

Research Article

Cardiac Function Evaluation Analyzing Spectral Components due to the Consumption of Energy Drinks

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Abstract: The aim of this study is to investigate the effect of energy drinks consumption on cardiac function of human being by analyzing the spectral components of pulse and ECG of several healthy people. Using pulse transducer connected with MP36 (Biopac, USA) data acquisition unit, pulse recordings were performed. With electrode lead set connected to the same MP36 data acquisition unit, ECG recordings were also performed. At before and after the consumption of energy drinks available in Bangladesh, pulse and ECG recordings as well as analysis were performed with Biopac software. After having energy drinks, the spectral components such as power of spectral density and amplitude of fast Fourier transform of pulse signal decreased about 47.5 and 37%, respectively. In case of ECG signal, the spectral components such as power of spectral density and amplitude of fast Fourier transform increased about 17 and 7.5% within a short interval about 0-20 min, then effective decrements about 10 and 18.5%, respectively started for long duration. Analyzing spectral parameters, the findings highlight the adverse impacts on cardiac function which may cause cardiac abnormality as well as severe cardiac disease due to the regular consumption of energy drinks.

Keywords: Biopac software, cardiac function, electrocardiogram, energy drinks, pulse, spectral components

INTRODUCTION

The electrical activity of the heart over a period of time can be represented by Electrocardiogram (ECG). Pulse is the tactile arterial palpation of the heartbeat. ECG and pulse can be used to determine the cardiac activity or function using the parameters such as R peak amplitude, QRS complex, R-R interval, p-p amplitude of pulse, pulse rate etc. The spectral component of ECG data has been used to estimate the cognitive states (Ahmad *et al.*, 2012). The spectral or frequency components of ECG and pulse can also be used to evaluate cardiac function. The spectral analysis of blood perfusion signal from human forearm skin has revealed five characteristic frequencies (Bracic and Stefanovska, 1998). In addition to the cardiac and respiratory rhythms around 1 and 0.3 Hz, respectively (Stefanovska and Kroselj, 1997), three frequencies have been detected in the regions around 0.1, 0.04 and 0.01 Hz in human skin (MuXck-Weymann *et al.*, 1996). Among these five frequency characteristics, heart or cardiac activity is detected within the frequency range about 0.6 to 1.6 Hz.

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 (Ishak *et al.*, 2012).

Energy drinks mostly contain caffeine, taurine, l-carnitine, carbohydrates, glucuronolactone, vitamins and other herbal supplements like ginseng and guarana among others (Bunker and McWilliams, 1979). Additives such as guarana, yerba mate, cocoa and kola nut may increase the caffeine content of energy drinks unbeknownst to consumers (Babu *et al.*, 2008), as manufacturers of these products are not required to include the caffeine content of these herbal supplements in the nutritional information (Seifert *et al.*, 2011). The “Magical” ingredients of these drinks have one thing in common: all of them contain a lot of caffeine (Islam *et al.*, 2012). These could be considered the “active ingredients” (Reissig *et al.*, 2009). 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 (Dworzariski *et al.*, 2009), as well as adverse effects in the cardiovascular, hematologic and gastrointestinal systems (Seifert *et al.*, 2011). Consumption of energy drinks has acute effects on intraocular pressure and blood pressure (Ilechie and Tetteh, 2011). 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 (Grosz and Szatmari, 2008).

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All companies that market these products usually target young adults. A survey of energy drink consumption by young people revealed that 51% reported consuming at least one energy drink per month (Malinauskas *et al.*, 2007). An investigation of the effects of energy drinks consumption on hemodynamic and electrocardiographic parameters in healthy young adults were done and reported a significantly increased heart rate and blood pressure within 4 h (Steinke and Lanfear, 2009). The effects of energy drinks consumption on blood perfusion in healthy young adults were studied using Laser Doppler Flowery (Islam *et al.*, 2012), as well as using Wavelet Transform (Rahman *et al.*, 2013). The effect of energy drinks consumption on cardiovascular system was not well studied and we hypothesized that the consumption of energy drinks changes micro vascular control mechanisms which would result in differences in the spectral components and their corresponding amplitudes. The aim of the present study is to determine the effects of energy drinks consumption on heart or cardiac activity by analyzing spectral or frequency components of cardiac activity related signal.

