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The Effects of Energy Drink Consumption on Kidney and Liver Function: A Comparative Study

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Abstract

The current study aimed to investigate the potential health impacts associated with Energy Drink (ED) consumption and its effects on general health, liver function, and kidney function among students at Jazan University. EDs contain a variety of ingredients such as taurine, arginine, caffeine, acidity regulators, B vitamins, vitamin C, herbal extracts, and sugar. Previous studies have reported that EDs contain more caffeine content more a cup of coffee. Fifty-seven volunteer female students from the same socioeconomic background were eligible for the study based on their ED consumption habits. The students were divided into four groups: the control group (1) which did not consume EDs (19 students), group (2) which consumed 2 - 3 cans per week (19 students), group (3) which consumed 4 - 7 cans per week (14 students), and group (4) which consumed more than 7 cans per week (5 students). Five milliliters of venous blood were drawn from all subjects to determine ALT, AST, and GGT levels for liver function tests and creatinine, urea, uric acid, and BUN levels for kidney function tests. The results of the kidney function analysis showed that uric acid levels significantly increased ($P < 0.05$) in group 3 compared to the control group. Creatinine analysis showed no significant relationship ($P > 0.05$) in all groups compared to the control group. The liver function analysis illustrated that, compared to the control group, only AST was significantly increased ($P < 0.05$) in groups 1 and 2. There was no significance in ALT and GGT in all groups. Overall, the study found that long-term ED consumption had a significant relationship to increased uric acid and AST concentrations, while urea and BUN decreased significantly. Further research is needed to understand the long-term health implications of ED consumption.

Keywords

Energy Drink, ALT, AST, GGT, Creatinine, Uric Acid

1. Introduction

Energy drinks (EDs) are non-alcoholic beverages containing a high amount of caffeine and several other psychoactive substances, including the amino acid taurine, the glucose derivative glucuronolactone, and herbal extracts such as ginseng and guaranà (another source of caffeine, with caffeine-like effects), often present in uncertain concentrations [1]. EDs were placed on the market in the 1960s in Europe and Asia and they have spread worldwide since the end of the last century [2]. The short- and long-term health effects of EDs consumption on the cardiovascular and central nervous system have been intensively studied. EDs have been shown to cause several adverse effects in humans, and particularly in young people, including high blood pressure, serious cardiovascular events, kidney disorders, metabolic adverse effects, poor sleep, seizures, and neuropsychiatric adverse effects [3].

In the U.S., energy drinks are the second most common dietary supplement used by young people; about 30% consume EDs on a regular basis (Simon and Mosher, 2007). The popularity of energy drinks in the Kingdom of Saudi Arabia does not seem to differ from other parts of the world, Around half of the Saudi University students who participated in a survey admitted to regular consumption of energy [4]. Consumption of EDs has been increasing dramatically in the last two decades, particularly among adolescents and young adults. EDs are aggressively marketed with the claim that these products give an energy boost to improve physical and cognitive performance. However, studies supporting these claims are limited. In fact, several adverse health effects have been related to ED; this has raised the question of whether these beverages are safe [5].

The ingredients present in EDs act as stimulants, and are not included in the list of materials under regulation by the Food and Drug Administration (FDA) of the United States of America. The levels of these stimulants vary amongst different brands of EDs, and in most cases, are higher than values allowable [6]. A study has shown that the caffeine levels in EDs are between 50 and 505 mg/can, which is much higher than the caffeine content of one can of Coke (34 mg) [7]. Reports of significant, adverse health problems due to ingestion of EDs have increased in recent years. Indeed, in 2013, ED-associated emergency interventions by the US Substance Abuse and Mental Health Services Administration doubled from 10,068 in 2017 to over 20,000 in 2011 [8].

