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Original article

The Impact of Energy Beverage Consumption on Arterial Endothelial Function in Young Healthy Adults

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Abstract

Background: Many studies on the cardiovascular complications linked to energy drinks consumption imply that their effect on endothelial function might be a causal factor in subsequent cardiac events. **Aim:** This research investigated whether energy drinks consumption could cause acute endothelial function impairment as surrogated by flow-mediated dilation in healthy young adults. **Subjects and methods:** This observational study was done in Benha University Hospital in the period from July 2021 to June 2022, and included 50 healthy young adults for analyzing the normal endothelial function before and after consuming a single popular energy drink (ED) can, to assess its effect on endothelial function. All subjects underwent full history taking, clinical examination, Electrocardiogram, and flow-mediated vasodilation (FMD) measurements. **Results:** We included 50 healthy adults (mean age 24.02 ±2.69 years, 56% males). Regarding flow-mediated dilation parameters mean (SD) of pre-cuff brachial a diameter 90 m after ED was 3.82 ±0.43 mm (percent change= 4.66%, P < 0.001) while mean of post-cuff brachial a diameter 90 m after ED was 4.06 ± 0.40 mm (percent change= 2.11%, P=0.001), and relative FMD 90 m After ED was 6.43 ± 2.69 (percent change= -15.75%, P= 0.040). Regarding Hemodynamic changes, there was a statistically significant difference before and after energy drink consumption regarding systolic, diastolic blood pressures, and heart rate (P < 0.001 for all). **Conclusion:** The young healthy participants who consumed energy drinks exhibited a considerable high heart rate, systolic and diastolic blood pressures, and a considerable decline in endothelial function.

Keywords: Energy beverage, Arterial endothelial function, Flow-mediated dilatation, Young adults, Hemodynamics

Introduction

Energy drinks (ED) are non-alcoholic beverages typically drunk to receive a boost of energy for everyday tasks. The EDs consumption is steadily rising and has become a widespread trend, especially amongst young people [(1)]. They are carbonated beverages that comprise water, taurine, caffeine, B-group vitamins, glucuronolactone, glucose, saccharose, guarana essence, inositol, gingko biloba, ginseng, and carnitine. These components vary by brand and type [(2)].

The EDs can boost energy and stamina, accelerate mental and physical performance, and reduce fatigue, so young people tend to consume them during studying, driving, playing, and partying [(3)].

The EDs effect on endothelial cells may provide insights onto their impact on the cardiovascular system. The endothelial cells comprise the blood vessels inner lining and play synthetic and metabolic roles [(4)]. The endothelial cells dysfunction or abnormal function is linked to impaired vascular reactivity, pro-adhesion, pro-thrombosis, pro-inflammation, pro-adhesion, and growth promotion [(5)].

Many studies on the cardiovascular complications linked to EDs consumption imply that their effect on endothelial function might have a role in subsequent cardiac events [(4)]. Singly or in combination, the EDs components may be linked to diminished endothelial function [(6)].

The endothelial dysfunction, in which the endothelium function of regulating vascular resistance is weakened, may be mechanistically associated with decreased coronary blood flow [(7)]. After being exposed to stress, cold, anger, mental arithmetic, exercise, cigarette smoking, excess food, alcohol, or cocaine, the inability to dilate the coronary arteries might lead to an imbalance between the supply and demand or coronary spasm, which may result in coronary vasospasm, myocardial ischemia, thrombosis, and/or cardiac arrhythmia [(8)].

The current research aimed investigating whether energy drinks consumption could cause acutely endothelial function impairment as surrogated by flow-mediated dilation in healthy young adults.

Methods

This observational study was conducted in the Cardiology and Radiology Departments, Benha University, in the period from July 2021 to June 2022, and included 50 healthy young adults to analyze normal endothelial function before and after consuming a single popular ED can to assess its effect on endothelial function. The Ethics Committee of Benha Faculty of Medicine approved the study protocol. All individuals gave their consent to participate in this research.

Inclusion Criteria:

- Individuals with no apparent diseases
- Both sexes were included

- Age 20-30
- BMI 19-25 kg/m^2

Exclusion Criteria

1. Patients treated with any medical condition or receiving any treatment
2. Pregnancy or lactation
3. Smoking
4. Have a family history of sudden death
5. Ones using energy drinks regularly

All studied groups underwent the following:

Study protocol and methods

A review of clinical and laboratory data of all subjects was done including:

- History: including Personal history, history of any medical condition or previous hospital admission, drug history, and family history.
- Clinical examination, including Vital signs and systematic examination
- Laboratory investigations:
  - Random blood sugar
  - Complete blood count
  - Kidney function testes
  - Liver function tests
  - Lipid profile And Virology
- Electrocardiogram (ECG)

The participants received an electrocardiogram (ECG), blood pressure, and pulse check. Then, they underwent the endothelial function baseline testing (BL) by the endothelium-dependent flow-mediated dilatation (FMD) technique with high-resolution ultrasound following its guidelines, after abstaining from caffeine and food for at least 24 hours and 8 hours, respectively[9].

