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Spectral Analysis of Biosignals to Evaluate Heart Activity due to the Consumption of Energy Drinks

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Abstract: *-* The heart activity is clearly evaluated in this study by analyzing spectral or frequency components of three Biosignals such as ECG, PPG and blood perfusion signal. This study is done with several healthy human subjects who are totally free from any type of cardiovascular diseases. ECG and PPG recordings were performed with electrode lead set and pulse transducer respectively connected to the same MP36 (Biopac, USA) data acquisition unit. LDF measurements were performed with skin surface probe connected to LDF100C module on middle finger tip. This LDF module was connected to MP150 (Biopac, USA) data acquisition unit. ECG, PPG and blood perfusion signal recordings were performed before and after having energy drinks available in Bangladesh. After consuming energy drinks, it is observed that the spectral or frequency components for ECG as well as PPG signal decreases with a significant rate from the instant of having ED. That is, the spectral parameters of heart activity decrease due to the consumption of energy drinks. The spectral analysis of LDF signal also results similar type of decrement in their spectral parameters for same type of energy drinks consumption. These results reflect adverse impacts of energy drinks consumption on heart activity.

Keywords: *- Biosignals, energy drinks, frequency spectrum, heart activity, spectral analysis.*

I. INTRODUCTION

Biosignals are defined as a summarizing term for all kinds of signals that can be measured and monitored from biological beings. The term Biosignal is often used to mean bio-electrical signal related to biological beings. Among the best-known bio-electrical signals or Biosignals are the Electroencephalogram (EEG), Electrocardiogram (ECG), Electromyogram (EMG), Electrooculogram (EOG), Photo Plethysmogram (PPG), Blood Perfusion Signal, Magnetoencephalogram (MEG), etc. Using differential amplifier EEG, ECG, EOG, PPG and EMG are measured that registers the difference between two electrodes attached to the skin. Blood Perfusion is measured with amplifier which uses Laser Doppler Flowmetry technique. This study is confined to three Biosignals- ECG, PPG and Blood Perfusion Signals.

Electrocardiography (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 conduction system [1]. Heart activity means the function of the heart which is examined applying different conditions over a period of time. A typical ECG consists of a P wave, a QRS complex, a T wave, and a U wave, which is normally invisible. A photo plethysmogram (PPG) is an optically obtained plethysmogram, a volumetric measurement of an organ. A PPG is often obtained by using a pulse oximeter/transducer which illuminates the skin and measures changes in light absorption [2]. With each cardiac cycle the heart pumps blood to the periphery. The change in volume caused by the pressure pulse is detected by illuminating the skin with the light from a light-emitting diode (LED) and then measuring the amount of light either transmitted or reflected to a photodiode. In biomedical engineering, spectral analysis of ECG and PPG is essential to evaluate heart activity.

Laser Doppler Flowmetry (or simply "LDF") is an established and reliable method for the measurement of blood perfusion in microvascular research. Periodic oscillations in the microvasculature are detected by the noninvasive technique of LDF. The spectral analysis of the signal (ECG, PPG and blood perfusion) from human skin has revealed five characteristic frequencies [3]-[4]. In addition to the cardiac and

respiratory rhythms around 1 and 0.3 Hz, respectively [4]-[5], three frequencies have been detected in the regions around 0.1, 0.04, and 0.01 Hz in human skin [3]-[5]. It is suggested that periodic oscillations with a frequency of around 0.1 Hz (a-waves) reflect intrinsic smooth muscle (myogenic) activity of blood vessels [6], whereas the frequency around 0.04 Hz (b-waves) represents neurogenic stimulation of resistance vessels [7]. Golenhofen suggested that oscillations of around 0.01 Hz (minute-rhythm) resulted from changes in metabolism of the perfused tissue [8]. The different spectral components are thought to modulate vascular smooth muscle cell activity. This results in a specific level of vascular tone, which in combination with the rheological properties and the active dilator activity, determines vascular resistance.

