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Energy Drink Consumption: Beneficial and Adverse Health Effects

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Abstract

Consumption of energy drinks has been increasing dramatically in the last two decades, particularly amongst adolescents and young adults. Energy drinks 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 energy drink; this has raised the question of whether these beverages are safe. This review was carried out to identify and discuss the published articles that examined the beneficial and adverse health effects related to energy drink. It is concluded that although energy drink may have beneficial effects on physical performance, these products also have possible detrimental health consequences. Marketing of energy drinks should be limited or forbidden until independent research confirms their safety, particularly among adolescents.

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Introduction

Energy drinks belong to a class of products, in liquid form, that typically contain caffeine, with or without other added dietary supplements. The first energy drink appeared in the U.S. in 1949 and was marketed as "Dr. Enuf". [1] In Europe, they were launched for the first time in 1987; then the market expanded throughout the world, becoming very popular after the launch of Red Bull in 1997. [2] Since then, the energy drink market has grown dramatically, with various brands released worldwide. The annual consumption of energy drinks in 2013 exceeded 5.8 billion liters in around 160 countries. [3] The estimated total U.S. retail market value for energy drinks was around 12.5 billion USD in 2012 and the market increased 56% from 2006 to 2002. [2]

Manufacturers recently have shifted their consumer focus from athletes to young people. Energy drinks are aggressively marketed in places popular with teens and young adults. Approximately, two thirds of energy drink consumers are 13-35 years old, and boys are two thirds of the market. [4] In the U.S., energy drinks are the second most common dietary supplement used by young people; about 30% consume energy drinks on a regular basis. [5] 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. [6]

Energy drinks are designed to give an "energy boost" to the drinker by a combination of stimulants and energy boosters. The major constituent in most energy drinks is caffeine. They usually contain 80-150 mg of caffeine per 8 ounces, which is equivalent to 5 ounces of coffee or two 12-ounce cans of caffeinated soda. [7] Most of the brands on the market contain large amounts of glucose while some brands offer artificially sweetened versions. Other commonly used constituents are taurine, methylxanthines, vitamin B, ginseng, guarana, yerba mate, acai, maltodextrin, inositol, carnitine, creatine, glucuronolactone, and ginkgo biloba.

Currently, significant concerns have been raised about the safety of these products. There have been several reports that showed adverse health effects associated with energy drink. Despite this, manufactures of energy drinks claim these products are suitable for consumers and that they are safe. In fact, the adverse health effects associated with energy drink remains controversial among scientists. There are limited comprehensive literature reviews that illustrate in detail the suitability and safety related to energy drink consumption, particularly among young adults. Here we review the available literature on the beneficial and adverse health effects related to energy drinks consumption.

Potential adverse effects of energy drinks in relation to their ingredients

Cardiovascular effect:

Several studies have shown an increase in heart rate and arterial blood pressure after energy drink consumption. These findings were attributed to the ergogenic effects of the caffeine content of the energy drink. In addition, significant cardiac manifestations such as ventricular arrhythmias, ST segment elevation and QT prolongation have been documented following energy drink overconsumption. [8] Additionally, atrial fibrillation has been reported after high energy drinks ingestion in two healthy boys, 14 and 16 years of age. [9] Recently, energy drink consumption has been related to myocardial infarction in healthy 17-and 19-year-old boys. [10, 11] This observation has been supported by the findings that consuming energy drinks reduces endothelial function and stimulates platelet activity through arachidonic acid-induced platelet aggregation in healthy young adults. [12] Recent reports have demonstrated a relationship between energy drink overconsumption and arterial dilatation, aneurysm formation, dissection and rupture of large arteries. [13]

Neurological and psychological effect:

