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To what extent do energy drinks negatively impact neurophysiological well-being?

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Abstract

The consumption of energy drinks has been increasing at an unprecedented rate over the last few years. However, the formulation of such drinks can lead to several impacts on the consumers' neurophysiological well-being. Whilst some of these impacts may be positive, core ingredients such as caffeine and glucose, when consumed in such high doses pose several threats to overall health. In light of the aforementioned, this research paper focuses on analysing the energy drinks industry, the drawbacks of the lack of regulatory overview in advertisements as well as the specific neurophysiological effects of caffeine and glucose consumption.

Introduction

The global energy drink industry made a whopping revenue of over 166 billion US dollars in 2022 (Ridder, 2022). For an industry that large, its potential negative impacts are certainly a matter of concern.

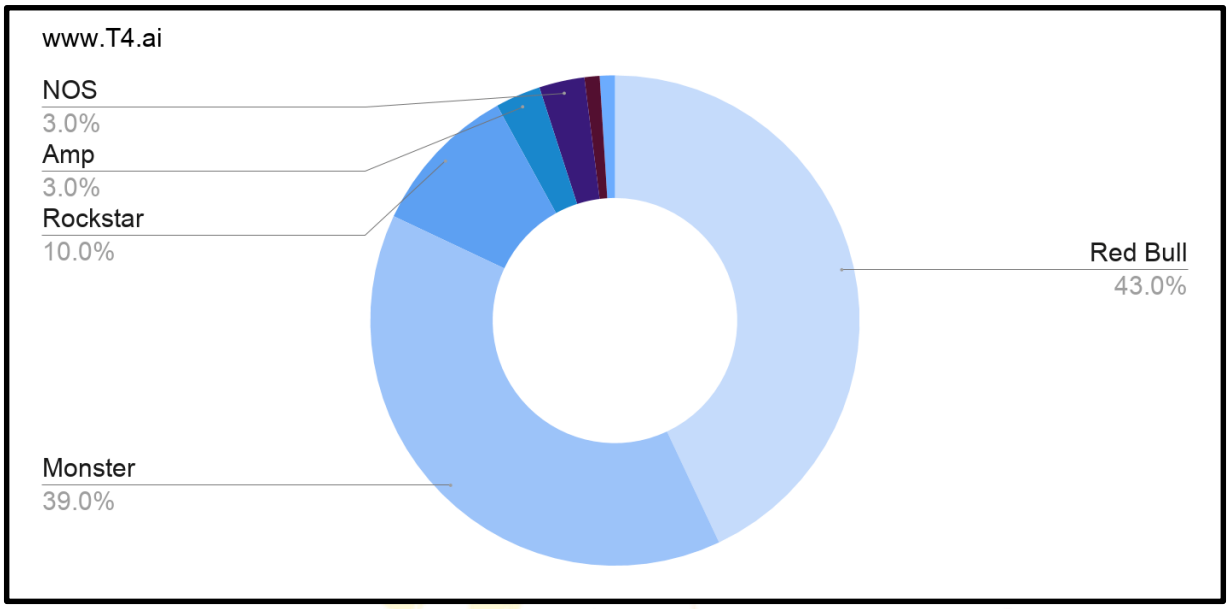
To provide context, the beginnings of the energy drink industry can be traced to the 1960s when a company named Taisho Pharmaceuticals introduced Lipovitan D, an entirely new and unfamiliar concoction, into the market advertised as an “energising tonic” (GO BIG, 2020). Initially, they were marketed towards young adults working night shifts or any other physically draining jobs but since then new firms like Red Bull and Monster have taken over, expanding their consumer base into students as young as 13 years old through their appealing yet slightly misleading advertisements. These companies’ tactical marketing strategies tap into a growing desire among consumers for convenient and immediate sources of energy to help them power through their busy lives. A recent study brought light to the fact that over 80% of teens aged 13-17 are regular consumers of energy drinks (National Center for Complementary and Integrative Health, 2018). These drinks contain copious amounts of stimulants

like caffeine and glucose, along with several others. For comparison, one can of Red Bull contains 11 grams of sugar per 100 ml (Red Bull, 2023) whereas 100 ml of a typical cappuccino contains only 2.71 grams. In 2022, the United States emerged with the highest per capita volume consumption of energy drinks with 28.4 litres per person, followed by Japan and Spain (Statista, 2023). Consumption of energy drinks at such high dosages has a significant impact on neurophysiological well-being, especially among teenagers. They have been known to trigger dehydration, insomnia, anxiety and panic attacks (Centers for Disease Control and Prevention, 2019), causing overall deterioration in mental and physical health.

