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ARAŞTIRMA / RESEARCH

Acute effects of caffeinated beverages on electrocardiographic and hemodynamic parameters in young adults

Genç yetişkinlerde elektrofizyolojik ve hemodinamik parametreler üzerine kafeinli içeceklerin akut etkileri

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Abstract

Purpose: The consumption of caffeinated beverages has significantly increased among young people in recent years. The objective of the study is to investigate the acute effects of caffeinated beverages on electrocardiographic and hemodynamic parameters of young adults.

Materials and Methods: Study was designed as a non-randomized, non-placebo controlled, three-arm parallel assignment. It was conducted on 56 individuals selected from a pool of students enrolled at Aydın Adnan Menderes University. Energy drink, coffee, cola and control groups were determined according to the results of the applicant acceptance questionnaire. Blood pressure and electrocardiogram were measured before and after consuming the drinks at 30 minutes and 60 minutes. Heart rate variability was detected from electrocardiogram signal and investigated by linear analysis.

Results: All caffeinated drinks increased the blood pressure. Only, heart rate was increased by energy drink and cola. There was a small increment in root-mean square differences of successive R-R intervals and the number of times successive heartbeat intervals exceed 50ms (NN50) values in coffee group. High frequency (HF) values were increased some for coffee and cola groups. But, low frequency (LF) and LF/HF values were decreased. These alterations were statistically significant for coffee group. PR interval and QRS complex did not alter, however, QTc interval was lower in energy drink and cola groups.

Conclusion: Caffeinated beverage consumption has the potential to induce adverse effects on cardiovascular system of young adults. Coffee appears to be more prominent than energy drink and cola.

Keywords:. Blood pressure, caffeinated beverages, electrocardiography, linear analysis

Öz

Amaç: Kafeinli içeceklerin tüketimi son yıllarda gençler arasında önemli ölçüde artmıştır. Çalışmanın amacı, kafeinli içeceklerin genç erişkinlerin elektrokardiyografik ve hemodinamik parametreleri üzerindeki akut etkilerini araştırmaktır.

Gereç ve Yöntem: Çalışma, randomize olmayan, plasebo kontrollü olmayan, üç kollu paralel bir atama olarak tasarlanmıştır. Aydın Adnan Menderes Üniversitesi'ne kayıtlı öğrenci havuzundan seçilen 56 kişi üzerinde gerçekleştirilmiştir. Başvuru kabul anketi sonuçlarına göre enerji içeceği, kahve, kola ve kontrol grupları belirlendi. Kan basıncı ve elektrokardiyogram, içecekleri tüketmeden önce ve 30 dakika ve 60 dakika sonra ölçüldü. Kalp hızı değişkenliği elektrokardiyogram sinyalinden tespit edildi ve lineer analiz ile araştırıldı.

Bulgular: Tüm kafeinli içecekler kan basıncını yükseltti. Sadece enerji içeceği ve kola kalp atış hızını artırdı. Kahve grubunun ardışık R-R aralıkları arasındaki farkların karekökü ve 50 milisaniyeyi aşan NN intervallerinin sayısı (NN50) değerlerinde küçük bir artış oldu. Kahve ve kola grupları için yüksek frekans (HF) değerleri biraz arttı. Ancak düşük frekans (LF) ve LF/HF değerleri de azalmıştır. Bu değişiklikler kahve grubu için istatistiksel olarak anlamlıydı. PR intervali ve QRS kompleksi değişmedi, ancak enerji içeceği ve kola gruplarında QTc intervali QTc intervali daha düşüktü.

Sonuç: Kafeinli içecek tüketimi, genç yetişkinlerin kardiyovasküler sistemi üzerinde olumsuz etkilere neden olma potansiyeline sahiptir. Kahve, enerji içeceği ve koladan daha etkin görünmektedir.

Anahtar kelimeler: Kan basıncı, kafeinli içecekler, elektrokardiyografi, lineer analiz.