The relative FMD (%) was determined by dividing the maximum post-cuff release diameter by the diameter at baseline. The pictures were examined for quality control. Each artery diameter was measured from the media-to-media points by two specialists using three measurements at the QRS complex, repeated three times, and averaged.

Then, the participants consumed a 24-oz Red Bull ED can, which comprises high-quality components, including Caffeine, B-Group Vitamins, Taurine, Alpine-Water, and Sugars.

A 250 ml Red Bull ED can comprise roughly the same caffeine amount as a cup of coffee, 80 mg. The sugar amount in a Red Bull ED can is equivalent to the amount of sugars in 100 ml of apple or orange juices, 11 gm.

The participants relaxed on the measurement chair during the 90 minutes interval between the ED consumption and the second FMD. They were not allowed to move, eat, or drink. Hemodynamic measures were also taken at baseline and 90 minutes after ED consumption. During all measures, the participants were positioned supine. The 90 minutes duration was determined since prior studies used the 90-minutes cut-time point in determining the peak effect of the drink. [8]

Flow-mediated vasodilation measurements

Between 8:00 am and 12:00 pm, all examinations were done in a semi-dark

and tranquil atmosphere in an average temperature of 23°C. The participants were lied supine while the electrocardiographic monitoring was performed. Then, the sphygmomanometer cuff was put in the right forearm center. The FMD examination was done following Thijssen et al. recommendations [10].

Using a 10 MHz resolution linear array vascular ultrasound transducer with a Philips iE33 ultrasound machine, and as a guide for the following measurements, the skin was marked using a pen. After noting the anatomical components around the vessel, the vessels diameter and flow velocity were taken. All measures were taken at the R wave peak on the ECG.

From the anterior vessel wall intima to the posterior wall intima, the vessels diameter was determined, and three successive measurements were averaged on the same picture.

Then, parallel to the vessel, the pulsed wave (PW) Doppler sample volume was positioned, and the flow velocity measurements were taken. The sphygmomanometer cuff was inflated to a level greater than 50 mm Hg above the systolic blood pressure, following the baseline readings, and the vessel was occluded for five minutes. Subsequently, the cuff was deflated, and the PW flow velocity measurements were taken 15 seconds later. During the post-deflation hyperemia period, two-dimensional grayscale pictures of brachial artery diameters were observed for three minutes.

Images captured at 15 seconds intervals were utilized to measure diameters. The average of three successive measurements was taken. The highest measurement was recorded as the diameter of the peak.

Following the baseline measurements, the volunteer was instructed to consume within 20 minutes a 355 ml Red Bull ED can comprising 284 mg taurine, 53.25 mg caffeine, and 39 mg sugar.

FMD %=(peak arterial diameter at hyper emia-

basal arterial diameter)/basal arterial di ameter) ×100[5]

Statistical analysis

The continuous and qualitative data were presented as mean ± SD and number (%), respectively.

The student t-test and the Chi-Square tests were utilized for analyzing the continuous and categorial data, respectively. A < 0.05 evidence level was considered statistically significant. SPSS – “special package for special sciences”, was utilized for data analysis.

Results

The mean age was 24.02 ±2.69 years ranged between 20 to 30 years old with mean BMI of 22.24 ±1.95 kg/m^2 ranged between 19 to 25. Twenty-eight patients (56%) were males and 22 (44%) were females, regarding blood pressure and heart rate in selected individuals before consuming EDs, the mean Blood pressure was 113.40/75.10 mmHg and mean heart rate was 71.10 ppm (Table 1).

The mean of pre cuff brachial diameter Before ED was 3.66 ±0.44 mm while mean

post cuff release brachial diameter Before ED was 3.98 ±0.42 mm and mean of Relative FMD Before ED was 9.15 ± 3.93 (P= 0.018 when compared to relative FMD after ED) (Table 2). Regarding Blood pressure and heart rate in selected individuals after consuming EDs, the mean Blood pressure was 118/78.8 mmHg and mean heart rate was 74.10 ppm (P < 0.001 for all) (Table 3).