Considering all the above, the research question for this paper is **"To what extent do energy drinks negatively impact neurophysiological well-being?"** In order to answer the question, this research paper aims to analyse the energy drinks industry, discuss the dangers of consuming such drinks and then proceed to evaluate the neurophysiological impacts of two of the core ingredients of energy drinks, i.e., caffeine and glucose.

The Energy Drinks Industry

As discussed earlier, the industry originated in Japan, but it was the entrance of Red Bull in Austria, in 1987 (GO BIG, 2020) that caused it to truly take off and become what it is today. Previously, the concept of "energy drinks" didn't exist, Lipovitan D was a one-of-a-kind product advertised as an "energizing toxin" claiming to increase alertness and help keep consumers awake. Red Bull decided to play off of this claim but had a radically different way of approaching it. Since traditional advertising was exceptionally expensive, a small start-up like Red Bull at the time could not afford it. So, it decided to go straight to its target audience. The company placed "mascots" on several college campuses that handed out free samples to stressed-out students in desperate need of an energy boost (Priya, 2020). By directly introducing the product into the market, they gained exponential growth in demand through pure word of mouth, this helped them expand enough to be able to explore other marketing strategies. As of 2022, despite the emergence of strong competitors like Rockstar and Monster, Red Bull holds a vast market share of 43% in the global industry - as can be seen in the graph below (T4, 2021).



Segwaying into the next point of contention, the size of the industry. The energy drinks industry has sky-rocketed in recent years, in 2021, it was valued at 86.35 billion USD and is expected to expand at a *compound annual growth rate (CAGR)* of 8.3% between 2022 and 2030 (Grand View Research, 2018). The reasons for this are multifold but most agree that it can be attributed to the lack of regulation in terms of advertising. The industry is self-regulated and there are no specific federal or state rules that govern the marketing and advertising of energy drinks in the United States. It falls under the jurisdiction of the Federal Trade Commission (FTC) which is responsible for protecting consumers from false or misleading advertising. However, the FTC's approach is complaint-based, meaning that enforcement action is only taken when a complaint has been filed (United States Congress et al., 2013/2017). The repercussions of this lack of regulatory overview are seen daily. Contextualizing this further, Red Bull is known for its clever and effective marketing campaigns which have helped to establish the brand as a leader in the energy drink market. One of the key strategies employed is the use of a "rhetorical hook" in its advertising - this refers to a technique where the company uses language and imagery to create a connection with its target audience and evoke a certain emotional response. For example, Red Bull's advertising often features extreme sports and high-adrenaline activities, along with slogans that promote the idea of "giving you wings" and encouraging people to push their limits (Priya, 2020). This creates a strong association between the brand and the idea of energy, power, and adventure, which has helped to build a loyal customer base and establish Red Bull as a household name. The same is the case for other major brands too. These tactics have been heavily criticized and proclaimed dangerous and irresponsible. One area of concern is the use of high-risk sports and activities, providing a glorified and sugar-coated image of these events leads to consumers seeking out the thrill and consuming excessive amounts of the product as a result. As established already, excessive amounts of energy drinks can have adverse effects on the human body. Another vital issue is the targeting of young people in advertising, as they can be particularly harmful to children and teenagers due to their high caffeine content. Due to the uproar this has caused, calls for stricter regulations on the marketing of energy drinks to minors have been made, including bans on advertising in certain media channels and on the use of certain marketing tactics.

That being said, the consumer profile of energy drinks is varied, initially, the primary target market was typically young adults, particularly men. With time, they have gained popularity among people with active lifestyles, such as athletes, bodybuilders and fitness enthusiasts, as well as those who work long hours or have demanding jobs, such as shift workers and university students. However, with the market increasingly diversifying, energy drinks are no longer just for young men, there is an increasing demand for them among children too.

The Dangers of Energy Drinks

The dangers of energy drinks extend far beyond mere injuries, they have been known to have several adverse effects too. As mentioned earlier, these include heart concerns like cardiac arrest and arrhythmia, dehydration, spike in blood sugar levels (Mahindra, 2022) and can even prove to be fatal in some cases. From 2009 to 2013, Monster Energy and 5-hour Energy, two major names in the market, were linked to 43 deaths as reported by the FDA's Center for Food and Safety and Applied Nutrition (CFSAN) Adverse Event Reporting System (CAERS) (Kaur et al., 2022)

