate sleep, and to improve athletic performance.³ There has been concern recently about the side effects of energy drinks, especially when combined with alcoholic beverages. Surveys have shown that increasing amounts of college students are mixing various energy drinks with alcoholic beverages, which can cause neurocognitive

impairment.⁴ Commonly reported side effects by the media and case reports include palpitations, arrhythmias, caffeine intoxication, diaphoresis, prolongation of QT interval, cardiac arrest, insomnia, and seizures.⁵ To our knowledge, there are no detailed studies using several non-invasive modalities evaluating the arrhythmogenic and hemodynamic effects of the 5-hour ENERGY® energy drink. The objective of this prospective study was to determine if consuming 5-hour ENERGY® drinks containing both caffeine and taurine can cause hemodynamic and electrocardiogram (ECG) changes on relatively healthy individuals when compared with a caffeine-free control group.

Methods

This was a prospective, single-center study that evaluated 30 healthy individuals. Our cohort consisted of medical students, residents, fellows, and hospital staff from St. John Providence Hospital between the ages of 20 and 65 years. Written consent explaining research protocol, risk and benefits was obtained from each participant. They went through a series of questionnaires regarding medical and social history. Exclusion criteria

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included history of arrhythmias, hyperthyroidism, cardiomyopathy (ischemic or non-ischemic), conduction system abnormalities, pre-excitation, interactions with home medications, obstructive sleep apnea, metabolic equivalents (METs) <4, phenylketonuria, age greater than 65 years, coronary artery disease, hypertension, pregnancy, chronic kidney disease, diabetes, seizure disorder, syncope and body mass index (BMI) > 30. Six participants were excluded from study given underlying medical problems, time commitment, or pregnancy. A total of 24 participants were studied, which included 14 males and 10 females. Initial demographics were obtained.

Alcohol (EtOH) use was defined as at least one drink a week, coffee consumption defined as one drink a day, and energy drink consumption as one drink a week. All eligible participants had a baseline ECG at initial evaluation to evaluate for any significant conduction abnormalities. This study was approved by the Institutional Review Board at St. John Providence Hospital.

Day 1 was for baseline measurements, and each participant had to abstain from caffeine for 24 h. Measurements and evaluation of brachial blood pressure and central pulse wave pressure with an AtCor (Sydney, Australia) device (non-invasive measurement of central pressure), ECG, and an exercise ECG stress test per Bruce protocol to achieve 85% target heart rate and 5-h Holter monitoring was performed after a 24-h caffeine-free period. On day 2, the same parameters were measured 2 h after consumption of the 5-hour ENERGY[®] drink. Each participant was his or her own control, and the data from the caffeine-free period were compared with the data after energy drink consumption.

Statistical analysis

A paired t-test was used to compare day 1 and day 2 measurements. Frequency tables for general demographics were obtained. A value of $P < 0.05$ was considered statistically significant.

Results

Regarding demographics, the mean age in study was 38.1 years, the mean weight 73.6 kg, and BMI 25 (Table 1). Two-thirds of participants slept less than 7 h at night, and 75% consumed at least one cup of coffee daily (Table 2). The majority (87%) consumed alcohol, and most participants did not routinely drink energy drinks.

The difference in METs and stage achieved on the Bruce protocol between Day 1 and Day 2 was not statistically significant (Table 4). None of the participants had to stop their exercise stress test early because of fatigue, and no critical symptoms were documented during exercise.

Table 1: Demographics.

N = 24	Mean	Range
Age (years)	38.1	25–65
Height (meters)	1.7	1.5–1.8
Weight (kg)	73.6	56–107 kg
BMI	25	21–29.9

Table 2: Hours of sleep and coffee intake.

Hours of sleep (n = 24)		Coffee (n = 24)	
<7	>7	No	Yes
16 (66%)	8 (3%)	6 (25%)	18 (75%)

Table 3: EtOH and energy drink use.