MATERIALS AND METHODS

Subjects preparation: This study was enrolled on the twelve healthy human subjects. All of them were young male and ages between 19 and 27. The subjects were totally free from smoking and drinking (having caffeinated or alcoholic drinks) at least 6 h prior to the study. During the week prior of the study, they had not taken any medicine. According to the approval of the local Ethics Committee the subjects were given their

Table 1: Demographic parameters of the study participants

Parameters	Value
Age (year)	22.50±2.81
Weight (kg)	64.92±8.22
Height (cm)	171.45±2.99
BMI (kg/m ²)	22.12±3.05

written consent. Table 1 shows the Mean±Standard Deviation (S.D.) for age, weight, height and Body Mass Index (BMI) of twelve healthy young male subjects.

Hardware setup: This experiment was performed in a quiet room maintaining the temperature at 25°C (24°-26°). The subjects were resting in the supine position throughout the whole experimental period. The setup procedure of hardware is shown in Fig. 1.

Pulse transducer (SS4LA) plugs into channel 2 of MP36 (Biopac, USA) data acquisition unit were used for pulse recordings. Window of the pulse sensor was cleaned and wrapped the transducer snugly around the tip of subject's index finger on the left hand. Pulse transducer was positioned such as the sensor was on the bottom of subject's fingertip (the part without the fingernail). Electrode lead set (SS2L) plugs into channel 1 of MP36 (Biopac, USA) data acquisition unit were used for ECG recordings. According to color code electrode lead set was attached to the electrodes (EL503) placed on the subject. The electrodes were placed on the subject's skin at least 5 min before the start of the calibration procedure because of optimal electrode adhesion. Electrode cables were positioned such a way that pulling on the electrodes or the transducer was not possible.



Fig. 1: Experimental setup for pulse and ECG recordings



Fig. 2: Utilization of biopac instruments for pulse and ECG recording

Data collection procedure: Subjects were restricted to take food at least 2 h prior to the test and relaxed in a supine position. Before the measurements were performed on the subject's body, at least 5 min was allowed for acclimatization. Royal Tiger Energy drinks were served for subjects that specifications were given as, 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 and artificial), preservatives (E211) and colors (E102). With a 10 min time duration, ECG and pulse were recorded before having energy drinks. For recording ECG and pulse after having energy drinks, time period about 1 h (60 min) were used. Due to the time limitation of recording using Biopac Student Lab (BSL) software, continuous ECG and pulse recordings were

not possible. Being energized, ECG and pulse recordings were performed discretely with some interval of time (i.e., at 6, 9, 12 etc., min from the instant of being energized). For physical medical history assessment every participant had an initial visit to the laboratory. The data recording procedure is shown in Fig. 2.

RESULTS

Recording of pulse signal: Pulse recording for a subject at forearm index finger tip is shown in Fig. 3 using pulse transducer connected to MP36 data acquisition unit and Acq Knowledge software. This recording is performed for both normal (before having energy drinks) and energized (after having energy drinks) condition. At normal condition, pulse recording is performed about 5 min. After having energy drinks, the same recording is performed discretely about 1 h (60 min) from the instant of being energized. Frequency or spectral components can be evaluated by analyzing these time varying pulse recordings.

Power spectral density of pulse signal: Analysis Power spectral density of pulse recording for a certain interval of time (about 30 sec) at both normal and