Individuals usually develop symptoms of caffeine intoxication in doses equal to or above 200 mg. Symptoms include anxiety, insomnia, gastrointestinal upset, muscle twitching, restlessness, and periods of inexhaustibility. [14] In addition, High caffeine intake is associated with acute and chronic daily headaches by stimulating a pro-nociceptive state of cortical hyperexcitability. [15] Four caffeine-induced psychiatric disorders have been recognized by the Diagnostic and Statistical Manual of Mental Disorders, 4th edition: Including caffeine intoxication, caffeine-induced anxiety, caffeine-

induced sleep disorder and caffeine related disorder. [16] A study of adolescents between 15- and 16-years-of age demonstrated a strong correlation between caffeine intake and violent behavior as well as conduct disorders. [17] Several reports have suggested that energy drink may contribute to ischemic stroke and lead to epileptic seizures. [18] Hallucinations might be observed in individuals that consume more than 300 mg of caffeine per day. [19] High levels of cortisol that follow caffeine intake could explain this. Cortisol enhances the physiological effects of stress resulting in a greater tendency for the subjects to hallucinate. [20]

In vitro studies found that a combination of caffeine, taurine and guarana may promote and enhance apoptosis by reducing both superoxide dismutase and catalase activities on human neuronal SH-SY5Y cells. [21]

Gastrointestinal and metabolic effects:

Energy drinks usually contain large amounts of sugar ranging from 21 g to 34 g per oz. The sugar content is mainly in the form of sucrose, glucose or high fructose corn syrup. Therefore, high energy drink intake may increase the risk of obesity and type 2 diabetes. [14] In addition, the high sugar content in energy drinks may reduce the activity, diversity and gene expression of intestinal bacteria resulting in increased risk of obesity and the metabolic syndrome. [22] Acute caffeine intake decreases insulin sensitivity, [23] which could explain the rise in blood glucose levels after energy drink consumption documented in some studies. [24] Beaudoin et al. demonstrated that caffeine intake reduces insulin sensitivity in a dose dependent manner, with 5.8% increase in insulin for each mg/kg increase in caffeine. [25]

A case has been reported of a woman that presented with jaundice, abdominal pain and highly elevated liver enzymes following energy drink overconsumption. [26] Huang et al. reported the same finding in a 36-year-old man. [27] Further studies are needed to determine, which individuals are highly susceptible and the underlying mechanism by which energy drinks cause hepatic injury.

Renal effects:

The caffeine in energy drinks has been shown to enhance diuresis. [28] Therefore, energy drinks should be avoided during prolonged exercise in a hot environment because of the potential for dehydration. Studies have reported that dehydration at a level of 1.5% during prolonged exercise may result in an increase in body temperature, heart rate and perceived rate of exertion. [29]

Caffeine also promotes sodium losses in urine (natriuresis), which effects the plasma volume and results in significant alteration of cardiovascular performance while exercising. [30] In addition, sodium imbalance during prolonged exercise in a hot environment may reduce isometric force in the legs. [31] Greene et al reported a case of acute renal insult in a 40-year-old-year man after daily intake of energy drinks for about 2-3 weeks. The serum creatinine was increased fivefold from baseline and returned to normal two days after energy drink consumption was discontinued. [32]

Dental effects:

A study in Sweden showed a strong relationship between energy drinks and dental erosion. [33] Similarly, Marshall et al demonstrated a similar observation in American children. [34] Energy drinks consumption was associated with about a 2.4-fold increase in dental erosion. This has been attributed to a low pH and the high sugar content of energy drinks. [35] In addition, Pinto et al found that energy drink intake may lead to cervical dentin hypersensitivity by removing the smear layer of the teeth. [36]

Beneficial effects:

The large amount of caffeine in energy drinks provides the consumer with the desirable effects of improved memory, increased alertness and elevated mood. The most widely cited study is the one conducted by Alford et al. [37] They examined the effects of a market leader energy drink on 36 individuals. Assessments included psychomotor performance (reaction time, concentration and memory), subjective alertness and physical endurance. They showed that the studied energy drink significantly enhanced aerobic endurance (maintaining 65-75% max. heart rate) and aerobic performance (maintaining max. speed) on cycle ergometers. Mental performance included choice reaction, concentration and memory also improved significantly, which indicated increased subjective alertness. [37] Another study showed that the same brand energy drink significantly

increases the upper body muscle endurance during repeated 'Wingate cycle performance' in young physically active subjects. However, no change was documented on anaerobic peak or average power. [38] Hoffman et al also demonstrated that energy drinks caused a significant increase in reaction performance during exercise, but with no effect on anaerobic power performance. [39] Likewise, Ivy et al in a double-blinded, randomized, crossover study examined the effects of pre-exercise consumption of energy drinks on 12 professional cyclists from both genders. The results showed significant improvement in endurance performance with no change in perceived exertion in the energy drink group compared to the placebo group. [40]