Regarding flow-mediated dilation parameters, mean (SD) of pre-cuff brachial artery diameter 90 m after ED was 3.82 ±0.43 mm while mean (SD) of post-cuff brachial artery diameter 90 m after ED was 4.06 ± 0.40 mm and relative FMD 90 m after ED was 6.43 ± 2.69 (Table 3).

Regarding Hemodynamic changes before and after energy drink consumption, there was a statistically significant difference before and after energy drink consumption according to (SBP, DBP, HR, pre-cuff brachial diameter, post-cuff release brachial a diameter and Relative FMD) (Table 3). Importantly, we did not record any significant occurrence of adverse effects and/or symptoms e.g., flushing or headache at the peak effect of the ED.

We used Linear regression analysis using the change (delta) of relative FMD (from baseline, i.e., before ED to after ED) as a dependent factor and using gender (male/female) as an independent factor. No significant relation between gender and relative FMD change was found (p=0.695).

Table 1: Baseline characteristics of study population

	Minimum	**Maximum**	**Mean**	**Std. Deviation**
Age (yrs)	20.00	30.00	24.02	2.69
BMI (Kg/m^2)	19.00	25.00	22.24	1.95

Gender	**Frequency**	**Percent**
Male	**28**	**56.0**
Female	**22**	**44.0**

Hemodynamics	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Baseline SBP (mmHg)	**90.00**	**130.00**	**113.40**	**12.55**
Baseline DBP (mmHg)	**60.00**	**85.00**	**75.10**	**7.99**
Baseline HR (bpm)	**60.00**	**90.00**	**71.10**	**8.10**

BMI= Body mass index; SBP= Systolic blood pressure; DBP= Diastolic blood pressure, HR= Heart rate

Table 2: Baseline flow-mediated dilation parameters before energy drink consumption

	Minimum	Maximum	Mean	Std. Deviation
Pre cuff brachial diameter before ED (mm)	3.00	4.50	3.66	0.44
Post cuff release brachial diameter before ED (mm)	3.20	4.80	3.98	0.42
Relative FMD before ED	2.22	19.35	9.15	3.93

FMD= Flow-mediated dilation; ED= Energy drink

Table 3: Hemodynamic changes before and after energy drink consumption

Item	Mean	T test	Sig.
Baseline SBP (mmHg)	113.40	0.832	<0.0001
Post ED SBP (mmHg)	118.00		
Percent change in SBP	4.34%	4.39	<0.0001
Baseline DBP (mmHg)	75.10	0.842	<0.0001
Post ED DBP (mmHg)	78.80		
Percent change in DBP	5.15%	5.84	<0.0001
Baseline HR (bpm)	71.10	0.643	<0.0001
Post ED HR (bpm)	74.10		
Percent change in HR	4.72%	3.22	0.002
Pre cuff brachial diameter before ED (mm)	3.66	0.961	<0.0001
Pre cuff brachial diameter 90 m after ED (mm)	3.82		
Percent change in Pre cuff brachial a diameter	4.66%	9.38	<0.0001
Post cuff release brachial diameter before ED (mm)	3.98	0.922	<0.0001
Post cuff brachial diameter 90 m after ED (mm)	4.06		
Percent change in Post cuff release brachial a diameter	2.11%	3.46	0.001
Relative FMD before ED	9.15	0.334	0.018
Relative FMD 90 m after ED	6.43		
Percent change in Relative FMD	-15.75%	-2.11	0.040

SBP= Systolic blood pressure; DBP= Diastolic blood pressure, HR= Heart rate; FMD= Flow-mediated dilation; ED= Energy drink

Discussion

The vascular endothelium functions as a barrier between the bloodstream and the vessel wall. In several ways, it is considered that changes in this single-cell layer of the arterial wall are of paramount relevance [(11)].

A decline in nitric oxide bioavailability is linked to the impairment of endothelial cell function. Nitric oxide is a vasodilator and platelet aggregation inhibitor with anti-proliferative and anti-inflammatory properties. FDM in the brachial artery is commonly utilized to indirectly measure endothelial cell function. It is a valid tool that strongly helps to predict cardiovascular events [(6)].

The energy products consumption, especially EDs, has become so common among young adults between 20 and 29 years old. The fact that the EDs manufacturers target young children and teenagers in their marketing campaigns should be an alarm for us [(12)]. They are marketed as drinks that enhance the physical and mental performance and lately as a substitute for coffee.

The EDs consumption has been associated with undesirable health problems, including risk-seeking behaviors, adverse cardiovascular effects, poor mental health, and dental, renal, or metabolic conditions [(13)].

Young healthy individuals who use energy drinks tend to have elevated heart rate and blood pressure and decreased endothelial function and hypercoagulability in the cardiovascular system. Additionally, many groups have detected a QTc interval prolongation linked to the EDs consumption [(14)].