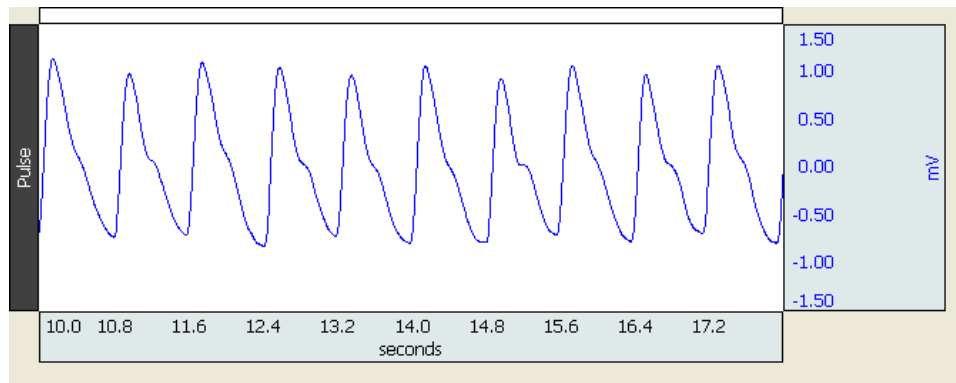


Fig. 3: Pulse recording using Biopac Student Lab (BSL) software

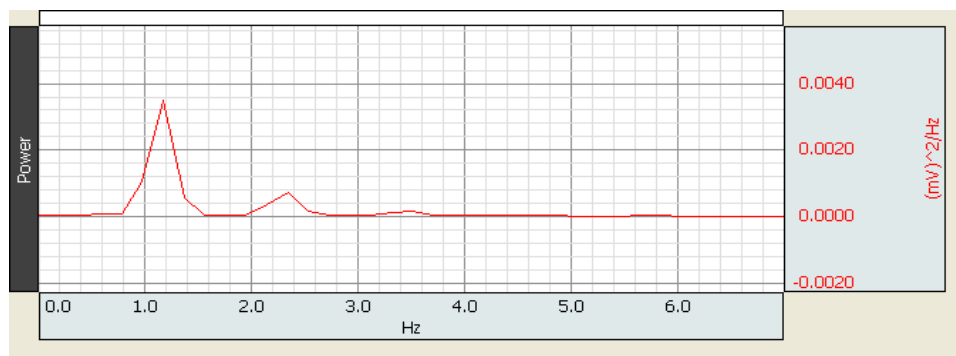


Fig. 4: Power spectral density of pulse signal before having ED

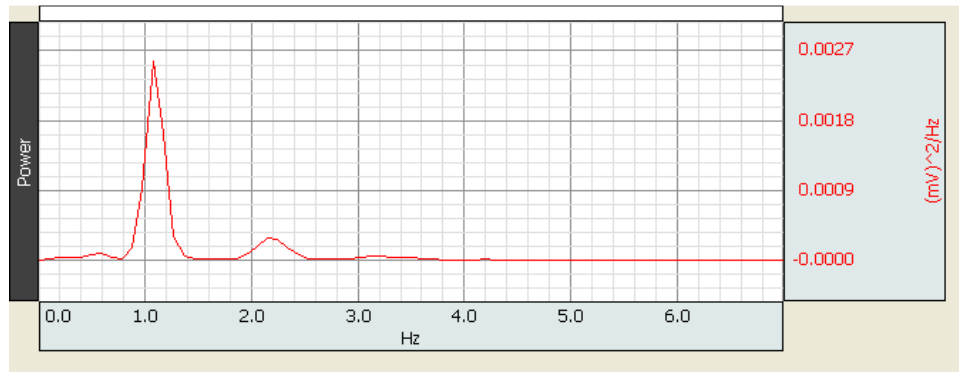


Fig. 5: Power spectral density of pulse signal after having ED

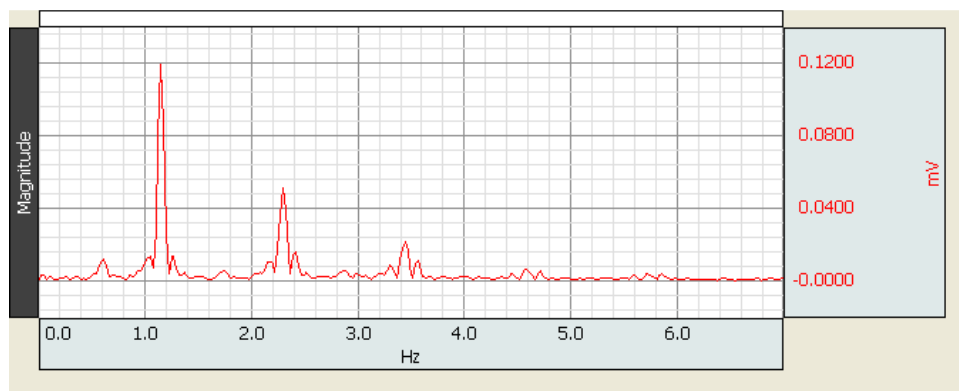


Fig. 6: Fast fourier transform of pulse signal before having ED

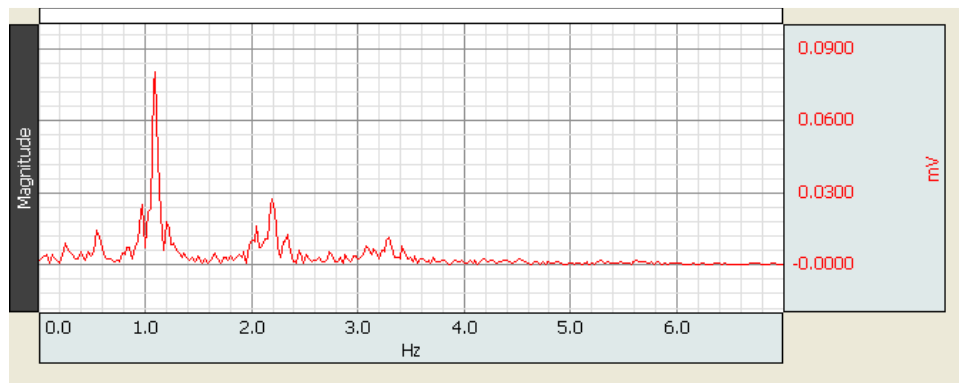


Fig. 7: Fast fourier transform of pulse signal after having ED

energized condition is shown in Fig. 4 and 5, respectively.

