Effects of Caffeinated Beverage Consumption on Electrocardiographic Parameters among Healthy Adults

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Abstract

The aim of this study is to investigate the effects of caffeinated beverage consumption on electrocardiographic parameters with several healthy young persons. Electrocardiogram (ECG) recordings have been performed with electrode lead set connected to MP36 data acquisition unit (Biopac, USA). Recordings of ECG as well as their analysis have been done using Biopac softwares at both before and after the consumption of caffeinated beverage available in Bangladesh. After having caffeinated beverage, the ECG parameters such as peak amplitude of different waves and their corresponding intervals of ECG signal have changed significantly. The peak amplitude of Q and S waves has not changed so significantly but P and T waves showed maximum decrement about 6% and 23% respectively. Besides, maximum increment in R peak of ECG is about 11% which may cause short term boost. Among different intervals of ECG, change in RR interval is more significant. RR interval increases from about 0.85 to 0.89 sec which is mainly liable to decrease heart rate from about 71 to 67 bpm due to the consumption of caffeinated beverage. The findings highlight insufficient increment in R peak amplitude but net decrement in peak amplitude of P and T waves as well as heart rate which may cause cardiac abnormality due to the regular consumption of caffeinated beverage.

Keywords: electrocardiogram (ECG), electrocardiographic parameter, heart activity, caffeinated beverage, cardiac function

1. Introduction

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 (Bempong, Houghton, & Steadman, 1993). It also represents the polarization and depolarization of cardiac tissues that are used to investigate any damage to the heart. The parameters by which heart activity can be explained are known as electrocardiographic parameters such as peak amplitude of different waves in ECG signal as well as their segments and intervals, heart rate etc. Heart activity means the function of the heart which is examined applying different conditions over a period of time. Cardiac function is the function of cardiovascular system which can be properly evaluated by analyzing ECG. A typical ECG consists of a P wave, a QRS complex, a T wave, and a U wave, which is normally invisible. In biomedical engineering, the maximum amplitude in the R wave is usually called "R peak amplitude" or just "R peak" (Walraven, 2011). Accurate R peak detection is essential in signal processing equipment for heart rate measurement and it is the main feature used for arrhythmia detection (Gacek & Pedrycz, 2011). Among different segments and intervals in ECG signal, RR interval is more significant than others. Heart rate calculation is done using RR interval of two successive R peak. An arrhythmia is the abnormality that occurs when the heart is not beating in a regular pattern.

A caffeinated beverage or caffeinated drinks is a drink which basically contains caffeine as a main stimulant. Caffeinated drinks are produced using carbonated water (carbon dioxide dissolved into water) and hence it is also called carbonated beverage. Coffee and tea are the most common naturally caffeinated beverages. Other drinks are basically artificially caffeinated as part of their production process. Caffeine is added in certain soft drinks and also all the energy drinks designed as a stimulant. Some commercially distributed drinks contain guarana, a South American berry with caffeine content about twice that of coffee beans (Yoo & Hoof, 2010).

Caffeinated drinks provide an extra boost in energy to the consumers, promote wakefulness, maintain alertness, and provide cognitive and mood enhancement (Ishak et al., 2012). It mostly contains caffeine, taurine, carbohydrates, glucuronolactone, vitamins, and other herbal supplements like ginseng and guarana among others (Bunker & McWilliams, 1979). 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, as well as adverse effects in the cardiovascular, hematologic, and gastrointestinal systems (Seifert et al., 2011). The market and degree of consumption of caffeinated drinks is increasing day by day, but only few have global knowledge of their ingredients and actual physiological and psychological effects (Grosz & Szatmari, 2008).