EtOH use (n = 24)		Number of energy drinks (n = 24)	
No	Yes	No	Yes
3 (12.5%)	21 (87.5%)	19 (79.2%)	5 (20.8)

There was a significant increase in central aortic systolic blood pressure after energy drink consumption from a mean of 101.3–108.7 mmHg ($p = 0.002$), and also an increase in central aortic diastolic pressure from a mean value of 72.4 mmHg to 74.8 mmHg ($p = 0.249$). There was a significant increase in brachial pressure after energy drink consumption from an average systolic blood pressure of 115 mmHg to 122.4 mmHg ($p = 0.007$) and diastolic pressure from an average of 86 mmHg to 90.5 mmHg ($p = 0.024$) (Figure 1).

There was widening of pulse pressure from pre-energy drink consumption to post-energy drink consumption in both central aortic and brachial pressure measurements. With central aortic pressure there was a significant increase from 28.6 mmHg to 33.8 mmHg ($p = 0.005$), and with brachial pressure there was an increase from 42.7 mmHg to 49.1 mmHg ($p = 0.016$) (Figure 2).

Average minimum and average maximum Holter heart rates were reviewed between Day 1 and Day 2 after caffeine consumption. The mean heart rates were similar before and after 5-hour ENERGY[®] drink consumption (Figure 4).

ECGs were reviewed pre- and post-energy drink consumption. There was no difference in the PR interval and QRS complex. The QT interval was prolonged from an average 411.5 ms to 434.1 ms ($p = 0.000$) (Table 5). There were no significant arrhythmias noted on the ECG stress test and on Holter monitor readings (Table 6).

Discussion

After consumption of 5-hour ENERGY[®] drinks, we found a statistically significant increase in central aortic systolic blood pressure, widening of pulse pressure, and an increase in brachial systolic and diastolic blood pressure. There was also prolongation of the QT interval, which was statistically significant ($p < 0.05$). No major arrhythmias were noted, and there were no significant changes in heart rate and no

Table 4: Exercise tolerance.

Exercise level achieved (n = 24)		
	Mean	$p \leq 0.05$
Day 1 METs	12.02	0.97
Day 2 METs	12.03	
Day 1 stage	3.6	0.257
Day 2 stage	3.8	

Systolic and Diastolic Blood Pressures Pre and Post Energy Drinks

Figure 1: Statistically significant increases in central aortic systolic, and brachial systolic and diastolic blood pressures after energy drink consumption when compared with the control group ($p \leq 0.05$).

Pulse Pressure Pre and Post 5 Hour Energy Drink

Figure 2: Widening of central aortic and brachial pulse pressure after energy drink consumption ($p \leq 0.05$).

Mean Arterial Pressure Pre and Post Energy Drink

Figure 3: Increase in central aortic mean arterial pressure post energy drink consumption ($p \leq 0.05$).

significant increase in frequency of premature atrial or ventricular contractions.

In a previous article, Kurtz et al.⁶ studied a small number of patients where they compared caffeinated energy shots with

non-caffeinated energy shots and found a significant increase in peripheral and central blood pressures.⁶ Franks et al.⁷ compared energy drinks versus caffeine supplementation on 24-h blood pressure monitoring. They found that energy

Sub study Analysis to Evaluate effect on Heart Rate

Figure 4: No significant increase in heart rate after energy drink consumption when compared with control.

Table 5: ECG changes before and after energy drink consumption. Significant prolongation in QTc interval.