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INTRODUCTION

Caffeinated beverages are widely consumed substances around the world. They are preferred by especially young people due to their high concentration level effect[1]. As they are frequently consumed in popular culture, the impact of caffeine on human health is one of the exciting subjects studied by researchers and scientists. As the name suggests, caffeine is the main ingredient of these beverages. Coffee, energy drink (ED), soft drinks, chocolate products, and tea are the natural sources of dietary caffeine[2]. The most consumed one is coffee due to its stimulative effect. Also, in recent years ED, which is another popular source of caffeine has become more widespread among young people. Health authorities have recently highlighted the risk of consumption among children, adolescents, and young adults[2]. Thus, it is important to investigate the pros and cons of consuming these beverages, especially for young people.

Caffeine, a methylxanthine, is one of the bioactive compounds of caffeinated beverages known to have adverse effects on the cardiovascular system. Since the structures of caffeine and adenosine were similar, it has an impact on the central nervous system by antagonizing adenosine receptors[3]. Furthermore, it is the inhibitor of phosphodiesterase enzymes, and this may account for caffeine's cardio-stimulatory actions since they are reported as cardiac stimulants[4,5]. Also, it reduces cytoplasmic Ca^{+2} in the vascular smooth muscle cell and increases the same in the endothelial cell by stimulating the synthesis of nitric oxide[6]. These cause cardiovascular effects such as peripheral vasoconstriction and subsequent increased blood pressure (BP)[7]. There are some studies related to these beverages' effects on various hemodynamic parameters in the literature. For instance, Elitok et al.[8] reported that acute consumption of EDs contributed to increased heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP). Similarly, Hara et al.[9] reported a significant increase in SBP and HR with respect to control after acute coffee consumption in non-habitual coffee consumers. As a result, it is supported by the studies that these beverages may have adverse effects on the cardiovascular system.

The studies in the literature point to a further need for assessing the acute effects of these caffeinated beverages on the cardiovascular system in detail. To our knowledge, there are no reports in which the acute effects of coffee, ED and cola were investigated and compared. Therefore, in this study, the objective of the study is to investigate the acute effects of caffeinated beverages on electrocardiographic and hemodynamic parameters of young adults and compare the findings.

MATERIALS AND METHODS

This study was conducted on healthy young adults at Aydın Adnan Menderes University. It is conducted due to the guidelines given in the Declaration of Helsinki and the Institutional Medical Ethics Committee of Adnan Menderes University (Protocol number: 2017/1211) approved the study procedures. All participants provided written informed consent.

Sample

Fifty-six participants participated who were in the first year of various faculties of Aydın Adnan Menderes University and aged between 18 to 24 (mean 19.14 ± 0.21) and underwent the study procedures during April – June 2019. An applicant acceptance questionnaire was applied to the participants to identify their age, weight, body mass index (BMI), and caffeine consumption habits. Accordingly, those with a BMI greater than 30 kg/m^2, a systemic disease, current caffeine habituation, smokers and drug usage, and also, the participants who have previous adverse reactions to caffeinated beverages were excluded to prevent undesired reactions associated with this condition. Subjects enrolled in the study were caffeine naïve, non-smokers, whose BMI was smaller than 30 kg/m^2, do not have a systemic disease and who had adverse reactions to caffeinated beverages before. They were grouped as ED (n=14), coffee (n=14), cola (n=14) and control (n=14). They were advised to avoid alcohol, coffee, energy drink and cola for at least 72 h prior to the tests and to come after fasting overnight (12h).

All measurements were done in a quiet, temperature- and humidity-controlled (~20°C, %40-60) laboratory and started between 08:30 – 09:00 to standardize the circadian influence. BP measurements and electrocardiogram (ECG) recordings were carried out before the consumption of drinks. After the measurements ED group consumed 473 ml of Red Bull energy drink, coffee group consumed 473 ml of Nescafe classic, cola group consumed 473 ml of Coca Cola which contains 151.4 mg, 378.4 mg and 40.4 mg

caffeine respectively[10]. Control group consumed the same amount of water within 5 minutes. The measurements were repeated after 30 minutes and 60 minutes.

Blood pressure measurements

SBP and DBP were measured manually with a stethoscope (Littman Classic II, Saint Paul, USA) and aneroid sphygmomanometer (Welch Allyn Tycos, New York, USA) following 30 minutes of rest in relaxed and sitting position. All measurements were obtained from the left arm.