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 [9]. These beverages have stimulant effects on the central nervous system (CNS) and their consumption is accompanied by an expectation of improving user's performance physically and mentally [10]. "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" [11]. Energy drinks have added caffeine and other ingredients that their manufacturers say increase stamina and "boost" performance. 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 [12], as well as adverse effects in the cardiovascular, hematologic, and gastrointestinal systems [13]. 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 [14]. 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 [15]-[17]. All the above studies are related with physical performance analysis but a very few studies on heart activity due to the consumption of energy drinks. The aim of the present study is to evaluate heart activity due to having energy drinks by analyzing spectral components of different Biosignals which are related to heart function. We hypothesized that having energy drinks changes microvascular control mechanisms of the skin which would result in differences in the spectral components.

II. MATERIALS AND METHODS

2.1 Subjects specification

Ten healthy young Subjects between 19 and 27 years old were enrolled for this study. The Subjects had not taken any medication during the week prior to the study. None of the Subjects were smokers and they refrained from alcohol and caffeine containing drinks and performed heavy exercise at least 6 hours prior to the study. The Subject had not any disorder, hypertension, heart surgery, stroke, or any history of cardiovascular degeneration. 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 examination and a medical history assessment. Details about the Subjects are listed in Table I.

Table I: Demographic Characteristics of Study Participants

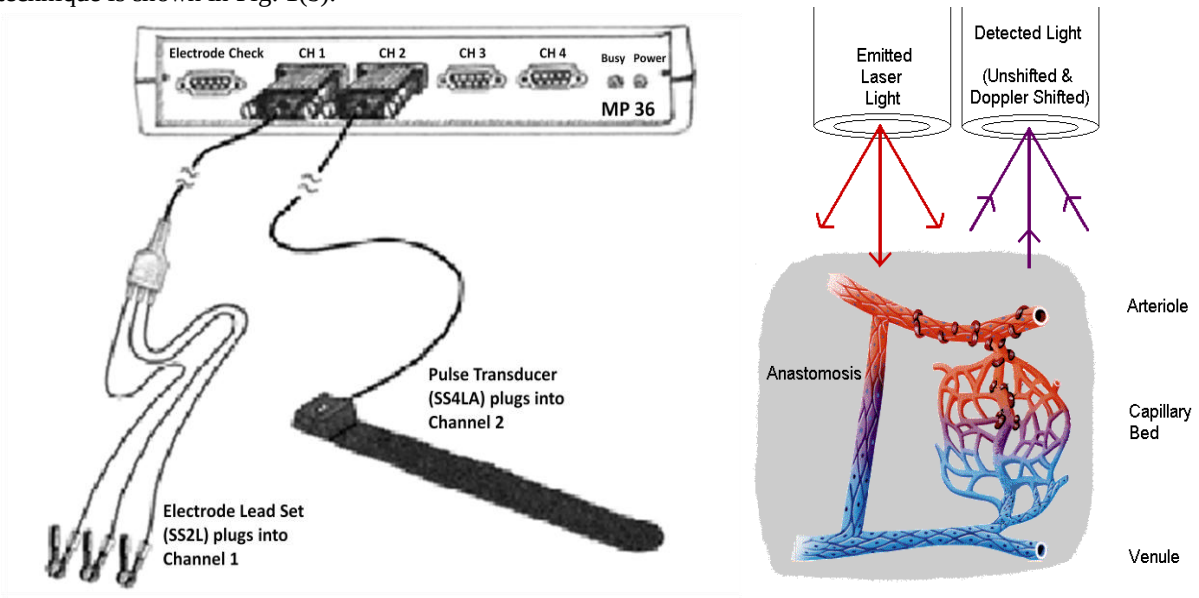
Parameters	***Value (N=10)***[a]
Age (yrs)	22.6 ± 3.04
Weight (kgs)	66 ± 7.92
Height (cms)	171.70 ± 2.99
BMI (kg/m^2)	22.44 ± 3.11

[a]Values are Mean ± Standard Deviation

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. ECG, PPG measurements were performed with electrode lead set (plugs into channel 1), pulse transducer (plugs into channel 2) respectively connected to the same MP36 (Biopac, USA) data acquisition unit as shown in Fig. 1(a). LDF measurements were performed with skin surface probe connected to LDF100C module on middle finger tip. This LDF module was connected to MP150 (Biopac, USA) data acquisition unit. The LDF100C Laser Doppler microvascular perfusion module works by illuminating tissue with low power laser light using a probe (TSD140 series) containing optical fiber light guides. Laser light from one fiber is scattered within the tissue and some is scattered back to the probe. Another optical fiber collects the backscattered light from the tissue and returns it to the module. The light is scattered by the static tissue structures and moving blood cells; the moving blood cells impart a Doppler Shift; an adjacent fiber detects light returned from the tissue; this light contains Doppler

shifted and unshifted light. Most of the light is scattered by tissue that is not moving but a small percentage of returned light is scattered by moving red blood cells. The light returned to the module undergoes signal processing to extract the signal related to the moving red blood cells. The principle of laser Doppler flowmetry technique is shown in Fig. 1(b).



