

## EFFECTS OF ENERGY DRINK CONSUMPTION ON ELECTROCARDIOGRAPH AND PHOTO PLETHYSMOGRAPH

Md. Bashir Uddin<sup>a</sup>, Mohiuddin Ahmad<sup>a</sup>, Mohd Abdur Rashid<sup>b\*</sup>

<sup>a</sup>Khulna University of Engineering & Technology, Khulna-9203, Bangladesh

<sup>b</sup>FSTK, Universiti Sultan Zainal Abidin, 21300 Kuala Terengganu, Malaysia

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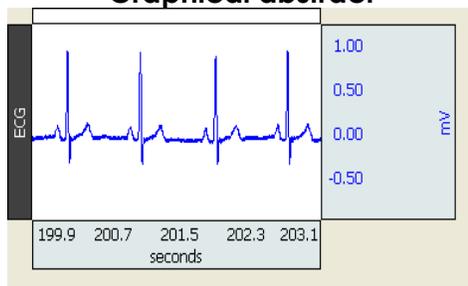
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\*Corresponding author  
marashid@uniswa.edu.my

### Graphical abstract



### Abstract

The effects of energy drinks (ED) consumption on electrocardiograph (ECG) and photo plethysmograph (PPG) of several healthy human subjects are evaluated in this study. ECG recordings were performed with electrode lead set connected to MP36 (Biopac, USA) data acquisition unit. PPG recordings were also performed with pulse transducer connected to same data acquisition unit. ECG and PPG recordings were performed before and after having ED available in Bangladesh. Recordings were done with some interval of time from the instant of having ED. After consuming ED, it is observed that the R peak amplitude of ECG which is a vital part of QRS complex increases to a significant value. The maximum increment in R peak amplitude of ECG is found about 4.8% due to having ED which may give a short-term little boost of energy. This increment in R peak amplitude of ECG effectively continues up to 90 to 95 minutes approximately from the instant of being energized. A significant decrement is observed in peak to peak amplitude of PPG and heart rate (HR) due to the consumption of ED which may lead cardiac abnormality as well. Though the consumption of ED gives a short-term energy boost, it may cause any kinds of long-term cardiac diseases.

**Keywords:** Energy Drinks (ED), Electrocardiograph (ECG), Photo Plethysmograph (PPG), Heart Rate (HR)

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## 1.0 INTRODUCTION

Energy drinks (ED) are a group of beverages used by consumers to provide an extra boost in energy, promote wakefulness, maintain alertness, and provide cognitive and mood enhancement [1]. Energy drinks mostly contain caffeine, taurine, l-carnitine, carbohydrates, glucuronolactone, vitamins, and other herbal supplements like ginseng and guarana among others [2]. Additives such as guarana, yerba mate, cocoa, and kola nut may increase the caffeine content of energy drinks unbeknownst to consumers [3], as manufacturers of these products are not required to include the

caffeine content of these herbal supplements in the nutritional information [4].

Electrocardiograph (ECG) is the electrical activity of the heart which is detected by using electrodes placed on skin. An ECG is used to measure the heart's electrical conductivity and also represents the polarization and depolarization of cardiac tissues that are used to investigate any damage to the heart [5]. The parameters by which heart activity can be explained are known as electrocardiographic parameters. R peak is the most important parameter to explain cardiac function. In biomedical engineering, the maximum amplitude in the R wave is usually called "R peak amplitude" or just "R peak"

[6]. QRS complex is most important among different waves, segments and interval because of the R peak. The value of R peak is very high compared to the others and can be used as a parameter to determine heart condition. Heart rate (HR) is the bits of heart per unit time (expressed in bits per minute) and HR calculation is done using RR interval of two successive R peak. A photo plethysmograph (PPG) is the tactile arterial palpation of the heartbeat. PPG is another parameter to evaluate cardiac activity.