Electrocardiographic measurements

ECG signals were recorded at 200 Hz sampling frequency by using ECG100C unit and BIOPAC Acqknowledge acquisition software (Biopac System Inc., Santa Barbara, CA) connected to a personal computer throughout the study in the supine position. Disposable Ag-AgCl electrodes were placed following the Einthoven triangle configuration. ECG was recorded for 5 minutes according to the recommendation of Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology[11]. PR interval, QRS complex and QTc interval values were measured from ECG signals. QTc was calculated by Bazett's formula (QTc=QT/RR). Their normal range values were 350-450 ms[12].

Pan and Thompkins algorithm was used for obtaining the heart rate variability (HRV) time series[13]. R peaks were detected, and R-R intervals are defined. RR interval (t_{RR}) is the time duration between two consecutive R peaks [14]. HR was determined as:

$$HR = \frac{60}{t_{RR}}$$

Linear analysis of HRV was performed by using Kubios HRV 2.2 (Version 2.2, University of Eastern Finland, Kuopio, Finland). HRV was analyzed in both the time domain and frequency domain. Standard deviation of normal-to-normal RR intervals (SDNN), root-mean square of differences between adjacent normal RR intervals in a time interval (RMSSD) and total number of adjacent RR intervals with a difference of duration greater than 50 ms (NN50) were investigated for the analysis of HRV in the time domain. RMSSD indicates the parasympathetic control of the HR during the normal rhythm. For frequency domain analysis, low frequency (LF) (0.04-0.15 Hz), high frequency (HF) (0.15-0.40 Hz) and the ratio between LF and HF components were evaluated. All analysis was performed according to the standards set by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology[11].

Statistical analysis

SPSS Statistics for Windows, Version 14.0. (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. The sample size was determined as 14 people each in the control and 3 different experimental groups. When the power analysis was performed with 14 people in the groups (standard deviation 0.59), the result was found to be 0.83. While testing, the t-test, which determines the differences between two independent groups, was applied and statistical significance (alpha) was found to be 0.05. Shapiro-Wilk normality test was used for determining the normality of the distribution. The data were analyzed with Bonferroni post-test if it was normally distributed, if not Kruskal-Wallis non-parametric test was used for the comparison of the groups. Comparisons of the values of SBP, DBP, HR and HRV indexes such as SDNN, RMSSD and NN50 were made by one-way analysis of variance (ANOVA) test. Moreover, the comparison of different measurement time data of a parameter of the same group was carried out by two-way repeated measures ANOVA. Mauchly's test was used for checking the sphericity violation of the repeated measures data. Descriptive statistics were presented as mean ± standard error of the mean. A p-value of less than 0.05 was considered to indicate statistical significance.

RESULTS

A hundred and fifty students were assessed for eligibility. Five volunteers gave up participating for personal reasons, 67 volunteers had smoking habits, 3 of them had a BMI greater than 30 kg/m², 2 volunteers had previous adverse reactions to caffeinated beverages, 14 volunteers had systemic diseases and 3 volunteers were excluded due to poor quality of ECG signal. Fifty-six participants were accepted into the study.The anthropometric characteristics of the participants are shown in Table 1. There were no significant differences in age, height, weight, and BMI values between the groups.

Table 1. The anthropometric characteristics of the participants.

	Energy drink	Coffee	Cola	Control
Age (yr)	19.00 ± 0.36	19.18 ± 0.48	19.09 ± 0.34	19.27 ± 0.52
Height (m)	1.73 ± 0.31	1.71 ± 0.02	1.73 ± 0.03	1.74 ± 0.02
Weight (kg)	63.96 ± 4.78	70.73 ± 4.07	69.12 ± 4.64	70.12 ± 4.21
BMI (kg/m^2)	21.04 ± 0.96	24.07 ± 1.01	23.13 ± 1.32	23.41 ± 1.39

BMI=Body mass index

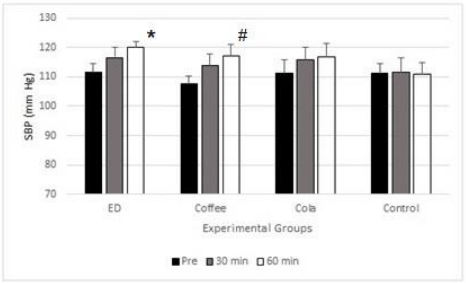

Figure 1. The variation of SBP within the groups during the experiment.