(a) (b)

Figure 1: (a) Setup for ECG and PPG recording, (b) Principle of Laser Doppler Flowmetry [18]

2.3 Spectral Analysis

Spectral analysis is referred to as frequency domain analysis or spectral density estimation, is the technical process of decomposing a complex signal into simpler parts. Many physical processes are best described as a sum of many individual frequency components. Any process that quantifies the various amounts (e.g. amplitudes, powers, intensities, or phases), versus frequency can be called spectral analysis as shown in Fig. 2. The Fourier transform of a function produces a frequency spectrum which contains all of the information about the original signal, but in a different form. A common technique in signal processing is to consider the squared amplitude, or power; in this case the resulting plot is referred to as a power spectrum. A fast Fourier transform (FFT) is an algorithm to compute the discrete Fourier transform (DFT) and it's inverse. A Fourier transform converts time (or space) to frequency and vice versa; an FFT rapidly computes such transformations. As a result, fast Fourier transforms are widely used for many applications in engineering, science, and mathematics. Fast Fourier transforms have been described as "the most important numerical algorithm of our lifetime" [19].

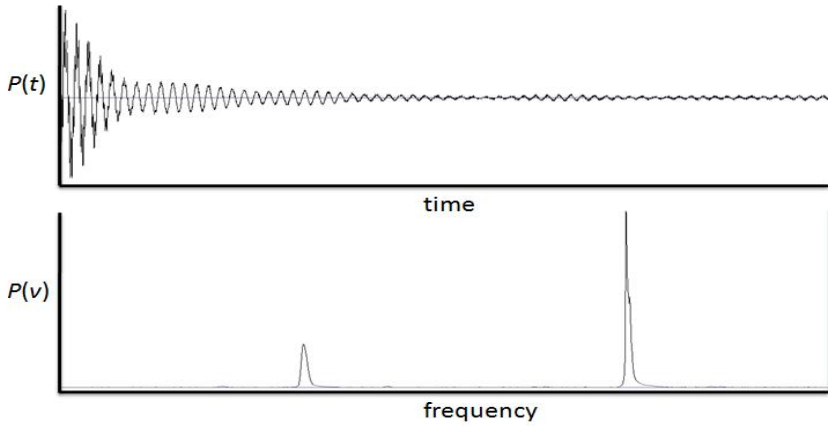


Figure 2: Frequency and time domain for the same signal [20]

The Power Spectral Density (PSD) describes how the power of a signal or time series is distributed over the different frequencies, as shown if Fig. 2. Here, power can be the actual physical power, or more often, for convenience with abstract signals, can be defined as the squared value of the signal. The total power *P* of a signal *x(t)* is the following time average:

$$P = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} x(t)^2 \, dt$$

The power spectral density can be defined as [21]-[22]:

$$S_{xx}(\omega) = \lim_{T\to\infty} \mathrm{E}[|x_T(w)|^2]$$

Here E denotes the expected value and $x_T(w)$ is a truncated Fourier transform, where the signal is integrated only over a finite interval [0, T]:

$$x_T(\omega) = \frac{1}{\sqrt{T}} \int_{0}^{T} x(t) e^{-j\omega t} \, dt$$

Spectral analysis of Biosignals collected from skin is performed by means of Biopac AcqKnowledge software in this study. The frequency spectrum of Biosignals is analyzed by Fast Fourier transform (FFT) and Power Spectral Density (PSD). For obtaining better spectral resolution in FFT and PSD we have used hamming window function. Following recent studies [3]-[4], the frequency interval studied (from 0.009 to 1.6 Hz) was divided into five subintervals as shown in Table II.