An energy drink contains some form of legal stimulant and/or vitamins which are meant to give consumers a short term boost in energy [7]. The magical ingredients of these drinks have one thing in common: all of them contain a lot of caffeine. These could be considered the "active ingredients" [8]. Different brands of energy drinks contain caffeine ranging from 50 mg to 550 mg per can or bottle. Energy drinks have added caffeine and other ingredients that their manufacturers say increase stamina and boost performance. They're designed for students, athletes and anyone else who wants an extra energy kick. Caffeine is one of the most commonly consumed alkaloids worldwide in the form of coffee, tea, or soft drinks, and in high doses may cause abnormal stimulation of the nervous system [9], as well as adverse effects in the cardiovascular, hematologic, and gastrointestinal systems [10]. With energy drinks becoming a worldwide phenomenon, the short- and long-term effects of these beverages must be evaluated more closely in order to fully comprehend the psychological impact of these products. The market and degree of consumption of energy drinks is increasing every year, but only few have global knowledge of their ingredients and actual physiological and psychological effects [11].

Energy drinks are caffeinated beverages designed primarily to increase the consumer's physical endurance. A survey of energy drink consumption by young people revealed that 51% reported consuming at least one energy drink per month [12]. It should be noted that, although energy drinks have been sold worldwide for more than a decade, only a few published studies have examined their effects on health and well-being. Steinke and Lanfear investigated the effects of energy drink consumption on hemodynamic and electrocardiographic parameters in healthy young adults, and reported a significantly increased heart rate and blood pressure within 4 hours [13]-[14]. The effects of energy drink consumption on blood perfusion using Laser Doppler Flowmetry in healthy young adults were studied in [15]-[17], and reported a significantly increased blood flow parameters. The aim of the present study is to determine the effects of energy drinks consumption in electrocardiographic and photo plethysmographic parameters such as R peak amplitude of ECG, peak to peak amplitude of PPG and heart rate (HR). Alternately, the aim is to evaluate heart activity due to the consumption of a specified energy drinks.

## 2.0 MATERIALS AND METHODS

### 2.1 Subjects

Twelve healthy young male subjects between 19 and 27 years old were enrolled for this study. The subjects had not taken any medication during the week of the study. None of the subjects were smokers and they refrained from alcohol and caffeine containing drinks at least 6 hours prior to the study. After being informed of the study design, they gave their written consent. The study was approved by the local Ethics Committee. Each participant had an initial visit to the experimental laboratory for a physical and a medical history assessment. The Mean  $\pm$  Standard Deviation (SD) for age, weight, height and Body Mass Index (BMI) of twelve healthy young male subjects are given in Table 1.

**Table 1** Demographic Parameters Of The Participants

Parameters	Value (N = 12) <sup>a</sup>
Age (yr)	22.5 $\pm$ 2.81
Weight (kg)	64.92 $\pm$ 8.22
Height (cm)	171.45 $\pm$ 2.99
BMI (kg/m <sup>2</sup> )	22.12 $\pm$ 3.05

<sup>a</sup>Value = Mean $\pm$ SD

### 2.2 Experimental Setup

The study was performed in a quiet room with the temperature kept at 25°C (24-26). The subjects were resting in the supine position throughout the whole experimental period. Supine sleeping position was selected for data collection because it is the most common sleeping position that helps to being sleep. ECG recordings were performed with electrode lead set (SS2L) plugs into channel 1 of MP36 (Biopac, USA) data acquisition unit. Electrode lead set was attached to the electrodes (EL503) placed on the subject following the color code. For optimal electrode adhesion, the electrodes were placed on the subject's skin at least 5 minutes before the start of the calibration procedure. PPG recordings were performed with pulse transducer (SS4LA) plugs into channel 2 of MP36 (Biopac, USA) data acquisition unit as shown in Figure 1. Window of the pulse sensor was cleaned and wrapped the transducer snugly around the tip of subject's index finger on the right hand. Pulse transducer was positioned so that the sensor is on the bottom of subject's fingertip (the part without the fingernail). Electrode cables were positioned such that they were not pulling on the electrodes or the transducer.