* statistically significant versus pre-drink value of ED (p=0.015), # statistically significant versus pre-drink value of coffee (p=0.034). SBP= Systolic blood pressure, ED=energy drink.

Hemodynamic parameters of ED, coffee, cola and control groups were given in Figure 1, 2 and 3. 60-minute SBP was increased significantly for both ED (p=0.015) and coffee (p=0.034) groups when compared to baseline values. However, the increase was not statistically significant for cola group. Also, 60-minute DBP value of coffee group was significantly higher than the baseline value (p=0.018). There is also an increase in DBP value of ED and cola group, but these changes were not significant when compared to the baseline value. For control group there was no significant difference found in SBP and DBP values across time. Furthermore, 60-minute HR values of the ED and cola groups were increased regarding pre-drink HR values. Only, the increase for ED group was statistically significant (p=0.029). The HR values of coffee group did not alter. Furthermore, control group's hemodynamic parameter values did not change significantly across time.

Linear analysis results of HRV for ED, coffee, cola and control groups were shown in Table 2. According to the time domain analysis of the data, no significant differences were observed in SDNN, RMSSD and NN50 values of drink groups at 60 minutes with regard to control and also to the baseline. Also, when we analyzed HRV data by frequency analysis, we determined a slight reduction in LF values of ED, coffee and cola groups after 60 minutes of drink consumption when compared to the baseline values.

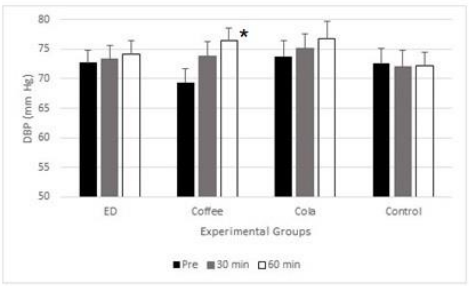

Figure 2. The variation of DBP within the groups during the experiment.

* statistically significant versus pre-drink value of coffee (p=0.018). DBP= Diastolic blood pressure, ED=energy drink.

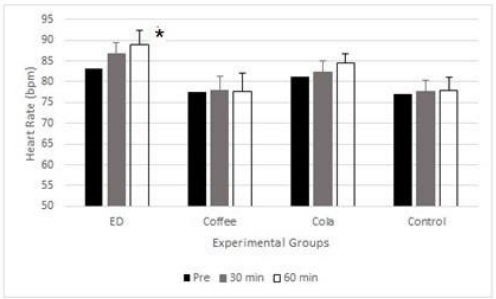

Figure 3. The variation of HR (mean) within the groups during the experiment.

* statistically significant versus pre-drink value of ED (p=0.029). bpm= beats per minute, ED=energy drink.

Furthermore, HF values were increased after drink consumption when compared to pre-drink values for all drink groups. This increment was statistically significant only for coffee group (p=0.024). In addition to this, there was a reduction in LF/HF ratio of all drink groups but similarly, this change was statistically significant only for coffee group

(p=0.011). Furthermore, these values of control group did not alter significantly across time. Beverage consumption had no effect on PR interval and QRS complex for each group (Table 3). QTc interval was increased significantly for ED group (p=0.035) and slightly for cola group when compared with the baseline values. However, there was no alteration for coffee group.

Table 2. Linear parameters of the groups before, after 30 min and 60 min of drink consumption.