Changes in ECG parameters		
	Mean (ms)	p ≤ 0.05
Day 1 PR interval	149.6	0.338
Day 2 PR interval	146.3	
Day 1 QRS	91.08	0.211
Day 2 QRS	87.8	
Day 1 QTc interval	411.5	0.000
Day 2 QTc interval	434.1	

Bold values signifies change in the QT interval with a significant p value.

drink supplementation increased the 24-h mean and daytime blood pressures compared with caffeine only.⁷ Another study by Steinke et al.² evaluated 15 healthy volunteers and looked at baseline ECG and vitals after consuming energy drinks for 5 days. That study did not find any changes in QTc interval, but they noticed an increase in heart rate by 5–7 bpm and an increase in systolic blood pressure of 10 mmHg.²

The two main ingredients of energy drinks are primarily caffeine and taurine. Caffeine is a non-selective antagonist of adenosine receptors with a half-life of 5 h. When blocked, it has profound effects on neurotransmitters (dopamine, acetylcholine, serotonin, and at higher doses norepinephrine). Caffeine dosages exceeding 500 mg inhibit gamma-aminobutyric acid neurotransmission and cause anxiety, insomnia, and rapid heart and respiratory rate. Taurine is a natural non-essential amino acid, and is found in high concentrations in the brain and mammalian heart. Taurine may have a role in memory enhancement but no studies have been conducted to date.⁸ However, it has been shown to increase and potentiate the effects of caffeine. There have also been some rat studies that have demonstrated positive and negative chronotropic effects on the right atrial muscle, depending on the calcium content.⁹

Energy drinks are popular across a wide demographic range and they do not require FDA approval. Multiple cardiac side effects have been reported in case studies and news media. We performed a survey among our hospital co-workers, peers, and colleagues and found that the 5-hour ENERGY[®] drink was the number 1 choice. Owing to the limited studies available on this beverage and the increase in popularity, we decided to examine the hemodynamic effects of 5-hour ENERGY[®] drinks.

Despite their popularity, we did not evaluate alcohol effects with energy drinks. There was one small study that compared energy drinks mixed with alcohol and evaluated hemodynamics after exercise. It found that subjects had a blunted decrease in heart rate after exercise but no significant arrhythmias.³

Table 6: No significant arrhythmias.

5-h Holter monitor recordings						
	Day 1 PVC	Day 2 PVC	Day 1 PAC	Day 2 PAC	Day 1 arrhythmia	Day 2 arrhythmia
Mean	6.13	2.5	1.5	3.75	0	0

PAC: premature atrial contraction, PVC: premature ventricular contraction.

This was a pilot study on relatively healthy individuals. We identified statistically significant cardiovascular outcomes such as elevated blood pressure, and prolongation of the QTc interval with no increase in exercise enhancement. Millions of people in today’s world are hypertensive, and energy drinks could contribute to their hypertension. Prolongation of QTc interval results in lengthening of the repolarization period and the potential for an ectopic beat to occur during a vulnerable period that may result in malignant arrhythmias. Ammar et al.¹⁰ evaluated the effects of moderate, single-dose caffeine consumption on ECG variables in healthy volunteers and found no acute increase in QTc interval when compared with baseline. This suggests that caffeine plus the extra ingredients in energy drinks such as taurine may contribute to QTc prolongation.

Multiple medications also prolong the QTc interval, including antiarrhythmic drugs, antihistamines, antibiotics, antidepressants, and antipsychotics. If these data were extrapolated and used to evaluate patients with uncontrolled hypertension, coronary artery disease, history of arrhythmias, or patients on medications that prolong QTc interval, there may be adverse outcomes. It is important to review a patient’s energy drink consumption because of potential of detrimental cardiac side effects.

Conclusion

This study further supports our theory that energy drink consumption may cause adverse cardiovascular outcomes. It is important to determine the type and quantity of energy drink being consumed by patients because of the synergistic effects with other medications and other cardiac side effects. Energy drink consumption may increase the risk of adverse cardiovascular events, particularly in individuals who are at risk of developing arrhythmias.

Limitations

This was a single-center study with a small sample size; most participants were healthy individuals with no active cardiac problems and did not routinely consume energy drinks. To our knowledge, there has not been a study that evaluated effects of energy drinks on patients with active cardiac problems on multiple medications.

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