Table II: Frequency Interval of Biosignals Collected from Skin

Origin of Oscillation (Activities)	*Frequency Range (Hz)*
Metabolic	0.0095-0.02
Sympathetic	0.02-0.06
Myogenic	0.06-0.20
Respiratory	0.20-0.60
Heart/Cardiac	0.60-1.60

III. RESULTS AND DISCUSSIONS

3.1 Measurements of Biosignals

A typical recording of ECG and PPG for a subject are shown in Fig. 3 and Fig. 4 respectively. These recordings are performed at both normal (before having energy drinks) and energized (after having energy drinks) condition to evaluate heart activity due to the consumption of energy drinks by analyzing spectral components of different Biosignals. To compare the results of ECG and PPG analysis 2 subjects from above 10 subjects have been selected and their LDF signal is recorded before and after having ED. Applying same conditions LDF recordings have been done as before. At least 10 min were allowed for acclimatization before the LDF measurements were performed on the skin of middle finger tip. Skin blood perfusion was measured immediately before and after 30 minutes of having energy drinks. Blood perfusion recording for a typical subject at before and after having energy drinks are shown in Fig. 5 and Fig. 6 respectively. From LDF or Blood perfusion recording it is seen that, due to having ED the maximum, minimum and average flows are increasing but the peak to peak flow decrement is more significant.

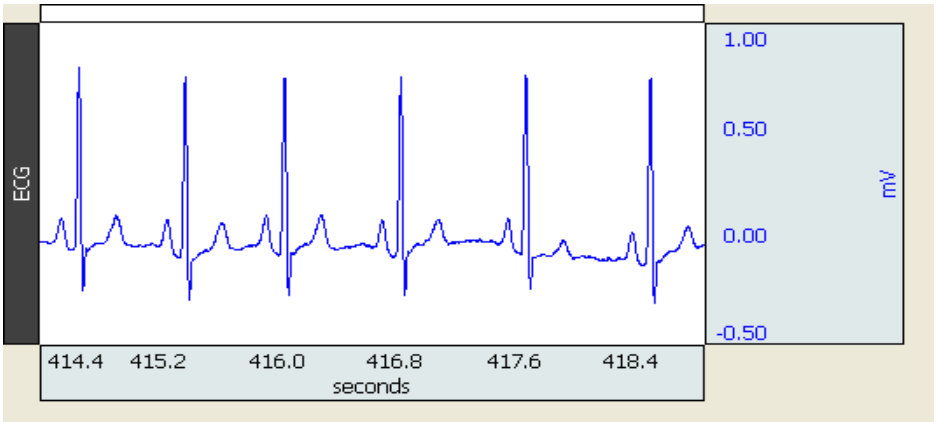


Figure 3: Recording of Electrocardiogram (ECG)

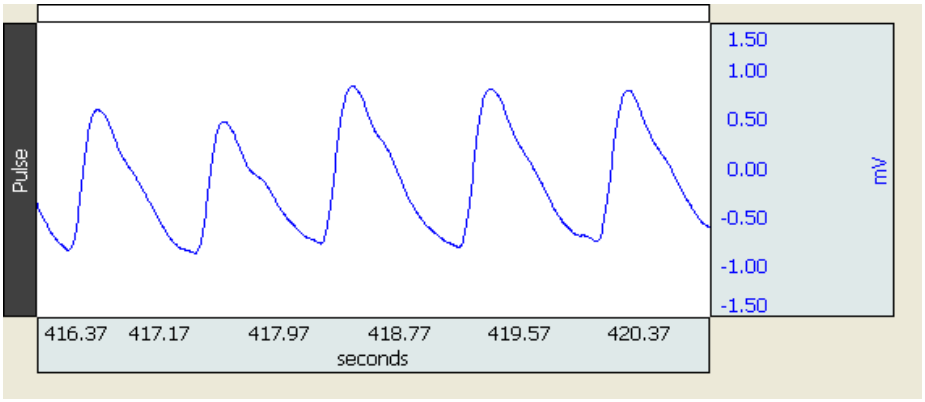


Figure 4: Recording of Photo Plethysmogram (PPG)