At normal condition, the maximum power of spectral density is found as $0.00346 \text{ (mV)}^2/\text{Hz}$ at 1.17 Hz. After being energized, the maximum power of spectral density is found as $0.00255 \text{ (mV)}^2/\text{Hz}$ at 1.07 Hz. We know that, the frequency range for heart activity is about 0.6 to 1.6 Hz. It is observed that, the power of spectral density which occurs within frequency range (cardiac activity) mentioned above decreases about 26% with respect to the normal condition.

Fast fourier transform of pulse signal: Fast Fourier transform of pulse recording for a certain interval of time (about 30 sec) at both normal and energized condition is shown in Fig. 6 and 7, respectively.

At normal condition, the maximum amplitude of Fast Fourier Transform (FFT) is found as 0.11879 mV at 1.15 Hz. After being energized, the maximum amplitude of fast Fourier transform is found as 0.08046 mV at 1.10 Hz. It is observed that, the amplitude of fast Fourier transform which occurs within frequency range of cardiac activity decreases about 32% with respect to the normal condition.

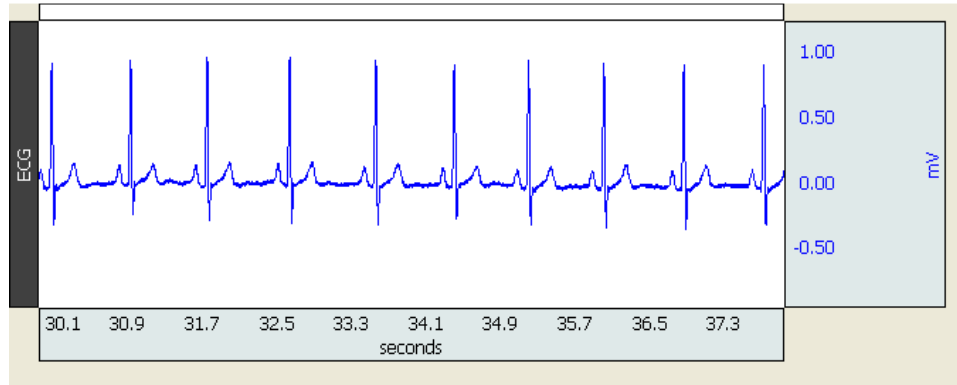


Fig. 8: ECG recording using Biopac Student Lab (BSL) software

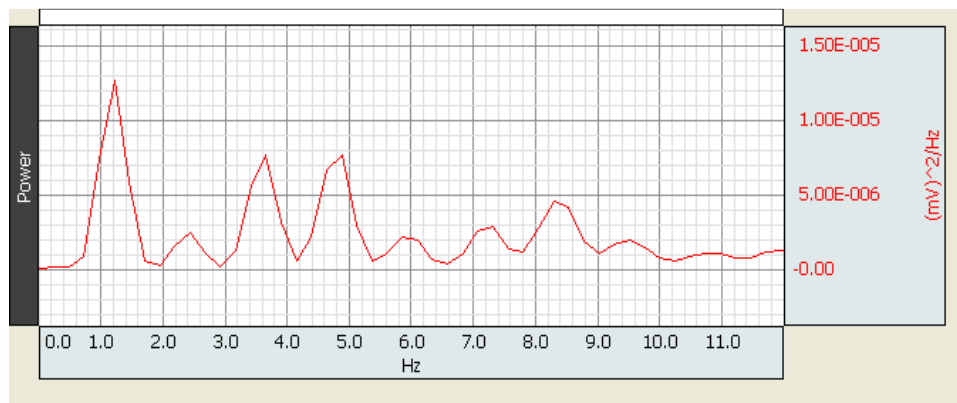


Fig. 9: Power spectral density of ECG signal before having ED

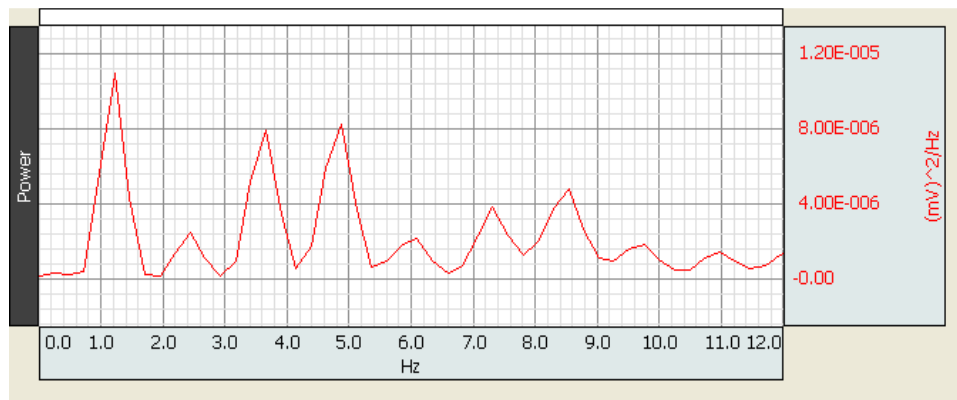


Fig. 10: Power spectral density of ECG signal after having ED