Healthy persons experienced increased systolic heart pressure (from 6 to 10 mm Hg) in the period of one to two hours after consuming an energy drink, as well as increased diastolic heart pressure (from 3 to 6 mm Hg) and increased heart rate (from 3 to 7 bpm), Atrial brillation was noted in healthy persons after

consuming an energy drink. With consumption of several energy drinks in a short period of time, researchers noted ventricular arrhythmia [9]. Haemorrhage of coronary arteries is likely in healthy adults who drink between 2 and 8 energy drinks. Researchers have established a link between excessive consumption of energy drinks and epileptic seizures, reversible cerebral vasoconstriction, brain haemorrhage, acute kidney failure, rhabdomyolysis, metabolic acidosis, hyperinsulinemia [10].

Although multiple effects of caffeine or caffeine-containing beverages have been observed on the GI tract, little attention has been paid to the possible contribution of these beverages to inflammation or the activation of immune cells. Recently, a study reported that EDs consumption can exert an anti inflammatory effect in vitro, by reducing the release of Interferon (IFN)-γ by endothelial cells, the secretion of Interleukin (IL)-6 and Tumor necrosis factor (TNF)-α by cell lines of monocytic origin, and can reduce experimental colitis in rats, suggesting that EDs can have an effect on inflammation and immune response [11].

Energy drinks contain from 0 to 67 grams of carbohydrates (glucose and fructose) per 240 ml of beverage. According to the criteria of British Food Standard Agency (FSA), this classies energy drinks among foods and beverages with high sugar content. Food and beverages containing more than 10 grams of sugar per 100 grams of product tend to fall into this group. The best-selling energy drink contains 11 grams of sugar per 100 ml of beverage, which equals six or seven teaspoons of sugar for a 250 ml can [12]. Sugary drink consumption is associated with obesity, dental cavities, type II diabetes, and cardiovascular diseases [13].

Khayyat *et al.* in 2014 mentioned that administration of ED caused renal toxicity that demonstrated by an elevation of urea, uric acid and creatinine and this elevation was time dependant [14]. This is in agreement with the results of Ugwuja (2014) who reported that, consumption of energy drink Bullet® alone or with alcohol resulted in higher urea, uric acid and creatinine in the serum of rats [15]. The authors attributed the effect of energy drinks on renal function to caffeine which is one of the main ingredients of energy drinks. Many researchers showed that caffeine can increase the serum urea and creatinine concentration [16]. Caffeine also promotes sodium losses in urine (natriuresis), which effects the plasma volume and results in significant alteration of cardiovascular performance while exercising [17]. In addition, sodium imbalance during prolonged exercise in a hot environment may reduce isometric force in the legs [18].

In energy supplements the content of niacin and caffeine is more than the content of vitamins and minerals. Caffeine in energy supplements has an effect like nicotine on cigarettes that can make people become dependent. Niacin and caffeine compounds are not energy source molecules but only function as simulants. Niacin combination and caffeine in energy supplements will stimulate the central nervous system to trigger a catabolism reaction (a reaction to produce energy) in the muscle [19].

In a healthy body condition, excess substances in energy supplements will be processed first in the liver and then excreted by the body through urine fluid, sweat, or faeces. With the presence of stimulant ingredients such as taurine and caffeine found in energy supplements, the liver's work becomes much more difficult. Direct toxicity will occur in a matter of hours and is fatal; while the toxicity effect does not occur directly due to long-term accumulation by slowly causing liver damage, Damage to liver function can be caused by a variety of factors, including a drinking habit, viral infections, and long-term use of certain drugs. People are increasingly suffering from liver damage as a result of their addiction to energy drinks. One bottle of energy drinks contains the equivalent of 40 mg of niacin. If consuming excessive niacin will cause liver damage, with an LD50 limit niacin is 50 mg/kg BB. Niacin needed by the body is based on the Nutrition Adequacy Rate (RDA), which recommends the consumption of niacin 14 mg/day in adult women and 16 mg/day in adult men [19].

2. Materials and Methods

Study population and design the study design is a cross-sectional analytical cohort study that aims to evaluate the effect of energy drink (ED) consumption on kidney and liver function tests. A total of 57 students and staff members from the Applied Medical Science College were recruited for the study, specifically those who consumed more than one can of ED per day. The study population was divided into four groups: a control group which did not consume EDs (19 participants), a group which consumed 2 - 3 cans per week (19 participants), a group which consumed 4 - 7 cans per week (14 participants), and a group which consumed more than 7 cans per week (5 participants).