Walsh et al assessed the effects of energy drinks on time to exhaustion during treadmill exercise. They observed a significant increase in time to exhaustion during a moderate intensity endurance run as well as improvement in perceived feelings of focus, energy and fatigue. [41] Another study evaluated the ability of caffeinated energy drinks to improve acceleration tolerance and strength under a "G" load. The results showed that energy drinks improved relaxed G tolerance and increased strength but had no effect on acceleration tolerance duration. [42]

The results of a recent study reported that consumption of approximately 3 mg/kg of caffeine in the form of energy drinks significantly improved the physical performance of female volleyball players. [43] Wesnes et al in a randomized, double blind, placebo controlled, cross over study examined the cognitive and mood effects of energy drinks on 94 subjects. Assessment of cognitive function was performed with a number of automated tests of memory and attention while mood was assessed with various different questionnaires such as the Profile of Mood states (POMS), Bond-Lader and Chalder Fatigue Scales. The results revealed that both cognitive function and mood were significantly improved in partially sleep-deprived individuals who consumed energy drinks. They were able to preserve their initial levels of attention for a period of six hours, whereas the placebo group failed. [44]

A number of studies have examined the behavioral effects of energy drinks containing caffeine, glucose, taurine, and vitamins amongst its components. These studies found improvements in aerobic and anaerobic cycling performance, [37] attention performance and/or reaction time tasks, [37, 45] afternoon driving performance, [46] and different indices of alertness. [37, 45, 46] Smit and Roger compared the behavioral effects of two tailor-made energy drinks with a still water and no treatment conditions. Both energy drinks contained 75 mg caffeine and the same calorie amount from glucose. In comparison to the water and no treatment groups, both drinks significantly increased reaction time and self-ratings of energetic arousal. However, no changes were observed for either memory or rapid visual information processing. [47]

The combination of caffeine and glucose in energy drinks may show restorative properties. [48] In one study, a glucose based energy drink was given to 11 tired volunteers being examined in a driving simulator. Significant improvement was observed in lane drifting and reaction times for two hours post consumption. [49] Another study examined the acute effects of a glucose based energy drink on cognitive function. The results showed that energy drink reduced both reaction times on the behavioral control tasks as well as ratings of mental fatigue, whereas it increased subjective ratings of stimulation. [50]

It is very important to note that although the above-mentioned studies have identified positive effects of energy drinks on exercise performance, other researches have documented no significant effects or detrimental health consequences. Al-fares et al [51] in a single blind placebo controlled study recently evaluated the effects of energy drinks on exercise performance in 32 untrained healthy females. They found that ingestion of energy drinks before exercise did not enhance the indices of physical performance, which included time to exhaustion, maximum oxygen consumption, blood pressure, heart rate, and capillary oxygen saturation. Similar findings were observed in a double blind, randomized, placebo controlled cross over study of 15 physically active volunteers. The study found no effect of energy drinks on ride time to exhaustion or heart rate. Subjective rating of exertion was also not changed. [52]

A recent study [53] evaluated the acute effects of energy drinks on exercise performance in 19 professional female volleyball players. The players were recruited in

a double blind, randomized, crossover study to determine grip strength, vertical jump and anaerobic power during three sessions. For each performance test, there was no significant change indicating that energy drink had no effect on improving physical performance.

The variability in the results of the above studies is mainly due to methodological differences. Variations in subjects, gender, dose of caffeine, ingredients of energy drinks, and type of placebo used contribute significantly to the inconsistency of the results.

Conclusion:

Energy drinks may show positive beneficial effects on exercise performance in various sport activities. However, while energy drinks might benefit performance, possible detrimental health problems have been documented, particularly amongst children and adolescents. Various parts of the body are negatively affected by energy drink consumption. Considering this fact and the increasing popularity of these drinks, caution should be exercised while consuming energy drinks. Overambitious marketing and non-scientific claims should be regulated by governments until independent studies confirm that that these products are safe.

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