### 2.3 Testing Procedure

Food intake was restricted to a light meal 2 hour prior to the test. The subject was relaxed in supine position. At least 5 minutes were allowed for acclimatization before the measurements were performed on the subject's body. Acclimatization is the process in which an individual organism adjusts to a gradual change in its environment (such as temperature, humidity, etc.). We selected 5 minutes for acclimatization because this duration is enough to adjust the gradual changes between body and environment. Royal Tiger Energy drinks of serving size of 270 ml/bottle which contains caffeine 54 mg/270 ml, sugar 41.5 gm/270 ml and other ingredients e.g. carbonated water, acidity regulators (E330, E331), vitamins, flavor (natural, nature identical & artificial), preservatives (E211) & colors (E102) were used in this experiment. Before having energy drinks, ECG and PPG recordings were performed with a time period about 10 minutes. After having energy drinks, ECG and PPG recordings were performed with a time period about 95 minutes. Continuous ECG and PPG recordings were not performed due to the time limitation of recording using Biopac Student Lab (BSL) software. Being energized, ECG and PPG recordings were performed discretely, i.e. with some interval of time. The whole procedure is shown in Figure 2.



Figure 2 ECG And PPG Recording Using Biopac Instrument

## 3.0 RESULTS

### 3.1 Recording of ECG

A typical recording of ECG for a subject at normal (before having ED) and energized (after having ED) condition are shown in Figure 3 and Figure 4 respectively. At normal condition, the maximum R peak amplitude of ECG, average R-R interval of ECG and heart rate (HR) are found about 0.952 mV, 879 ms and 68 BPM (beats per minute) respectively. After having ED, the maximum R peak amplitude of ECG, average R-R interval of ECG and HR are found about 1.056 mV, 937 ms and 64 BPM respectively. Heart rates are calculated from average R-R interval of ECG, as showed in (1). There is an increment in

maximum R peak amplitude of ECG, average R-R interval of ECG and decrement in HR due to consumption of ED.

$$HR(BPM) = \frac{60}{R\ to\ R\ Interval(\ sec )} \quad (1)$$

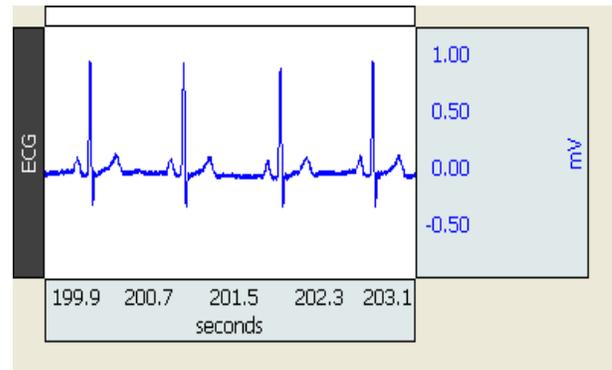


Figure 3 ECG Recording Before Having ED

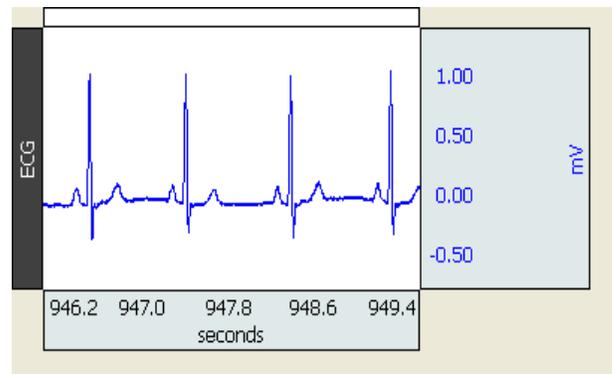


Figure 4 ECG Recording After Having ED

### 3.2 Recording of PPG

A typical recording of PPG for a subject at normal (before having ED) and energized (after having ED) condition are shown in Figure 5 and Figure 6 respectively. At normal condition, the maximum peak to peak amplitude of PPG is about 1.792 mV. After having ED, the maximum peak to peak amplitude of PPG is about 1.958 mV. There is an increment in maximum peak to peak amplitude of PPG for this subject only but an effective decrement in maximum peak to peak amplitude of PPG is found in our study for other subjects due to consumption of ED.