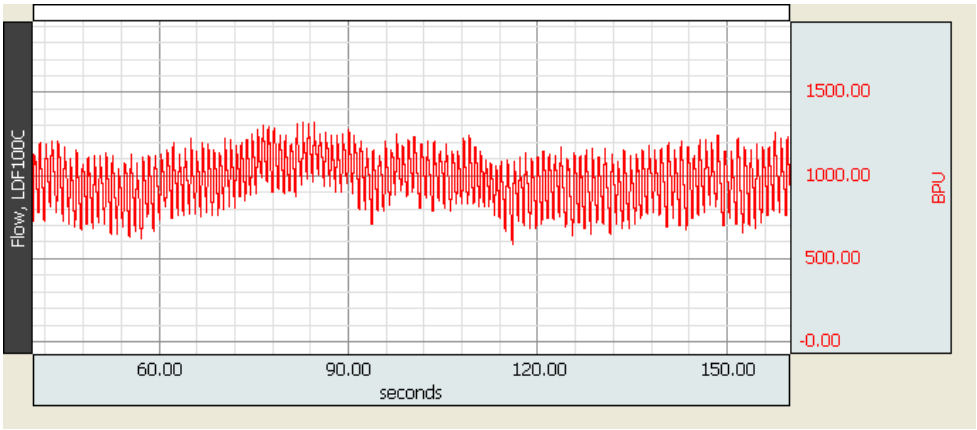


Figure 5: Recording of Blood Perfusion Signal before having ED

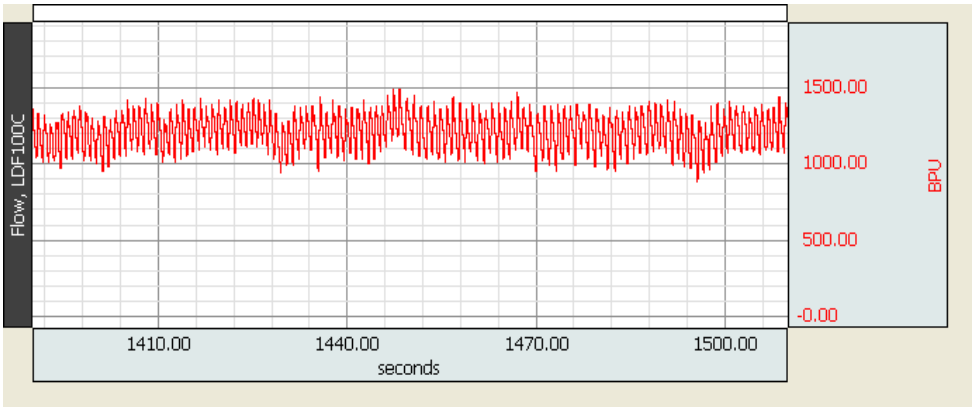


Figure 6: Recording of Blood Perfusion Signal after having ED

3.2 Spectral Analysis of Biosignals

In this study, spectral analysis of blood perfusion signal is shown only and the results are compared with spectral analysis of ECG and PPG because spectral analysis of ECG and PPG are already done in previous works. FFT analysis of blood perfusion signal before and after having ED for a typical subject is shown in Fig. 7 and Fig. 8 respectively. Before having ED the peak magnitude of FFT within cardiac activity is 17.37 BPU, occurs at 1.04 Hz. After having ED the peak magnitude of FFT within cardiac activity is 13.52 BPU, occurs at 0.96 Hz. PSD analysis of blood perfusion signal before and after having ED for a typical subject is shown in Fig. 9 and Fig. 10 respectively. Before having ED the peak power of PSD is 111.8 $(BPU)^2$/Hz occurs at 1.04 Hz which is also within cardiac frequency range. After having ED the peak power of PSD is 67.77 $(BPU)^2$/Hz occurs at 0.98 Hz which is also within cardiac frequency range. It is seen that, due to having ED the amplitude of FFT and the peak power of PSD within cardiac activity is decreasing. The reason behind this decrement may be the decrement in peak to peak flow of LDF signal.