Consumption of caffeinated beverage (energy drink) by young people revealed that 51% reported consuming at least one energy drink per month (Malinauskas et al., 2007). The effects of energy drinks consumption on hemodynamic and electrocardiographic parameters in healthy young adults were investigated, and reported a significantly increased heart rate and blood pressure within 4 hours (Steinke et al., 2009). The effects of energy drinks consumption on blood perfusion in healthy young adults were studied using Laser Doppler Flowmetry (Islam, Uddin, & Ahmad, 2012), as well as using Wavelet Transform (Rahman, Khatun, & Islam, 2013). The effects of caffeinated beverage consumption on electrocardiographic parameters weren't well studied and we hypothesized that the consumption of caffeinated beverage changes cardiac control mechanisms which would result in differences in the peak amplitude and their corresponding intervals of ECG signal. The aim of the present study is to determine the effects of caffeinated beverage consumption on electrocardiographic parameters analyzing peak amplitude of different waves and their corresponding intervals of ECG using Biopac accessories.

2. Materials and Methods

2.1 Selection of Subjects

Twelve healthy human subjects were enrolled for this study. All of them were young male and ages between 19 and 27. Each of the subjects was totally free from smoking and drinking (having caffeinated or alcoholic drinks) at least 6 h prior to the study. No one of them was affected by any type of cardiovascular diseases. They had not taken any medicine or medication during the week of the study. According to the approval of the local Ethics Committee, the subjects were given their written consent. Before ECG recording, their age, weight and height were noted. The mean ± standard deviation (range) of subjects for age (yr), weight (kg), height (cm) and Body Mass Index (kg/m^2) are 22.5 ± 2.81, 64.92 ± 8.22, 171.45 ± 2.99 and 22.12 ± 3.05 respectively.

(a)   (b)

Figure 1. Setup - (a) lead connection with MP36 (Biopac Student Lab Manual, 2008), (b) complete setup for ECG recording

2.2 Setup of ECG Recordings

The recording of ECG was performed in a quiet room maintaining the temperature at 25 °C (24^0-26^0). Throughout the whole experimental period, the subjects were resting in the supine position. Total setup for ECG recording is shown in Figure 1. Electrode lead set (SS2L) plugs into channel 1 of MP36 (Biopac, USA) data acquisition unit was used for ECG recordings. According to color code, electrode lead set was attached to the electrodes (EL503) placed on the subject's skin. The electrodes were placed on the subject's skin at least 5 minutes before the start of the calibration procedure for optimal electrode adhesion. Electrode cables were positioned such a way that pulling on the electrodes or the transducer was not possible.

2.3 Procedures of ECG Recordings

Food intake was totally restricted to a light meal 2 h prior to the test. At least 5 minutes were allowed for acclimatization, before the measurements were performed on the subject's body. Royal Tiger Energy Drink (caffeinated beverage) was served to each subject and the specifications of that drink are 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 & artificial), preservatives (E211) & colors (E102). Before having caffeinated beverage, ECG was recorded with about 10 minutes time duration. For ECG recording after having caffeinated beverage, time period about 1.5 h (90 minutes) were allocated. Due to the time limitation of recording using Biopac Student Lab (BSL) software, continuous ECG recordings were not possible. After being energized, ECG recordings were performed discretely with some interval of time (i.e. at 5, 20, 40, 65 and 90 minutes from the instant of being energized). For physical medical history assessment every participant had an initial visit to the laboratory.