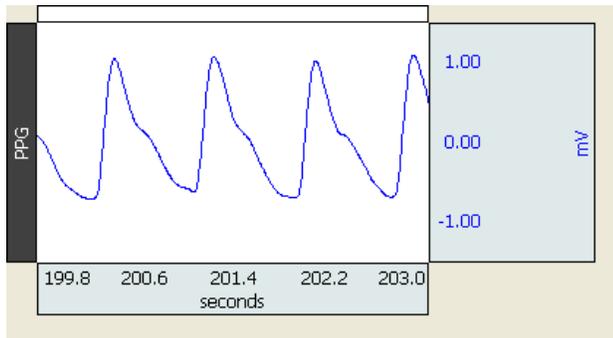


Figure 5 PPG Recording Before Having ED

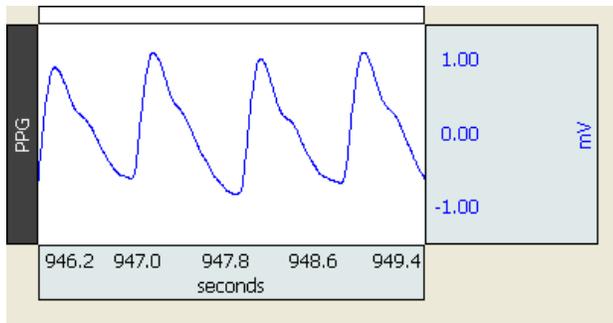


Figure 6 PPG Recording After Having ED

### 3.3 Statistical Analysis

Table 2 shows the average values of R peak amplitude of ECG, peak to peak amplitude of PPG and heart rate (HR) for twelve healthy young male adults with some interval of time. The readings at time 0 minute indicate the average values of electrocardiographic and photo plethysmographic parameters at normal condition. Average values of electrocardiographic and photo plethysmographic parameters at energized condition are shown in some interval of time (i.e. after 6, 9, 12, etc. minutes of having ED). Average data are shown here up to 95 minutes from the instant of having ED. It is observed that, R peak amplitude of ECG increases and this increment continues up to about 90 minutes from the instant of being energized and then shows a decremental tendency to reach in the normal condition. An effective decrement in peak to peak amplitude of PPG and HR is observed due to having ED.

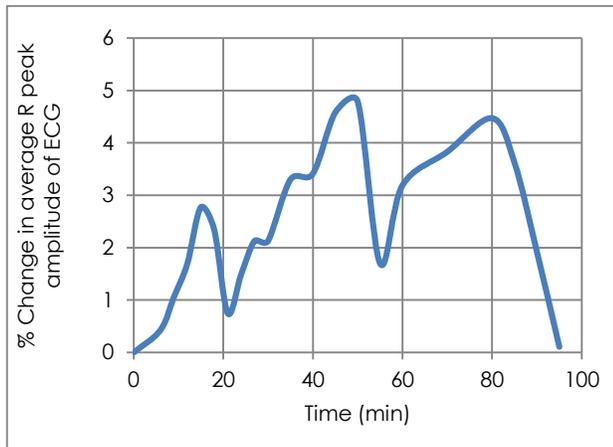
Table 2 Average Changes In ECG And PPG With Time

Time (min)	R Peak Amplitude of ECG (mV)	P-P Amplitude of PPG (mV)	HR (BPM)
00	0.939	2.31	72
06	0.943	2.33	73
09	0.949	2.14	71
12	0.955	2.29	71
15	0.965	2.44	70
18	0.961	2.28	69
21	0.946	2.46	70
24	0.953	2.19	70
27	0.959	2.23	69
30	0.959	2.33	70
35	0.970	2.46	69
40	0.971	2.18	70
45	0.982	2.11	69
50	0.984	2.30	69
55	0.970	1.94	69
60	0.969	2.07	69
70	0.975	2.09	67
80	0.981	2.10	67
85	0.973	2.14	67
90	0.957	2.06	67
95	0.940	1.89	68