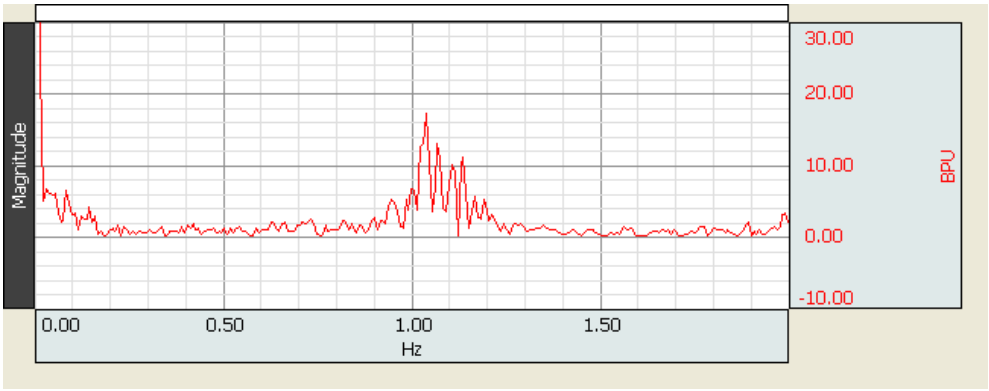


Figure 7: Fast Fourier Transform of Blood Perfusion Signal before having ED

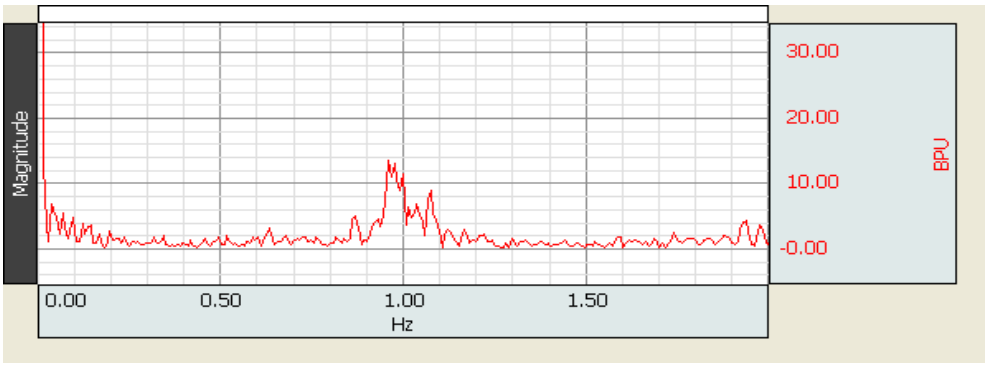


Figure 8: Fast Fourier Transform of Blood Perfusion Signal after having ED

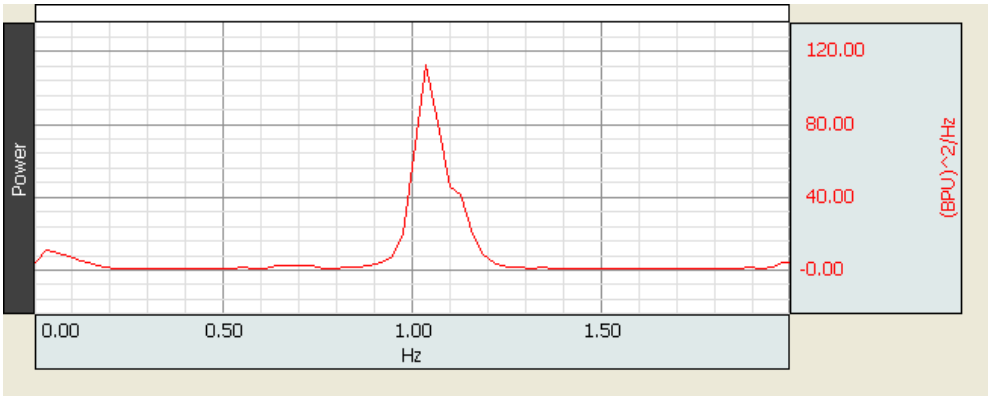


Figure 9: Power Spectral Density of Blood Perfusion Signal before having ED

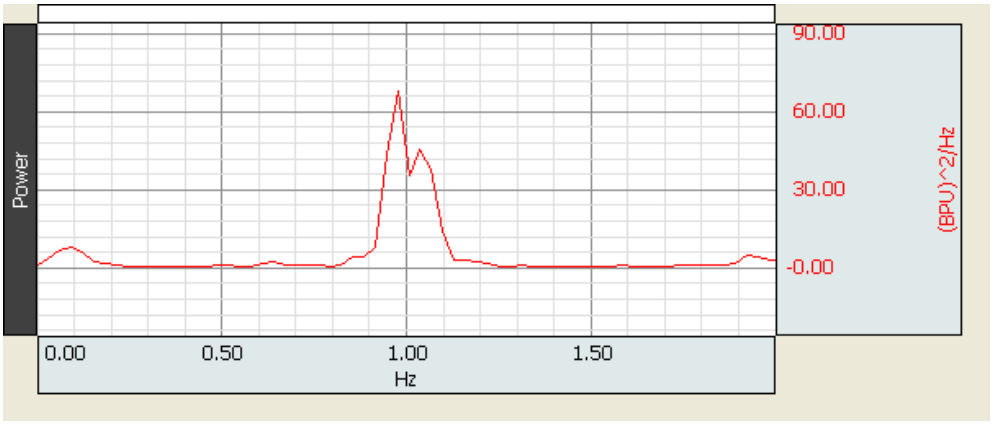


Figure 10: Power Spectral Density of Blood Perfusion Signal after having ED

3.3 Heart Activity Evaluation

The changes in average spectral components of blood perfusion signal due to having ED are listed in Table III. It is seen that for both FFT and PSD, frequency parameters of blood perfusion signal decreases within frequency range of heart activity due to having ED. The frequency spectrum related results of ECG and PPG signals have been compared with the frequency spectrum related results of blood perfusion signal which is shown in Table IV. Frequency spectrum analysis of blood perfusion signal shows that about 34% decrement in FFT and PSD parameters due to the consumption of ED. In previous chapter we have got about 40% decrement in FFT and PSD parameters for PPG signal and about 15% decrement in FFT and PSD parameters for ECG signal. For ECG, PPG and blood perfusion signal, the net change is negative which is also identical (approximately) in some cases. The blood perfusion signal analysis also shows similar results as in case of ECG and PPG signal analysis. Since the nature of signals is different, it is impossible to get 100% identical results.

Table III: Average Changes in Spectral Components of Blood Perfusion Signal

Type of Spectral Analysis	*Frequency band*	*Before having ED*		*After having ED*	
		Peak occurs at (Hz)	*Peak magnitude (BPU) or Power ((BPU)^2/Hz)*	*Peak occurs at (Hz)*	*Peak magnitude (BPU) or Power ((BPU)^2/Hz)*