Sample collection and methods 4 ml of venous blood samples were collected from each participant using a syringe and under antiseptic conditions. The samples were collected in dry serum tubes and left to clot for 10 - 15 minutes before being centrifuged at 1000 ×g for 5 minutes. The serum was separated and stored at −20˚C in aliquots for liver function tests (ALT, AST, GGT) and kidney function tests (Creatinine, Urea, Uric acid, BUN). The blood samples were analyzed at the biochemistry lab of the Applied Medical Science College using an automated Humastar 200 instrument and a semi-automated Microlab 300 instrument. The tests were estimated using colorimetric and kinetic methods with human reagent kits.

2.1. Eligibility Criteria

Inclusion Criteria: Participants who consumed at least 2 cans of ED per week for at least two years. Exclusion Criteria: Participants who consumed less than 2 cans of ED per week, pregnant women, individuals with high blood pressure, and patients with hepatitis B or C.

2.2. Statistical Analyses

Data are presented as mean ± SE. One-way analysis of variance (ANOVA) was

used for assessing differences among groups, followed by Bonferroni post-hoc paired comparison using Windows SPSS version 20.0 (SPSS Inc., Chicago IL, USA). $P < 0.05$ was considered statistically significant.

3. Results

The study included 57 participants, whose ages ranged from 18 - 34 years old with a mean of 20.98 and a standard deviation of 2.6. Blood samples were collected from 19 participants who did not consume energy drinks as a control group, and from 38 energy drink consumers. When comparing the mean liver function test results between the control group and energy drink consumers, it was found that there was no significant difference in ALT and GGT levels. However, there was a significant difference in AST levels, with an increase observed in energy drink consumers.

Similarly, when comparing the mean kidney function test results between the control group and energy drink consumers, it was found that there was no difference in creatinine and uric acid levels. However, there were significant differences in urea and BUN levels, with a decrease observed in energy drink consumers.

When the energy drink consumers were divided into three groups based on the frequency of their energy drink consumption, the following was observed:

Kidney function analysis showed that uric acid levels were significantly increased ($P < 0.05$) in group 3 (with a mean of 7.33 ± 0.956) compared to the control group. However, there was no significance in group 1 (with a mean of 4.87 ± 0.299) and group 2 (with a mean of 4.86 ± 0.312). Urea levels were significantly decreased ($P < 0.05$) in group 1 and 2 (with means of 30.61 ± 2.16 and 30.07 ± 2.16 respectively) compared to the control group, but there was no significance in group 3 (with a mean of 38 ± 1.84). BUN levels were also significantly decreased ($P < 0.05$) in group 1 and 2 (with means of 17.76 ± 0.861 and 14.30 ± 1.01 respectively), but there was no significance in group 3. Creatinine analysis showed no significant relation ($P > 0.05$) in all groups compared to the control group (with means of 0.60 ± 0.048, 0.64 ± 0.038 and 0.65 ± 0.036 respectively) as shown in Table 1.

Liver function analysis illustrated that compared with the control group, only AST was significantly increased ($P < 0.05$) in group 1 and 2 (with means of 32.36 ± 4.96 and 25.75 ± 3.88 respectively). There was no significance in ALT levels in all groups (with means of 13.25 ± 1.65, 14.13 ± 1.53 and 12.5 ± 2.5 respectively) and no significance in GGT levels in all groups (with means of 15.21 ± 2.25, 15.64 ± 2.73 and 15 ± 4.92 respectively) as Table 2.

In summary, creatinine levels were found to increase at a very small rate with increasing energy drink consumption, with the most significant effect observed in group 3, which consumed more than 7 cans per week. Uric acid levels were found to increase significantly in group 3 compared to the control group. Urea and BUN levels were found to decrease significantly in energy drink consumers compared to the control group. ALT levels were found to increase in groups 1

Table 1. Kidney function analysis.