		Energy drink	Coffee	Cola	Control
SDNN (ms)	Pre	40.20 ± 4.84	60.42 ± 8.85	56.45 ± 9.36	50.89 ± 12.85
	30 min	41.33 ± 6.34	58.93 ± 5.64	55.39 ± 9.22	51.37 ± 9.65
	60 min	44.07 ± 4.58	62.18 ± 8.22	58.66 ± 9.75	51.81 ± 8.81
	P	0.854	0.652	0.102	0.336
RMSSD (ms)	Pre	43.83 ± 6.16	80.92 ± 14.35	68.24 ± 15.61	58.99 ± 9.81
	30 min	44.31 ± 4.12	83.73 ± 13.64	69.60 ± 13.78	56.77 ± 14.63
	60 min	42.43 ± 5.18	82.12 ± 14.73	65..21 ± 12.33	59.41 ± 11.56
	P	0.129	0.762	0.154	0.657
NN50 (beat)	Pre	24.50 ± 4.57	130.40 ± 17.54	33.82 ± 8.62	58.91 ± 19.45
	30 min	25.00 ± 4.78	135.00 ± 15.89	39.36 ± 8.11	57.73 ± 18.75
	60 min	24.27 ± 6.36	133.45 ± 17.82	43.30 ± 9.01	56.40 ± 17.35
	P	0.982	0.226	0.314	0.969
LF (Hz)	Pre	507.20 ± 87.67	878.80 ± 28.68	1021.73 ± 34.07	438.60 ± 83.73
	30 min	503.00 ± 67.11	874.80 ± 64.60	1009.91 ± 31.60	437.89 ± 85.38
	60 min	501.91 ± 38.49	867.56 ± 51.57	966.80 ± 47.40	438.27 ± 86.21
	P	0.885	0.465	0.651	0.293
HF (Hz)	Pre	527.09 ± 19.34	2100.55 ± 45.22	2051.82 ± 47.74	1325.40 ± 60.37
	30 min	613.80 ± 62.38	4183.00 ± 97.55	2074.80 ± 82.82	1325.00 ± 76.07
	60 min	717.91 ± 20.27	4539.67 ± 51.06	2133.00 ± 60.33	1329.27 ± 59.03
	P	0.784	0.024	0.254	0.124
LF/HF	Pre	1.42 ± 0.23	0.92 ± 0.24	1.22 ± 0.04	0.73 ± 0.24
	30 min	1.06 ± 0.32	0.54 ± 0.24	0.87 ± 0.03	0.75 ± 0.17
	60 min	0.83 ± 0.18	0.35 ± 0.11	0.89 ± 0.02	0.70 ± 0.21
	P	0.735	0.011	0.991	0.167

P refers to the differences between the pre and 60th min values of groups. SDNN= Standard deviation of normal-to-normal RR intervals, RMSSD=Root-mean square of differences between adjacent normal RR intervals in a time interval, NN50= Total number of adjacent RR intervals with a difference of duration greater than 50 ms, LF=Low frequency, HF=High frequency.

Table 3. Electrocardiographic parameters of the groups before, after 30 min and 60 min of drink consumption..

		Energy drink	Coffee	Cola	Control
PR interval (ms)	Pre	0.124 ± 0.003	0.149 ± 0.005	0.155 ± 0.006	0.128 ± 0.005
	30 min	0.121 ± 0.008	0.148 ± 0.005	0.156 ± 0.04	0.132 ± 0.004
	60 min	0.123 ± 0.015	0.147 ± 0.006	0.154 ± 0.029	0.128 ± 0.004
	P	0.835	0.984	0.974	0.867
QRS complex (ms)	Pre	0.102 ± 0.003	0.094 ± 0.012	0.062 ± 0.002	0.096 ± 0.003
	30 min	0.101 ± 0.003	0.092 ± 0.003	0.062 ± 0.002	0.095 ± 0.030
	60 min	0.098 ± 0.003	0.091 ± 0.003	0.063 ± 0.002	0.096 ± 0.008
	P	0.693	0.362	0.939	0.575
QTc interval (ms)	Pre	0.337 ± 0.005	0.366 ± 0.009	0.345 ± 0.010	0.355 ± 0.006
	30 min	0.330 ± 0.009	0.370 ± 0.009	0.338 ± 0.006	0.354 ± 0.006
	60 min	0.322 ± 0.006	0.371 ± 0.009	0.336 ± 0.007	0.353 ± 0.007
	P	0.035	0.655	0.705	0.963

P refers to the differences between the pre and 60th min values of groups

DISCUSSION

The objective of this study was to investigate whether caffeinated beverages affect electrocardiographic and hemodynamic parameters in young adults and to compare the effects with each other. To the best of our knowledge, this is the first study that investigated the acute effects of ED, coffee and cola on the

cardiovascular system and provided a comparison. The principal finding of the study was the possible adverse effects of acute caffeinated beverage consumption on the cardiovascular system. Coffee has the most elevating effect on blood pressure and has no effect on heart rate and QTc interval. However, ED and cola consumption increased the heart rate and decreased QTc interval significantly.