### 3.4 Graphical Analysis

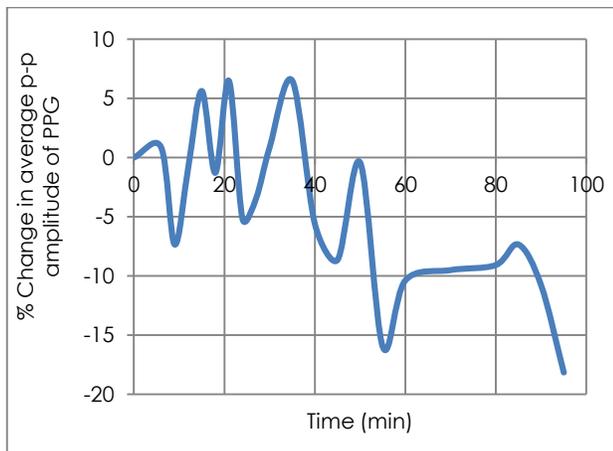
The percentage change in average R peak amplitude of ECG with time is shown in Figure 7, which is calculated using (2). The percentage change at time 0 minute is zero which indicates the normal condition. After having energized, the maximum increment in average R peak amplitude of ECG is about 4.8%. Graph shows that about 0 to 2.7% increment in 0 to 21 minutes duration, 0.7% to 4.8% increment in 21 to 55 minutes duration, 1.6% to 4.4% increment in 55 to 90 minutes duration occurs in average R peak amplitude of ECG approximately. After 90 minutes, increment in average R peak amplitude of ECG is below 2% and tries to go to become normal rapidly at about 95 minutes. The total effective increment (>1%) in average R peak amplitude of ECG lasts about 90 to 95 minutes.

$$\% \text{ Change} = \frac{\text{Value}_{\text{Energized}} - \text{Value}_{\text{Normal}}}{\text{Value}_{\text{Normal}}} \times 100 \quad (2)$$

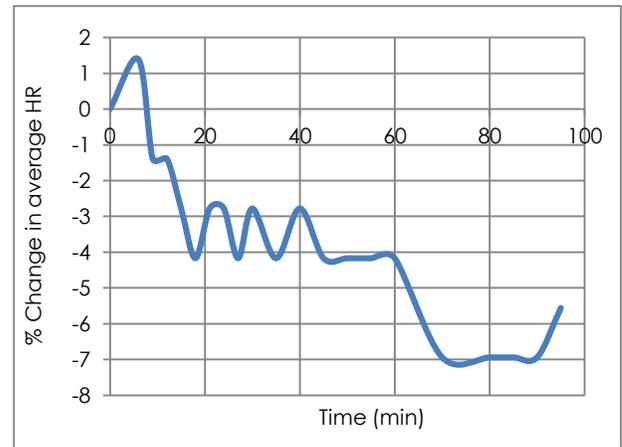


**Figure 7** Percentage Change In Average R Peak Amplitude Of ECG With Time

The percentage changes in peak to peak amplitude of PPG and HR with time are shown in Figure 8 and Figure 9 respectively, as calculated using (2). After having energized, the percentage change in peak to peak amplitude of PPG is irregular and holds average normal value up to about 40 minutes. After 40 minutes, there is a significant decrement in peak to peak amplitude of PPG due to ED consumption. An insufficient increment in HR (about 0 to 1.4%) lasts about 8 minutes and then decrement with a higher rate due to having ED. About 0 to 4.2% decrement in HR is found within 8 to 60 minutes interval. A higher decrement about 4% to 7.2% in HR is found within 60 to 90 minutes interval. Graph shows a negative impact on peak to peak amplitude of PPG and HR due to ED consumption.



**Figure 8** Percentage Change In Average P-P Amplitude Of PPG With Time



**Figure 9** Percentage Change In Average HR With Time

#### 4.0 DISCUSSIONS

The results of the present study demonstrate a significant increment and decrement in electrocardiographic and photo plethysmographic parameters. Due to the consumption of ED, the R peak amplitude which is one of the principle vital parameters of ECG increases to a significant value with respect to the normal condition. A corresponding effective decrement in peak to peak amplitude of PPG and HR is observed due to the consumption of energy drinks. Table 3 shows the percentage change in electrocardiographic and photo plethysmographic parameters such as the R peak amplitude of ECG, peak to peak amplitude of PPG and HR with respect to the normal condition.