3. Results

3.1 Recording of ECG Signal

ECG recording using Biopac accessories for a typical subject is shown in Figure 2. Electrode lead set was connected to MP36 data acquisition unit and the total system was interfaced with computer. Using Biopac Student Lab (BSL) software (Biopac software) in computer, ECG recording was performed. ECG Recording was performed for both normal (before having caffeinated drinks) and energized (after having caffeinated drinks) condition. At normal condition, ECG recording was performed about 10 minutes. After having caffeinated drinks, the same recording was performed about 1.5 hour (90 minutes) from the instant of being energized. From Figure 2, it is seen that the ECG recording contains all wave components such as P, Q, R, S and T as well as their corresponding amplitudes are significant. Besides, different intervals such as RR interval (R peak to R peak), RT interval (R peak to T peak) and PR interval (P peak to R peak) are also notable.
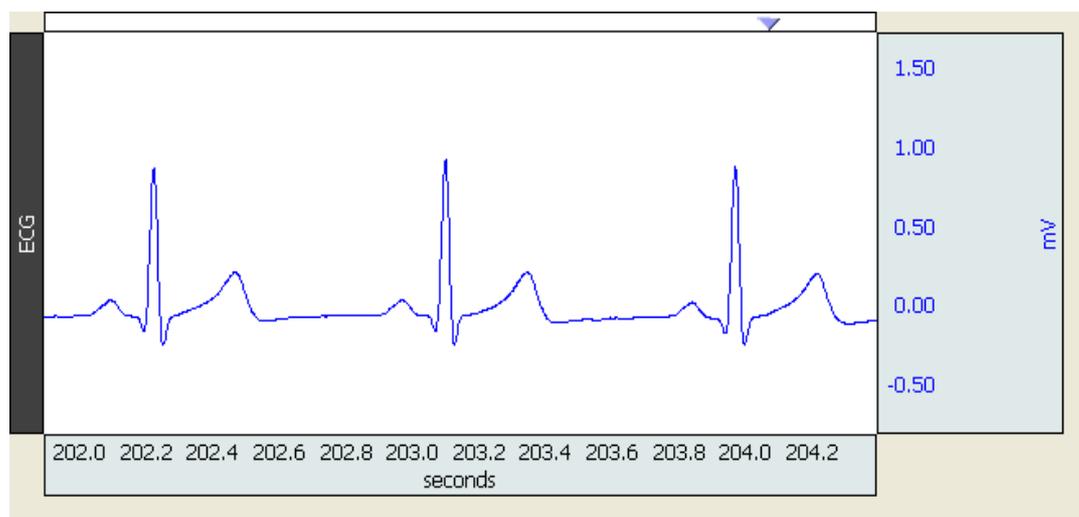
Figure 2. ECG recording using Biopac Student Lab (BSL) software

3.2 Normal vs Energized ECG Signal

For a typical subject, ECG recording before and after having caffeinated beverage is shown in Figure 3. ECG recording before having caffeinated drinks is indicated by Normal ECG (00) using pure line and after having caffeinated drinks is indicated by Energized ECG (05) using dotted line. Energized ECG (05) indicates the ECG recording after five (05) minutes from the instant of having caffeinated drinks. Due to the consumption of caffeinated drinks, the electrocardiographic parameters such as peak amplitude of P, Q, R, S, & T waves as well as their segments & intervals are changed to a notable value. These changes can be noticed after 20, 40, 65, & 90 minutes of having caffeinated drinks as well. ECG parameters mentioned above before and after having caffeinated drinks are comparable from Figure 3. There is a notable incremental change in peak amplitude of P, Q and S wave; significant increment in peak amplitude of R wave; notable decremental change in peak amplitude of T wave are observed due to the consumption of caffeinated drinks. Besides, less significant change in PR and RT intervals are also investigated.
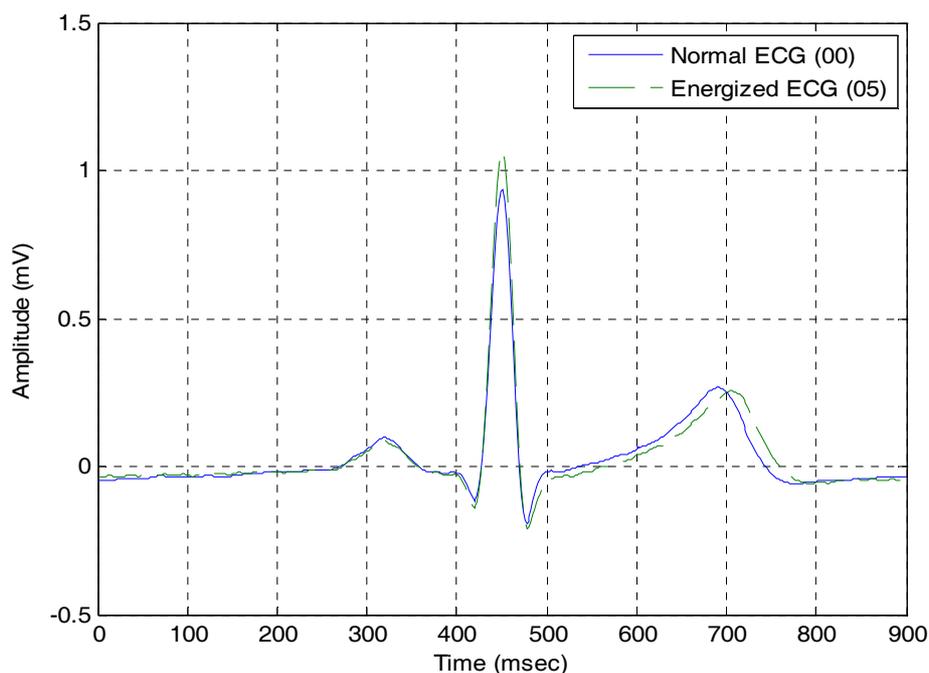
Figure 3. ECG signal comparison before and after having caffeinated beverage