Recording of ECG signal: For exp ECG recording for a subject is shown in Fig. 8 using electrode lead set connected to MP36 data acquisition unit and Acq Knowledge software. This recording is performed for both normal (before having energy drinks) and energized (after having energy drinks) condition. At normal condition, ECG recording is performed about 5 min. After having energy drinks, the same recording is performed discretely about 1 h (60 min) from the instant of being energized. Frequency or spectral

components can be evaluated by analyzing these time varying ECG recordings.

Power spectral density of ECG signal: Power spectral density of ECG recording for a certain interval of time (about 30 sec) at both normal and energized condition is shown in Fig. 9 and 10, respectively.

At normal condition, the maximum power of spectral density is found as $1.26E-005 \text{ (mV)}^2/\text{Hz}$ at 1.22 Hz. After being energized, the maximum power of

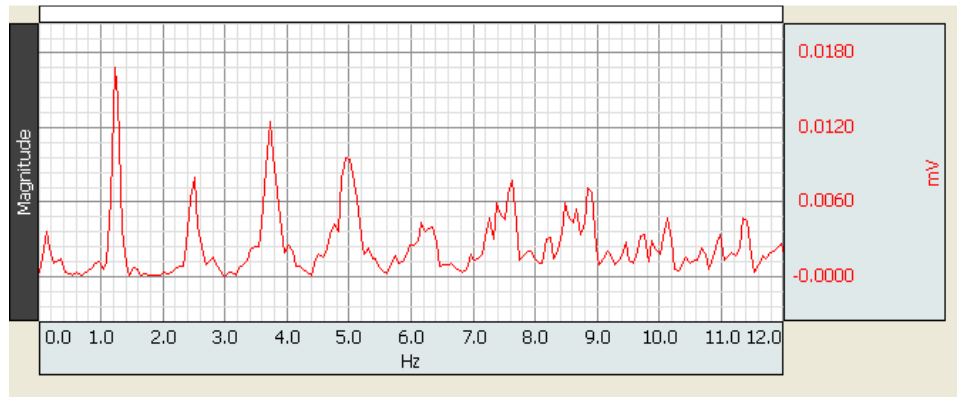


Fig. 11: Fast fourier transform of ECG signal before having ED

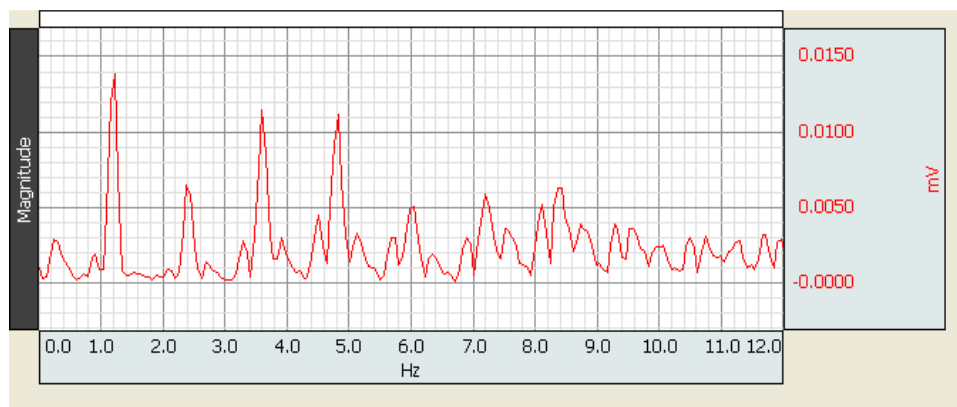


Fig. 12: Fast fourier transform of ECG signal after having ED

spectral density is found as $1.10E-005 \text{ (mV)}^2 / \text{Hz}$ at 1.22 Hz. It is observed that, the power of spectral density which occurs within frequency range of cardiac activity decreases about 13% with respect to the normal condition.