The main bioactive component of caffeinated beverages is caffeine which is considered as the potential cause of the effect of these beverages on cardiovascular risk[15]. Caffeine in particular has various physiological effects such that coronary vasoconstriction, increase in BP, stimulation of gastric secretion, and relaxation of smooth muscle cells through actin depolymerization[16]. In particular, a number of reports have been published in the literature related to the adverse cardiovascular effects of some caffeinated beverages such as the increased risk of atrial fibrillation, ventricular tachyarrhythmias, and QTc prolongation[17-19]. On the other hand, some researchers have suggested that caffeine is beneficial for human health[10, 20]. Nevertheless, such suggestions are still not conclusive and even conflicting. Thus, more detailed and comprehensive studies are needed for confirmation.

Many research studies related to BP and caffeine were worked out to this day. Some of the studies reported no change in BP[21, 22] however the others reported significant increments[8, 9, 23]. Despite contradictory results, there is still a consensus that caffeine causes an increase in BP via sympathetic over-activation and antagonism of adenosine receptors. In our study, we observed a significant increase in both SBP and DBP for coffee and ED groups after 30 minutes of drink consumption with respect to pre-drink values. This increase was further emphasized at 60 minutes significantly. This is compatible with the study of Papakonstantinou et al.[24] in which both SBP and DBP values were increased after the consumption of 200 ml of hot instant coffee (Nescafe classic). Similarly, Elitok et al.[8] reported an increase in both SBP and DBP after the consumption of 355 ml ED (Red Bull). In our study, the amount of increase is much more than in these studies. This might be due to the bigger amount of drink consumed which contains more caffeine. This can be explained by the dose-dependent manner of caffeine metabolism[25]. On the other hand, in our study, although there was a significant increase in heart rate after the consumption of cola and energy drink, this effect was not observed after coffee consumption. This unchangeability for coffee group was in line with the studies which reported no alteration in heart rate in response to coffee consumption[9, 26, 27]. The contents of ED and cola might affect the responses. For instance, taurine and glucose are known to rise HR[28] and cause an increase in cardiac output[29], respectively and taurine can cause arrhythmias by affecting the sodium channels deleteriously[30]. Also, it was reported that ephedra and guarana produced elevated ephedrine blood concentrations, increased heart rate, and blood pressure, and had unfavorable effects on glucose and potassium homeostasis[31]. Furthermore, small doses of yohimbine can increase blood pressure by causing a relatively selective α2 blockade[32]. Another important ingredient of energy drink, ginseng has adverse effects such that hypotension, palpitations, tachycardia, and edema[33]. However, the amount of ginseng in energy drinks is far below the amounts to cause adverse effects[34]. Unfortunately, to our knowledge, there are no scientific reports that investigated the cardiovascular effects of glucuronolactone alone and in combination with other ingredients of energy drink. Therefore, conclusions couldn't be reached regarding whether it has adverse effects or not.

In this study, we analyzed SDNN, RMSSD and NN50 which are time-domain indices and found no statistically significant difference in values of ED, coffee and cola groups when compared to control group after the consumption of the drinks. This result is in agreement with the study of An et al.[35] in which these time-domain parameters were calculated after 60 minutes of ED consumption. SDNN reflects all cyclic components which are responsible for HRV. These components are predominantly vagally mediated, even when a long period of sympathetic stimulation was recorded[36]. However, we recorded the signals from the participants for 5 minutes which can be accepted as a short recording duration. Therefore, we may have missed the changes in these parameters. Similarly, RMSSD reflects the beat-to-beat variance in HR and is used to estimate the vagally mediated changes reflected in HRV[37]. Since NN50 and RMSSD are calculated using the difference between successive NN intervals the same explanation can be valid for both.