3.3 Changes in Peak Amplitude

Electrocardiographic parameters such as peak amplitude of P, Q, R, S and T wave were evaluated from ECG recording for both before and after having caffeinated beverage. Peak amplitude based ECG parameters variation with time for a typical subject is shown in Figure 4. Data at time 0 min indicates the peak amplitude for normal condition (without consuming caffeinated drinks). Data after 0 min to 90 min indicate the peak amplitude for energized condition (with consuming caffeinated drinks). Due to having caffeinated drinks, peak amplitude of P and Q wave shows a notable decrement with time. In case of S and T waves, both incremental and decremental changes are observed in their peak amplitude. The highest decrement in peak amplitude of S and T waves are observed within about 30 to 50 min from the instant of having caffeinated drinks. There is more significant change in peak amplitude of R wave. After having caffeinated drinks, significant increment in R peak amplitude is observed with time and it gets maximum increment at about 20 min and then shows a tendency to decrease. These significant changes in ECG parameters prove that the effect of having caffeinated drinks lasts some interval of time and then finished.
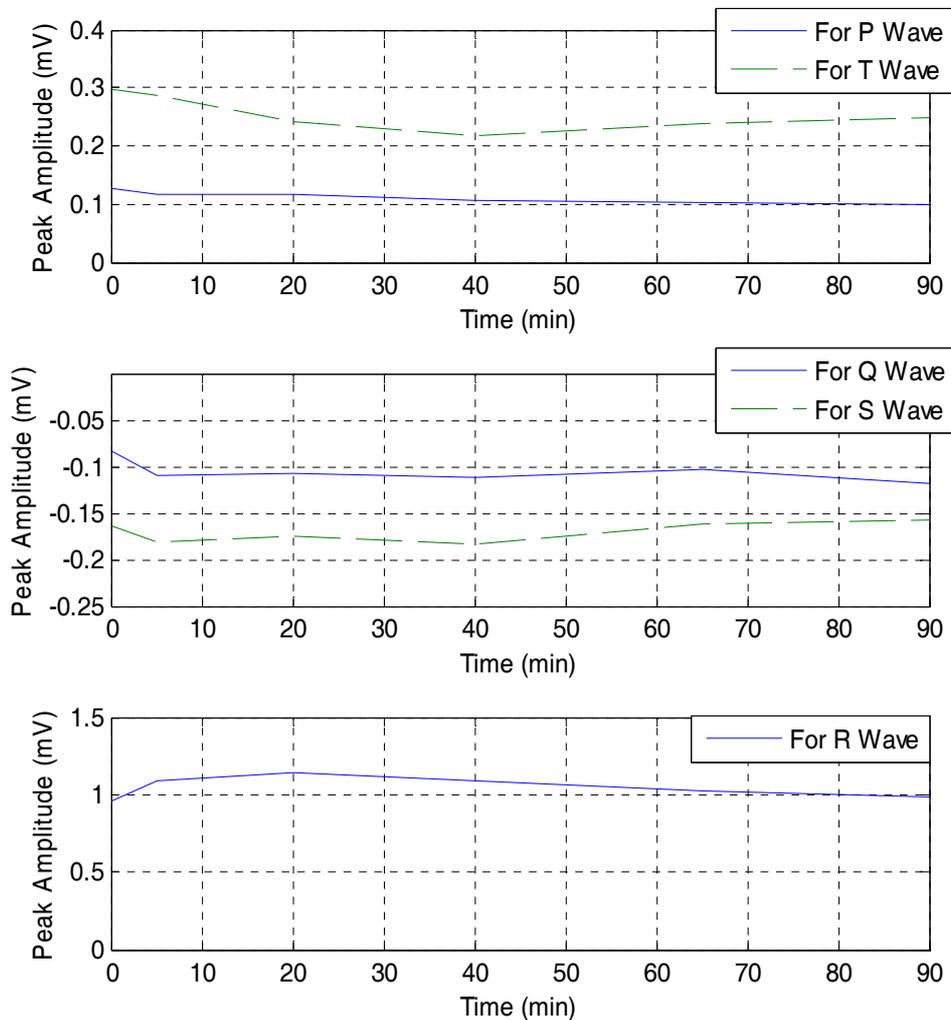
Figure 4. Amplitude variation of different waves of ECG signals due to having caffeinated beverage