Fast fourier transform of ECG signal: Fast Fourier transform of ECG recording for a certain interval of time (about 30 sec) at both normal and energized condition is shown in Fig. 11 and 12, respectively.

At normal condition, the maximum amplitude of Fast Fourier Transform (FFT) is found as 0.01684 mV at 1.22 Hz. After being energized, the maximum amplitude of fast Fourier transform is found as 0.01377 mV at 1.22 Hz. It is observed that, the amplitude of fast Fourier transform which occurs within frequency range of cardiac activity decreases about 18% with respect to the normal condition.

Statistical analysis of spectral components: Table 2 shows the average values of spectral or frequency components occur within the frequency range of cardiac activity for twelve healthy male adults with some interval of time.

The readings at time 0 min indicate the average value of spectral or frequency components at normal

condition. Average values of spectral or frequency components at energized condition are shown in some interval of time (i.e., after 6, 9, 12, etc., min from the instant of being energized). Average data showed here upto 55 min from the instant of having energy drinks. It is observed that, the spectral or frequency components for pulse signal decreases with a significant rate from the instant of being energized. Though there is an insufficient increment in spectral or frequency components for a short interval about 15 to 20 min, the effective decrement in spectral components starts after that increment for ECG signal due to the consumption of energy drinks.

Graphical evaluation of spectral components: The percentage change in average power of spectral density and average amplitude of FFT for pulse signal is shown in Fig.13 and 14, respectively.

The percentage change at time 0 min is zero which indicates the normal condition. After having energized, the maximum decrement in average power of spectral density and average amplitude of FFT for pulse signal is about 47.5 and 37%, respectively with respect to the normal condition. Graph shows irregular rapid decrement in power of spectral density and amplitude of FFT upto the time about 40-45 min and then shows a

Table 2: Average change in spectral or frequency components with time

Time (min)	For pulse		For ECG	
	Power of spectral density ((mV) ² /Hz)	Magnitude of FFT (mV)	Power of spectral density ((mV) ² /Hz)	Magnitude of FFT (mV)
00	0.00799	0.15267	1.08E-05	0.01016
06	0.00772	0.12668	1.19E-05	0.01091
09	0.00726	0.12891	1.12E-05	0.01038
12	0.00744	0.11252	1.21E-05	0.01031
15	0.00784	0.15309	1.26E-05	0.01092
18	0.00762	0.12633	1.14E-05	0.00918
21	0.00666	0.14351	0.97E-05	0.00830
24	0.00652	0.12815	1.15E-05	0.00908
27	0.00613	0.12849	1.00E-05	0.00902
30	0.00646	0.11760	1.11E-05	0.01035
35	0.00681	0.13278	0.99E-05	0.01086
40	0.00429	0.11201	0.98E-05	0.00967
45	0.00495	0.09693	1.10E-05	0.00943
50	0.00477	0.12612	1.10E-05	0.00969
55	0.00540	0.10940	1.11E-05	0.00935