It is known that HF component reflects parasympathetic activity and is related to the HR variations due to the respiratory cycle[37]. Also, LF component refers to the baroreceptor control

mechanisms and reflects the effect of sympathetic and vagal systems together[14]. We determined a tendency to reduction in LF and LF/HF ratio values of ED, coffee and cola groups and also a tendency to an increase in HF values after 30 and 60 minutes of drink consumption. These results reflect a probable increased vagal modulation. Furthermore, it is well known that caffeine intake increases vagal autonomic nerve activity in resting subjects[38] and low LF/HF ratio reflects parasympathetic dominance[37]. Like our results, Wiklund et al.[39] showed a decreased LF/HF ratio and increased HF power in their study and reported that intake of an ED alone appeared to increase vagal activity during rest. They found a significant reduction for LF/HF ratio, different than our study. This may be because of the high dose of ED consumed. We have found a significant reduction in LF/HF ratio for coffee group which includes a larger amount of caffeine than ED. Furthermore, this significance may be due to the amount of caffeine. Also, our study was in line with Monda et al.[21] who reported an increase in HF after the consumption of espresso containing 75 mg caffeine. However, there were some conflicting studies in which Nelson et al.[40] and An et al.[35] found no significant differences in time domain parameters at rest after 60 minutes of ED consumption. This may be due to the differences in volume consumed and study design.

The acute effects of caffeinated beverages on electrocardiographic parameters were evaluated in various studies[7, 8, 19]. Most of them reported that PR interval and QRS complex were not changed after caffeinated beverage consumption[19, 23, 41]. This was consistent with our results. Furthermore, QTc interval values of ED and cola group were decreased by 60 minutes after the beverage consumption it is compatible with the study of Garcia et al.[42] which reported a QTc shortening after consuming an energy drink containing 147.2 mg caffeine similar to our study. This may be because of either hyperfunction of the delayed rectifier potassium current or hypofunction of the calcium current. These result in a shortening of the repolarization period which explains the short QT interval, and short atrial and ventricular effective refractory periods. Ellermann et al.[43] suggested that high-dose taurine may be responsible for the abbreviation of effective refractory periods.

Moreover, there were some conflicting data in the literature which reported unchanged or increased QTc interval after ED consumption[7, 8, 23, 44]. This can be because of the difference in caffeine amount consumed. However, QTc interval duration stayed constant after coffee consumption different than ED and cola. Our result was consistent with previous research in which no significant change was reported[26, 45]. As a result, we suggest that caffeine alone does not affect the duration of QTc interval.

There were several limitations in this study. The number of participants was relatively small. The dose of caffeinated beverages consumed in this study can be considered as low dose. Results may vary at higher doses. The duration of ECG signal recording was relatively short. Longer-term effects can be studied if the recording period is increased. The effects of energy drink and cola ingredients could not be clearly investigated. Furthermore, our results are limited to the population studied, their effects on older or people with cardiovascular risk factors couldn't be evaluated.

In conclusion, caffeinated beverage consumption has possible negative effects on the electrocardiographic and hemodynamic parameters of young adults. Coffee has the most effect on these parameters when compared to ED and cola. Further studies must be planned to investigate the effects of these beverages at high doses and also their effects on various populations. Also, a study of us investigating the effects of the ingredients of energy drink on the human cardiovascular system is ongoing.

Yazar Katkıları: Çalışma konsepti/Tasarımı: ŞGÇ, MDB; Veri toplama: ŞGÇ, MDB; Veri analizi ve yorumlama: ŞGÇ, MDB; Yazı taslağı: SGÇ; İçeriğin eleştirel incelenmesi: ŞGÇ, MDB; Son onay ve sorumluluk: ŞGÇ, MDB; Teknik ve malzeme desteği: ŞGÇ, MDB; Süpervizyon: ŞGÇ, MDB; Fon sağlama (mevcut ise): yok.
Etik Onay: Bu çalışma için Adnan Menderes Üniversitesi Tıp Fakültesi İnvaziv Olmayan Klinik Araştırmalar Etik Kurulundan 30.04.2019 tarih ve 2017/1211 protokol numarası kararı ile etik onay alınmıştır.
Hakem Değerlendirmesi: Dış bağımsız.
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