3.4 Variations in Different Intervals

ECG parameters such as RR, RT and PR intervals were evaluated from ECG recording for both before and after having caffeinated beverage. Interval based ECG parameters variation with time for a typical subject is shown in Figure 5. Data at time 0 min indicates the intervals for normal condition (without consuming caffeinated drinks). Data after 0 min to 90 min indicate the intervals for energized condition (with consuming caffeinated drinks). Due to having caffeinated drinks, no significant change is found in RT and PR intervals but notable change is found in RR interval of ECG signal. RR interval increases with time for this typical subject and hence heart rate of this subject decreases after consuming caffeinated drinks.
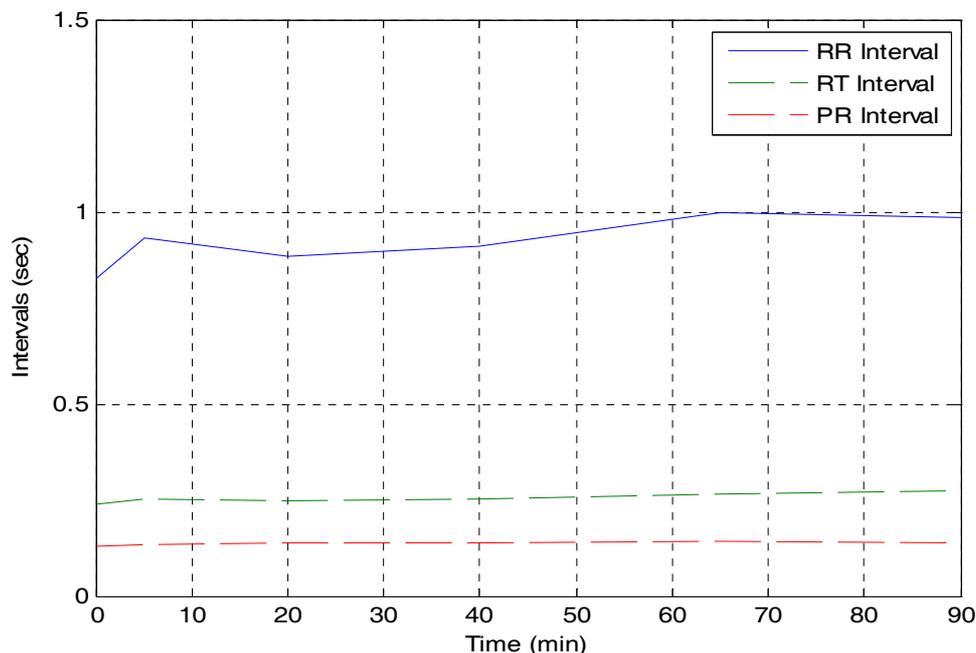
Figure 5. Variations of different intervals of ECG signal with time due to having caffeinated beverage