FFT	Heart (0.6-1.6 Hz)	1.06	17.95	1.02	11.81
PSD		1.06	97.6	1.00	63.79

Table IV: Comparison of Spectral Components of Different Biosignals

Signal type	*Type of Spectral Analysis*	*Frequency band*	*Peak magnitude (BPU) or Power ((BPU)^2/Hz) before having ED*	*Peak magnitude (BPU) or Power ((BPU)^2/Hz) after having ED*	*% Change due to having ED*
ECG	FFT	Heart (0.6-1.6 Hz)	0.01016	0.00830	- 18.30%
	PSD		1.08E-05	0.97E-05	- 10.19%
PPG	FFT		0.15267	0.09693	- 36.51%
	PSD		0.00799	0.00429	- 46.31%
LDF	FFT		17.95	11.81	- 34.21%
	PSD		97.60	63.79	- 34.64%

The heart activities are clearly evaluated due to the consumption of ED analyzing spectral components of different Biosignals. Consumption of ED affects heart activity that is determined in this study using ECG, PPG and blood perfusion signal. The spectrum or frequency components for PPG signal decreases with a significant rate from the instant of being energized. Also a net decrement in spectrum components is noticed for ECG signal due to the consumption of ED. By analyzing spectrum components of blood perfusion signal, approximately same results are found as in case of ECG and PPG. Thus the results of this study are verified with the analysis of spectral components of blood perfusion signal.

IV. CONCLUSION

In this work, ECG, PPG and blood perfusion signal acquisition were performed using Biopac equipments in before and after the consumption of energy drinks. By analyzing spectral components of Biosignals (ECG, PPG and blood perfusion) it is clear that the consumption of ED affects Biosignals which in turns reduces the spectral components. The result of this study reflects negative impacts on heart activity that are not in favor to the human being. It is the time to be concern about the negative aspects of energy drinks consumption.