In healthy young adults, according to research, the brachial artery FMD response to post-occlusion hyperemia is around 7%, with a range of 5% to 9.5% [(15)].

Our sample size was calculated using G*Power software version 3.1.9.2 based on a previous study [(16)], which reported a large FMD effect size after using energy beverage of approximately 1. The minimal sample size calculated was 10. The sample size was increased to 50 patients to adjust for using a non-parametric test to be 12. Alpha and power were adjusted at 0.05 and 0.8, respectively.

In the current research, the mean age was 24.02 ±2.69 years ranged between 20 to 30 years old with mean BMI of 22.24 ±1.95 kg/m^2 ranged between 19 to 25. Twenty-eight patients (56%) were males and 22 (44%) were females. As we selected volunteers in this study with specific criteria to ensure being a healthy young youth with no underlying cardiovascular pathology can interfere with our results, so volunteers' basic criteria were in the same line with many previous studies. In a previous study [(16)], forty-four volunteers (34 males) were included, 52% Caucasians and 27% Asians. Their average age was 24.7 years, and their BMI average was 23.4 kg/m^2.

Table.1 reveals these demographic data. While in another study [(17)], thirty healthy volunteers (15 males) were included. Their age ranged from 19 to 45. The volunteers were healthy, non-obese, and has a 24.2±5.3 kg/m^2 mean BMI.

Regarding blood pressure and heart rate in selected individuals before consuming EDs, the mean blood pressure was 113.40/75.10 mmHg, and the mean heart rate was 71.10 ppm. This was in line with Worthley et al**.**, the basal characteristics were 61 BPM heart rate and 81.2 mmHg mean arterial pressure [(18)], while in Akhundova et al. study, the basal characteristics were 111±11.4 mmHg systolic blood pressure, 72.3±7.9 mmHg diastolic blood pressure, and 72.6±9.5 BPM heart rate [(17)].

Regarding Hemodynamic changes before and after energy drink consumption, there was a statistically significant difference before and after energy drink consumption according to (SBP, DBP, HR, Pre cuff brachial diameter, Post cuff release brachial diameter and Relative FMD).

Our results agree with Higgins et al. study, the heart rate (62.3 ± 9.1 vs. 67.1 ± 8.7; p = 0.00005) and the diastolic blood pressure (67.6 ± 6 vs. 69.2 ± 6.5; p = 0.02) were considerably increased [(16)]. The electrocardiogram values did not alter at baseline or after consuming EDs.

The FMD investigation revealed a statistically considerable decline in endothelial function as determined by brachial artery diameter 90 minutes after consuming an ED [(16)]. The %FMD before

and after consuming an ED was 5.1 ± 4.1% and 2.8 ± 3.8%, respectively, (p = 0.004).

In contrast to our results, Akhundova et al. found no considerable alteration in systolic or diastolic blood pressures and heart rates 60 minutes before and after consuming EDs [17].

We used Linear regression analysis using the change (delta) of relative FMD (from baseline, i.e., before ED to after ED) as a dependent factor and using gender (male/female) as an independent factor.

We found no statistically significant relation between gender and relative FMD change (p=0.695). In contrast, Akhundova et al. reported that after consuming EDs, females had a 3% increase in preocclusion arterial diameters, while men had a 2.6% decrease (p=0.026) [17].

The lowest caffeine quantity was used in an ED to study its effect on endothelial functions [18]. The negative effects of EDs containing 80 mg caffeine were demonstrated on endothelial function using peripheral arterial tonometry hyperemia index and an increase in platelet reactivity. The peripheral arterial tonometry usage to determine the endothelial functions could be accountable for the different results, despite the fact that the caffeine doses utilized in the current research are close to their study. It was demonstrated that peripheral arterial tonometry, which predominantly examines the microvascular bed, did not correlate with FMD [19]. No considerable effects on the heart rate or blood pressure were noted on consuming low caffeinated EDs. The studies that utilized greater caffeinated EDs demonstrated a rise in at least one variable, such as systolic and diastolic blood pressures or heart rate [16], which is consistent with our findings.

FMD is an effective method to study the reactions of larger conduit arteries.

The vasodilatory response of a medium-sized conduit artery, such as the brachial artery is depending on nitric oxide (NO), while the hyperemic reactions in the microvascular bed are the result of more sophisticated processes that are not depending on NO [20].

Conclusion

The young healthy participants who consumed energy drinks exhibited a considerable high heart rate, systolic and diastolic blood pressures, and a considerable decline in endothelial function.

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