*Effect on R peak amplitude of ECG:* Consumption of ED causes a significant increment in R peak amplitude of ECG. After being energized, the R peak amplitude of ECG increases about 0 to 4.8% with respect to the normal condition and this increment continues up to 90 minutes approximately. Increment in average R peak amplitude of ECG is below 2% and tries to go to become normal rapidly at about 95 minutes. The effectiveness of energy drinks consumption lasts about 90 minutes by analyzing the R peak amplitude of ECG. It may give a short-term little boost of energy to the consumer due to having ED.

*Effect on peak to peak amplitude of PPG:* An irregular change in peak to peak amplitude of PPG is found due to the consumption of ED and holds average normal value up to about 40 minutes from the instant of being energized. A significant decrement in peak to peak amplitude of PPG is found after 40 minutes and this decrement continues up to undefined time due to the consumption of ED. It demonstrates a negative impact on peak to peak amplitude of PPG due to having energy drinks.

*Effect on HR:* A significant increment and decrement in HR is found due to the consumption of ED. Initially about 0 to 1.4% increment in HR is found

within 5 minutes which is very insufficient and then decrement starts due to having ED. About 0 to 4.2% and 4% to 7.2% decrement in HR is found within 8 to 60 and 60 to 90 minutes interval respectively. It also demonstrates a negative effect on HR due to having ED.

## 5.0 CONCLUSIONS

Electrocardiograph as well as photo plethysmograph recordings and their analysis were performed using Biopac software at both before and after the consumption of energy drinks. By analyzing electrocardiographic and photo plethysmographic parameters, the R peak amplitude of ECG increased about 4.8% and it continued up to 90 to 95 minutes from the instant of being energized that may be liable to give a short-term energy boost to the consumer. Also a corresponding decrement (negative impact) was observed in peak to peak amplitude of PPG and HR which may cause any kinds of cardiac problems.

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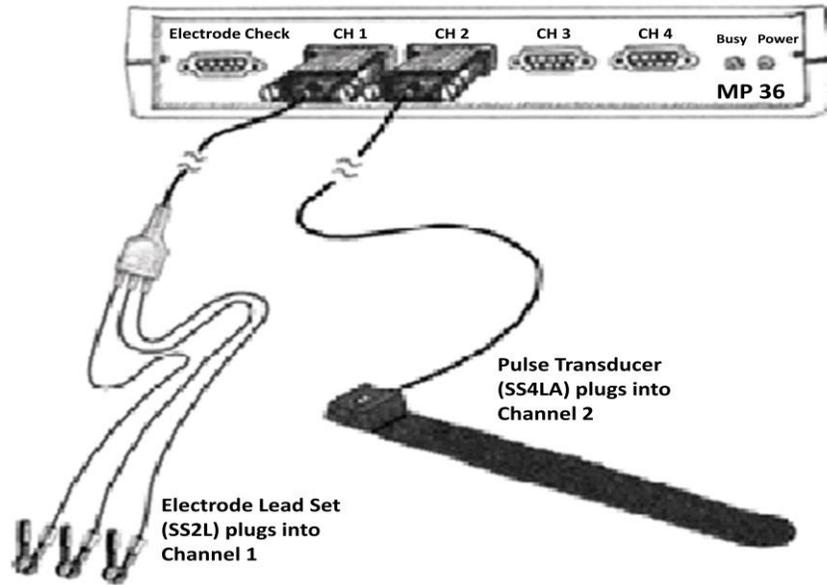


Figure 1 Experimental Setup For ECG And PPG Recordings [18]

Table 3 Percentage Changes In ECG And PPG With Time

Parameters	Percentage changes in ECG and PPG parameters with respect to normal condition						
	0-5 min	5-25 min	25-45 min	45-65 min	65-85 min	85-90 min	90-95 min
R peak amplitude of ECG	0 to 0.4	0.4 to 2.7	1.6 to 4.5	1.6 to 4.8	3.6 to 4.4	1.8 to 3.6	0.1 to 1.8
p-p amplitude of PPG	0 to 3.0	-7.5 to 6.5	-8.5 to 7.0	-16.5 to -0.2	-9.5 to -7.5	-11.0 to -7.5	-18.0 to -11.0
Heart Rate (HR)	0 to 1.4	-4.2 to 1.5	-4.2 to -2.8	-5.6 to -4.2	-7.2 to -5.6	-7.1 to -7.0	-7.0 to -5.5