V. ACKNOWLEDGEMENTS

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REFERENCES

[1] D. K. Bempong, P. J. Houghton, and K. Steadman, The xanthine content of guarana and its preparations, *Int. J. Pharmacog.*, 31(3), 1993, 175-181.

[2] K. Shelley and S. Shelley, *Pulse Oximeter Waveform: Photoelecrtic Plethysmography*, Clinical Monitoring, 2001, 420-428.

[3] M. Bracic and A. Stefanovska, Wavelet based analysis of human blood flow dynamics, *Bulletin of Mathematical Biology*, 60, 1998, 417-433.

[4] A. Stefanovska and P. Kroselj, Correlation integral and frequency analysis of cardiovascular function, *Open systems & information dynamics*, 4, 1997, 457-478.

[5] M. E. MuXck-Weymann, H. P. Albrecht, D. Hager, D. Hiller, O. P. Hornstein, and R. D. Bauer, Respiratory-dependent laser Doppler flux motion in different skin areas and its meaning to autonomic nervous control of the vassel of the skin, *Microvascular Res.*, 52, 1996, 69-78.

[6] E. G. Salerud, T. Tenland, G. E. Nilsson, and P. A. OXberg, Rhythmical variations in human skin blood flow, *Int. J. Microcirc. Clin. Exp.*, 2, 1983, 91-102.

[7] J. Kastrup, J. BuXhlow, and N. A. Lassen, Vasomotion in human skin before and after local heating recorded with laser Doppler flowmetry. A method for induction of vasomotion, *Int. J. Microcirc. Clin. Exp.*, 8, 1989, 205-215.

[8] K. Golenhofen, Slow rhythms in smooth muscle. In 'Smooth Muscle', Edward Arnold Ltd., London, 1970, 316-342.

[9] K. A. Dolan, The Soda with Buzz, *Forbes*, 2005.

[10] Frucor – Our brands – V. Available at: www.frucor.com. au/index.php/our_brands/v_au/

[11] S. M. Seifert, J. L. Schaechter, E. R. Hershorin, and S. E. Lipshultz, Health Effects of Energy Drinks on Children, Adolescents, and Young Adults, *Pediatrics*, 127(3), 2011, 511-528.

[12] C. J. Reissig, E. C. Strain, and R. R. Griffiths, Caffeinated energy drinks: a growing problem, *Drug Alcohol Depend, 99(1-3)*, 2009, 1-10.

[13] L. Italie, F-bomb makes it into mainstream dictionary, *The Washington Times*, 2012.

[14] C. Nordqvist, French ban on Red Bull (drink) upheld by European Court, *Medical News Today*, 2004.

[15] L. Steinke and D. Lanfear, Effect of 'energy drink' consumption on hemodynamic and electrocardiographic parameters in healthy young adults, *Ann Pharmacother, 43(4)*, 2009, 596-602.

[16] A. Ilechie and S. Tetteh, Acute effects of consumption of energy drinks on intraocular pressure and blood pressure, *Clinical Optometry, 3*, 2011, 5-12.

[17] M. M. Islam, M. B. Uddin, and M. Ahmad, Determination of the Effect of Having Energy Drinks on Respiratory and Heart Function Analyzing Blood Perfusion Signal, *Proc. 15th IEEE Conf. on Computer and Information Technology (ICCIT)*, Chittagong, Bangladesh, 2012, 113-118.

[18] *Biopac Blood flow Monitor*, Biopac Systems, Inc. ISO 9001:2000, http://www.biopac.com/Manuals/laser-doppler-flow.pdf

[19] G. Strang, Wavelets, *American Scientist*, 82(3), 1994, 253.

[20] *Fast Fourier Transform*, Available at: http://en.wikipedia.org/wiki/File:Time_domain_to_frequency _domain.jpg

[21] F. Rieke, W. Bialek, and D. Warland, *Spikes: Exploring the Neural Code (Computational Neuroscience)*, MIT Press, 1999.

[22] S. Millers and D. Childers, *Probability and random processes*, Academic Press, 2012, 370–375.