		Mean ± SE	significance
Creatinine	Control	**0.62 ±0.026**	
	Group 1	**0.60 ±0.048**	**NS**
	Group 2	**0.64 ±0.038**	**NS**
	Group 3	**0.65 ±0.036**	**NS**
Uric	Control	**4.88 ±0.474**	
	Group 1	**4.87 ±0.299**	**NS**
	Group 2	**4.86 ±0.312**	**NS**
	Group 3	**7.33 ±0.956**	**P < 0.05**
Urea	Control	**38 ± 1.84**	
	Group 1	**30.61 ± 2.16**	**P < 0.05**
	Group 2	**30.07 ± 2.16**	**P < 0.05**
	Group 3	**32 ± 4.56**	**NS**
BUN	Control	**17.76 ± 0.861**	
	Group 1	**14.30 ± 1.01**	**P < 0.05**
	Group 2	**14.05 ± 1.01**	**P < 0.05**
	Group 3	**14.95 ± 2.13**	**NS**

Control group: a control group which did not consume EDs (19 participants), Group 1: a group which consumed 2 - 3 cans per week (19 participants), Group 2 a group which consumed 4 - 7 cans per week (14 participants), Group 3: a group which consumed more than 7 cans per week (5 participants). BUN: Blood urea nitrogen.

Table 2. Liver function analysis.

		Mean ± SE	significance
AST U/ml	Control	**17.71 ± 1.75**	
	Group 1	**32.36 ± 4.96**	**P < 0.05**
	Group 2	**25.75 ± 3.88**	**P < 0.05**
	Group 3	**17 ± 2**	**NS**
ALT U/ml	Control	**12.85 ± 1.75**	
	Group 1	**13.25 ± 1.65**	**NS**
	Group 2	**14.13 ± 1.53**	**NS**
	Group 3	**12.5 ± 2.5**	**NS**
GGT U/ml	Control	**15.79 ± 1.09**	
	Group 1	**15.21 ± 2.25**	**NS**
	Group 2	**15.64 ± 2.73**	**NS**
	Group 3	**15 ± 4.92**	**NS**

Control group: a control group which did not consume EDs (19 participants), **Group 1:** a group which consumed 2 - 3 cans per week (19 participants); **Group 2** a group which consumed 4 - 7 cans per week (14 participants); **Group 3:** a group which consumed more than 7 cans per week (5 participants). **AST:** Aspartate Transaminase, **ALT:** Alanine Transaminase, **GGT:** Gamma-Glutamyl Transferase.

and 2 compared to the control group, while levels in group 3 decreased compared to the control group, with no significant relation observed. AST levels were found to increase in groups 1 and 2 compared to the control group, while no change was observed in group 3 compared to the control group. A significant relationship was observed in groups 1 and 2. GGT levels were found to decrease between groups groups 1, 2 and 3 compared to the control group.

4. Discussion

Energy drinks (EDs) are non-alcoholic drinks with high concentrations of caffeine (>150 mg/L), together with other substances that may be ergogenic (such as taurine, ginseng, guarana, or other herbal extracts, L-carnitine, and B vitamins), and occasionally sugars or sweeteners. The typical serving size for caffeine is 50 to 505 mg, which is three or more times the amount of caffeine in soft drinks [20].

Energy drinks have become increasingly popular in Saudi Arabia in recent years, with a wide variety of brands and flavors available on the market. These drinks are marketed as a way to boost energy and improve focus and concentration, making them popular among students, athletes, and professionals. According to research by [21], energy drinks are consumed by many people in Saudi Arabia and the majority of consumers are young adults aged between 18 - 24 years old. The research also shows that the most common reason for consuming energy drinks is to improve physical and mental performance.

However, energy drinks can have negative effects on health, particularly if consumed in large quantities. A study by [21] found that frequent consumption of energy drinks is associated with an increased risk of hypertension and obesity. The study also found that energy drink consumption is associated with poor dietary habits and a lack of physical activity.

The objective of this research was to examine the impact of consuming energy drinks on the kidney and liver functions of female applied medical science students. The results showed no correlation between energy drink consumption and creatinine levels in the serum. This finding is consistent with another study that found no significant differences ($P > 0.05$) in creatinine levels between the experimental and control groups [22].