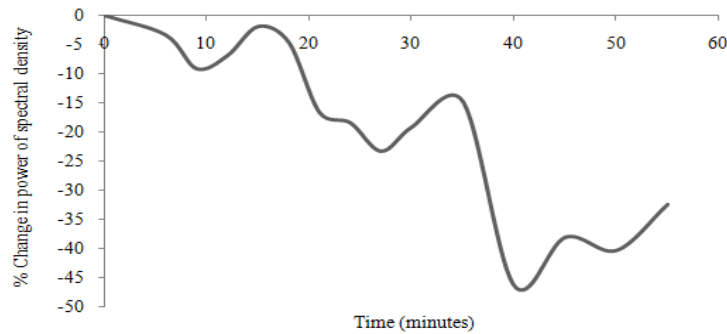


Fig. 13: Percentage change in power of spectral density with time for pulse

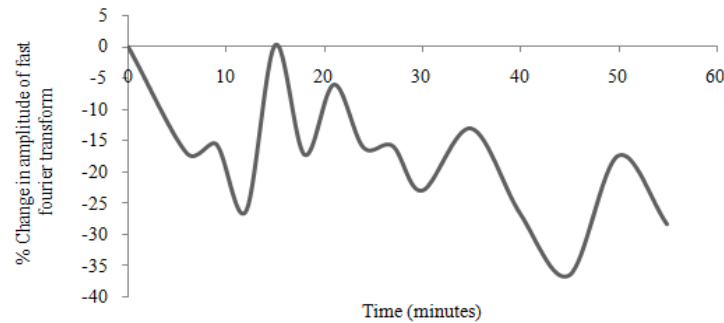


Fig. 14: Percentage change in amplitude of FFT with time for pulse

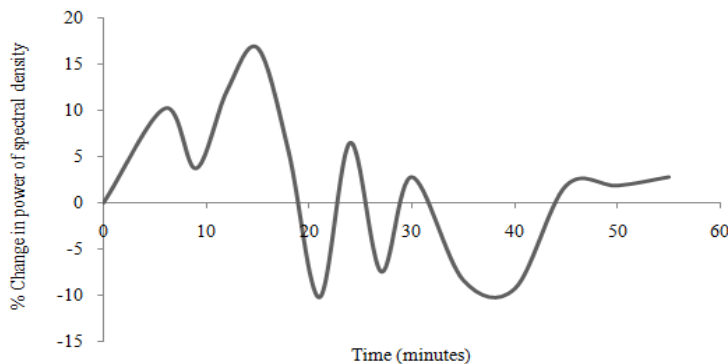


Fig. 15: Percentage change in power of spectral density with time for ECG

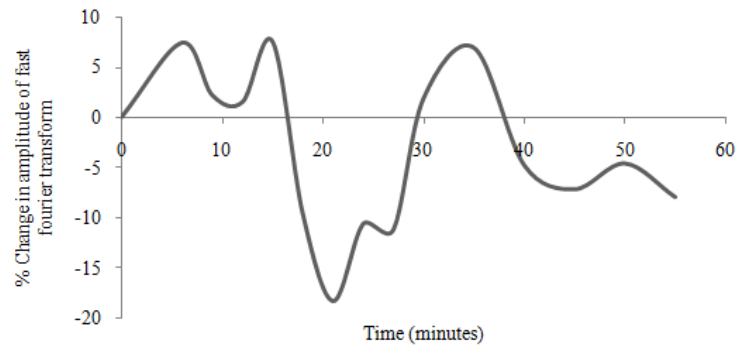


Fig. 16: Percentage change in amplitude of FFT with time for ECG

tendency to reach to the normal condition due to having energy drinks.

For ECG signal, the percentage change in average power of spectral density and average amplitude of FFT is shown in Fig. 15 and 16, respectively. The percentage change at time 0 min is zero which is the normal condition. After having energy drinks, the maximum increment in average power of spectral density and average amplitude of FFT for ECG signal is about 17 and 8%, respectively with respect to the normal condition. This increment continues up to about 15-20 min from the instant of being energized. The above short time increment in spectral components indicates a positive impact on cardiac activity due to the consumption of ED. After this short interval (about 0-20 min), the maximum decrement in average power of spectral density and average amplitude of FFT for ECG signal is about 10 and 18%, respectively with respect to the normal condition. Graph shows both irregular increment and decrement in power of spectral density and amplitude of FFT within the specified time period.

DISCUSSION

The results of this study demonstrate a notable decrement in spectral or frequency components which partially reflects the heart or cardiac activity due to the consumption of energy drinks. Table 3 shows the percentage change in spectral or frequency components with time for both pulse and ECG.

Effect on cardiac function analyzing spectral components of pulse signal: Energy drinks consumption cause a significant decrement in spectral or frequency components such as power of spectral density and amplitude of Fast Fourier Transform (FFT) with respect to the normal condition for pulse signal. The frequency range of cardiac activity is about 0.6-1.6 Hz. From spectral analysis of pulse signal, it is seen that the peak power of spectral density and peak amplitude of FFT occur within the frequency range of cardiac activity mentioned above. After being energized, the maximum decrement in power of spectral density is

about 47%. Statistics show that about 0-9% decrement in 0-10 min duration, 2-13% decrement in 10-20 min duration, 13-23% decrement in 20-30 min duration, 13-46.5% decrement in 30-40 min duration and 32-47.5% decrement in 40-55 min duration due to the consumption of energy drinks. After having energy drinks, the maximum decrement in amplitude of FFT is about 37%. It can be seen from statistics that about 0-19% decrement in 0-10 min duration, 0-27% decrement in 10-20 min duration, 6-23% decrement in 20-30 min duration, 13-27% decrement in 30-40 min duration and 17-37% decrement in 40-55 min duration due to the consumption of energy drinks. It is clear from the spectral components analysis of pulse that the consumption of energy drinks has negative impacts on cardiac activity due to the successive decrements in spectral parameters.