3.5 Statistical Analysis of ECG Parameters

The change in average peak amplitude of different waves of ECG signal with time due to the consumption of caffeinated beverage is shown in Table 1. The readings (range) at time 00 minute indicate the average value of peak amplitude of corresponding waves at normal condition. Average values of peak amplitude at energized condition are shown in some interval of time (i.e. after 05, 20, 40, 65 and 90 minutes from the instant of being energized). The ranges of readings of peak amplitude of corresponding waves are presented as mean ± standard deviation (SD). The average peak amplitude of P wave decreases with time which is notable. Besides, a significant decrement in average peak amplitude of T wave is also noticed due to having energized. In case of Q and S waves, a variable (random) change is noticed with time. Though there are less significant changes in peak amplitude of P, Q, S and T wave; change in peak amplitude of R wave with time is more significant. The peak amplitude of R wave increases after having energized and it gets maximum increment at about 20 min from the instant of drinking and then shows a tendency to decrease to reach at normal condition.

Table 1. Average changes in peak amplitude of ECG signal components with time

Time (min)	Peak amplitude of ECG Signal components (mV)[a]				
	P wave	Q wave	R wave	S wave	T wave
00	0.1165±0.0246	0.0548±0.0349	1.1213±0.5547	-0.2276±0.0875	0.2367±0.0731
05	0.1158±0.0318	0.0633±0.0483	1.1880±0.5710	-0.2268±0.0915	0.2293±0.0708
20	0.1146±0.0226	0.0584±0.0487	1.2340±0.5778	-0.2249±0.0889	0.2140±0.0465
40	0.1117±0.0255	0.0621±0.0427	1.2263±0.5629	-0.2471±0.1055	0.1794±0.0502
65	0.1103±0.0251	0.0606±0.0389	1.1871±0.5646	-0.2194±0.0958	0.2049±0.0489
90	0.1073±0.0191	0.0644±0.0417	1.1550±0.5550	-0.2211±0.0935	0.2027±0.0645

[a]Values are Mean ± SD.

Average change in different intervals of ECG signal with time due to the consumption of caffeinated beverage is shown in Table 2. Table 2 shows less significant increment in PR interval, moderately significant increment in RT interval and more significant increment in RR interval. Due to the consumption of caffeinated beverage, increments in different intervals are noticed but RR interval increment is remarkable. In this study, the time

interval between two successive R peaks is assumed as RR interval. Heart rate (HR) decreases as the RR interval increases and vice versa i.e. heart rate is inversely proportional to the RR interval as shown in Equation (1) and Equation (2). From Table 2, it is noticed that RR interval increases or heart rate decreases with time due to the consumption of caffeinated drinks.

$$HR \propto \frac{1}{RR\ Interval} \tag{1}$$

$$HR = \frac{60}{RR\ Interval\ in\ \sec}\ BPM \tag{2}$$

Table 2. Average changes in different intervals of ECG signals with time

Time (min)	Change in different intervals of ECG Signal (sec)[a]		
	RR Interval	RT Interval	PR Interval
00	0.8522 ± 0.0536	0.2244 ± 0.0162	0.1184 ± 0.0131
05	0.8530 ± 0.0544	0.2328 ± 0.0162	0.1216 ± 0.0159
20	0.8478 ± 0.0571	0.2332 ± 0.0199	0.1206 ± 0.0178
40	0.8736 ± 0.0822	0.2340 ± 0.0194	0.1228 ± 0.0177
65	0.8720 ± 0.1162	0.2378 ± 0.0185	0.1248 ± 0.0197
90	0.8860 ± 0.0913	0.2438 ± 0.0197	0.1258 ± 0.0192

[a]Values are Mean ± SD.