Our research indicated a strong relationship between energy drink consumption and levels of uric acid in one of the group (3). This aligns with the findings of another study, which found that high doses of energy drinks combined with alcohol resulted in significant ($P < 0.05$) increases in uric acid levels [15].

The results of our research showed a significant decrease in urea concentration with energy drink consumption ($P < 0.05$), which contrasts with another study that found a significant increase ($P < 0.05$) in urea concentrations in the experimental groups compared to the control group in rats [22]. A reduced urea concentration is often a sign of advanced liver disease, highlighting the central role that the liver plays in urea production through the urea cycle. Urea cycle

defects, a rare group of conditions characterized by an inherited deficiency of any one of the five enzymes in the urea cycle, can lead to reduced urea synthesis and a corresponding decrease in plasma/serum urea concentration [22].

Our study found no connection between energy drink consumption and ALT levels ($P > 0.05$), with all participants having low ALT values. This is consistent with another study that showed rats given energy drinks had lower ALT levels than the control group (Ebuehi, *et al.* 2011). However, another study found a significant increase ($P < 0.05$) in ALT levels in experimental rats compared to the control group [15].

The results of our study indicated no correlation between energy drink consumption and ALT ($P < 0.05$), but all the consumers had low ALT values. This is consistent with another study that found lower ALT in rats given energy drinks compared to the control group [23]. However, another study showed higher ALT levels ($P < 0.05$) in experimental rats in general as compared to the control group (Ugwuja 2014). Our study showed a significant increase in AST levels with energy drink consumption ($P < 0.05$), which aligns with another study that found higher AST levels in rats co-administered higher doses of energy drinks and alcohol [15]. In contrast, another study found lower AST in rats given energy drinks

The results of our research indicated that there was no association between the consumption of energy drinks and the levels of Gamma Glutamyl Transferase (GGT). However, other studies have suggested that excessive consumption of energy supplements can lead to an increase in GGT levels. This increase can be influenced by several factors, including the use of certain drugs, alcohol consumption, and long-term consumption of high-energy supplements. Factors like these can affect the results of a Gamma Glutamyl Transferase (GGT) test and, for example, drugs like phenytoin and flaccid can result in a false positive outcome [4].

In another study, the consumption of energy drinks (ED) by rats over a period of 12 weeks caused significant damage to both the liver and kidneys. This was indicated by significant increases in the levels of serum AST, ALT, ALP, creatinine, BUN, and uric acid. The presence of elevated levels of hepatic enzymes in the blood is a reliable marker of liver damage due to toxic substances. This is similar to the increases in serum AST, ALT, and ALP levels observed in rats that were exposed to caffeinated energy drinks [24].

Following the consumption of Redbull®, there were changes in the carotid artery and middle cerebral artery velocities, cardiac output, heart rate, and a small but not statistically significant rise in systolic and diastolic blood pressure. Whatever pathophysiological mechanisms are in fact behind these modifications is still unknown [25].

Although energy drink intake was widespread among medical students, their understanding of the substances and potential health hazards was lacking [26].

In conclusion, the study found that long-term ED consumption had a significant relationship with increasing uric acid and AST concentrations, while urea

and BUN decreased significantly. Further research is necessary to understand the long-term health implications of ED consumption. In the end, energy drinks can be a convenient and effective way to boost energy and improve focus, but it is important to consume them in moderation and be aware of the potential negative side effects. It is always recommended to check with a healthcare professional before consuming energy drinks, especially if you have any underlying health conditions.

The study found that long-term ED consumption had a significant relationship with increasing uric acid and AST concentrations, while urea and BUN decreased significantly. Energy drinks can be a convenient and effective way to boost energy and improve focus, but it is important to consume them in moderation and be aware of the potential negative side effects. It is always recommended to check with a healthcare professional before consuming energy drinks, especially if you have any underlying health conditions. Further research is necessary to understand the long-term health implications of ED consumption.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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