Effect on cardiac activity analyzing spectral components of ECG signal: Consumption of energy drinks causes a significant increment and decrement in spectral or frequency components such as power of spectral density and amplitude of Fast Fourier Transform (FFT) with respect to the normal condition for ECG signal. From spectral analysis of ECG signal, it is seen that the peak power of spectral density and peak amplitude of FFT occur within the frequency range of cardiac activity (0.6-1.6 Hz). After being energized, the maximum increment and decrement in power of spectral density is about 17 and 10%, respectively. From the instant of having energy drinks, the power of spectral density for ECG signal increases to a significant level and these increments continue up to about 19 min. The above short time increment in power of spectral density indicates a positive impact (short-term boost) on cardiac activity due to the consumption of ED. After this short interval (about 0-19 min), effective decrements in power of spectral density start. Statistics indicate that about 0 to 10% changes in 0 to 10 min duration, 17 to -7% changes in 10 to 20 min duration, 6.5 to -10% changes in 20 to 30 min duration, 3 to -10% changes in 30 to 40 min duration and 2.5 to -9% changes in 40 to 55 min

Table 3: Percentage change in spectral or frequency components with time with respect to the normal condition

Spectral parameters	Percentage (%) change in spectral or frequency components with time				
	0-10 min	10-20 min	20-30 min	30-40 min	40-55 min
Power of spectral density (for pulse)	0 to -9	-2 to -13	-13 to -23	-13 to -46.5	-32 to -47.5
Amplitude of FFT (for pulse)	0 to -19	0 to -27	-6 to -23	-13 to -27	-17 to -37
Power of spectral density (for ECG)	0 to 10	17 to -7	6.5 to -10	3 to -10	2.5 to -9
Amplitude of FFT (for ECG)	0 to 7.5	7.5 to -17	2 to -18.5	7.5 to -5	-5 to -8

duration due to the consumption of energy drinks. After taking energy drinks, the maximum increment and decrement in amplitude of FFT is about 7.5 and 18.5% respectively. From the instant of being energized, the amplitude of FFT for ECG signal increases to a notable level and these increments continue up to about 17 min. The above short time increment in amplitude of FFT indicates a positive impact (short-term boost) on cardiac activity due to the consumption of ED. After this short interval (about 0-17 min), effective decrements in amplitude of FFT start. Statistics shows that about 0 to 7.5% changes in 0 to 10 min duration, 7.5 to -17% changes in 10 to 20 min duration, 2 to -18.5% changes in 20 to 30 min duration, 7.5 to -5% changes in 30 to 40 min duration and -5 to -8% changes in 40 to 55 min duration due to the consumption of energy drinks. From spectral components analysis of ECG signal, it is also seen that, the consumption of energy drinks has both positive and negative impacts on heart activity due to the successive increments and decrements in spectral parameters, respectively. Though there is a short period of increments (energy boost period) in spectral components, the decremental period (negative impact) in spectral components is more and significant which reflects the adverse effects of having ED.

Thus analyzing spectral components of cardiac function related signals, the consumption of energy drinks shows adverse impacts on cardiac activity. The cardiac activity is found within a short range of frequencies as about 0.6-1.6 Hz. An effective reduction in spectral components of cardiac function related signal has observed in this study within the frequency range of cardiac activity. Though there have less significant increment in spectral components for short time duration, the reduction in spectral components for long time shows adverse impacts on cardiac activity. All the results in this study are based on those subjects who don't drink energy drinks regularly. So, the regular consumption of energy drinks may cause cardiac abnormality as well as severe cardiac disease.

CONCLUSION

The Cardiac function was evaluated in this study by analyzing the spectral components of pulse and ECG due to having energy drinks. There was less significant positive impact of having energy drinks on cardiac activity. The spectral analysis of pulse and ECG showed the severe adverse impact of energy drinks consumption on cardiac function. There were slight

disturbance in data collection due to the lack of some subject's awareness which were not so significant.

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