4. Discussion

The results of this study demonstrate a notable change in ECG parameters such as peak amplitude of different waves as well as different intervals of ECG signal. The effects of caffeinated beverage consumption on peak amplitude and different intervals of ECG signal are described below.

The percentage changes in average peak amplitude of different waves of ECG signal with time are shown in Table 3. These percentage changes are calculated using Equation (3). In Table 3, minus (-) sign indicates the decrement in peak amplitude with respect to normal condition. In case of P wave, the decremental percentage change is observed i.e. the peak amplitude of P wave decreases with time. Also the percentage change in peak amplitude of Q, S and T waves are variable and the highest increment or decrement in peak amplitude of these waves are found within 20 to 40 min from the instant of being energized. Though there are less significant percentage changes in peak amplitude of P, Q, S and T wave; percentage change in peak amplitude of R wave with time is more significant. The percentage increment in peak amplitude of R wave is found after having energized and it gets maximum percentage increment at about 20 min from the instant of having caffeinated drink and then shows a tendency to decrease to reach at normal condition.

$$\%\ Change\ (peak\ amplitude) = \frac{(Amplitude_{Energized} - Amplitude_{Normal}}{Amplitude_{Normal}} \times 100 \tag{3}$$

Table 3. Percentage changes in average peak amplitude of different waves of ECG signals with time

Time (min)	% Change in average peak amplitude of different waves of ECG signal with time				
	P wave	Q wave	R wave	S wave	T wave
00	0%	0%	0%	0%	0%
05	-2.10%	1.15%	6.16%	-0.05%	-3.07%
20	-0.40%	-26.06%	11.18%	-1.48%	-5.97%
40	-3.23%	14.05%	10.82%	7.49%	-23.36%
65	-4.20%	14.46%	6.44%	-4.93%	-7.96%
90	-6.37%	34.68%	3.77%	-3.12%	-11.61%

Different intervals of ECG signal are affected due to the consumption of caffeinated beverage. RR interval is more affected than RT and PR interval. Less significant increment in PR interval is found in this study as well as for RT interval. RT interval is more affected than PR interval. All the effects on different intervals are incremental. The most significant increment is found in RR interval as shown in Table 2. Due to the consumption of caffeinated drinks, the average RR interval increment is remarkable which about 0.85 to 0.89 sec. The heart rate decreases from 71 to 67 bpm (bits per minute) with time due to the consumption of caffeinated drinks.

Analyzing peak amplitude of different waves and their intervals of ECG signal, the consumption of caffeinated beverage affects the peak amplitude and different intervals to a significant level. Since the impacts on R peak amplitude are positive to give short term boost to the caffeinated drinks consumer, the change in peak amplitude of other waves are not so satisfactory. Besides, consumption of caffeinated drinks increases RR interval which in turn decreases the heart rate. Reduction in heart rate may cause causes cardiac irregularities due to the consumption of caffeinated drinks. All the results in this study are based on those subjects who don't drink caffeinated drinks regularly. The regular consumption of caffeinated drinks may cause cardiac abnormality as well as severe cardiac disease.

5. Conclusion

The effects of caffeinated beverage consumption on electrocardiographic parameters were evaluated in this study by analyzing peak amplitude variation of different waves and their corresponding intervals of ECG signal. There was less significant positive impact which gives short term boost but other impacts on ECG parameters were not in favor to the human being. ECG parameters analysis after having caffeinated beverage showed negative impacts on peak amplitude and heart rate which may lead any type of heart abnormality. It is suggested that the consumers of caffeinated beverage should avoid it as much as possible to avoid cardiac irregularities.

Acknowledgements

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