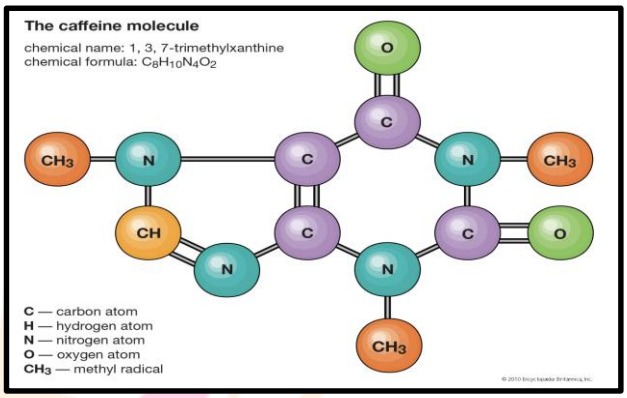
These detrimental impacts can be linked back to the formulation of energy drinks as a whole. Most energy drinks are composed of carbonated water, caffeine, sugars like sucrose or glucose as well as some herbal stimulants like taurine, L-carnitine and B vitamins (Harvard School of Public Health, 2019). That being said, the manufacture of these drinks is still a bit of a grey area, not much is known about it. Despite this uncertainty, there are some glaringly obvious concerns regarding the quantity used of some of these ingredients.

Firstly, caffeine is a very common stimulant consumed by a large majority of the population to help increase focus and thereby improve efficiency. When consumed in recommended amounts, it can prove to be quite helpful but when consumed excessively, can act as a toxin. In 2012, 14-year-old girl, Anais Fournier lost her life at the hands of caffeine toxicity. It is claimed that the cause of death was cardiac arrhythmia brought on after drinking just two 24-ounce cans of Monster energy drink (Hall, 2012). These cans contain about 245mg each, consuming two cans would lead to an intake of 490mg in one go. This is leaps above the amount that is considered safe for consumption which is about 400mg per day as stated by the FDA (U.S. Food and Drug Administration, 2020).

The same misuse is seen with other ingredients as well. Consuming large amounts of sugars, whether that be in the form of glucose, sucrose or fructose, can have dire impacts on neurophysiological well-being (Kaur et al., 2022). It is believed that an adult should consume no more than 30g of simple sugars per day (NHS, 2022). Long-term consumption of energy drinks containing unhealthy amounts of sugars can give rise to nearly irreversible medical conditions like insulin resistance, diabetes and obesity (Kaur et al., 2022).

Overall, the make-up of energy drinks is a major contributing factor to the health concerns they pose and something that should be carefully considered while investigating their impacts on both physical and mental health.

The Neurophysiological Impacts of Caffeine Consumption



As has been determined in the aforementioned sections, caffeine and glucose are two of the core ingredients in energy drinks and can subsequently pose several risks to consumers. To understand the impact of caffeine on the human body, it is essential to first take a deeper look at the biochemical identity of this substance. Its chemical name is 1,3,7-trimethylxanthine and has the chemical structure of $C_8H_{10}N_4O_2$. It is classified as a nitrogenous organic compound under the alkaloid group, a group known to have visible physiological impacts (Britannica, 2018a). To provide more context, examples of other alkaloids include drugs such as morphine and nicotine (Britannica, 2018b).

Caffeine is one of the most widely used stimulants in the world, over 9 in 10 Americans, about 93%, claim to consume caffeine with 3 in 4 (75%) consuming it at least once a day (Food Insight, 2022). The first documentation of caffeine being used is in the form of tea in China around 1000 BC, but the discovery of coffee can be traced back to 850 AD Ethiopia (Walsh, 2020). Legend says a herder took note of the "jumpy" behaviour exhibited by his goats after eating the berries of an arabica plant and decided to take them to a local monk who used them to brew the first known cup of coffee. That being said, the chemical structure of caffeine itself was not identified until the young German physician, Friedlieb Ferdinand Runge isolated and purified the white crystalline substance in 1819 (Tilling, 2001). Structurally, caffeine very closely resembles purine (Institute of Medicine et al., 2001), a colourless crystalline compound used in making some of the nitrogenous bases found in DNA, specifically adenine and guanine (National Cancer Institute, 2011). It is a naturally occurring compound found in the fruits, leaves and beans of coffee, cacao and guarana plants (Harvard School of Public Health, 2019). Brazil is known to be the hub of coffee beans production, single-handedly making up about 40% of the global market supply (Deshmukh, 2021). Since its discovery, caffeine has taken the world by storm and is now found in a myriad of products ranging from food items to cosmetics. Several under-eye serums, face masks and anti-cellulite creams weave their marketing around the presence of coffee or caffeine claiming that it "wakes up" your skin (Scarso, 2021). Caffeine is not only limited to tea and coffee anymore, but also found in chewing gum, medication and even water! (Persad, 2011).

As stated earlier, according to the FDA, the amount of caffeine considered safe for daily consumption is 400mg, however, The American Academy of Paediatrics suggests that for children aged 12 to 18, caffeine consumption should be limited to 100mg per day. A standard 16-ounce can of an energy drink contains about 170mg of caffeine (Harvard School of Public Health, 2020), making even the consumption of just one can of an energy drink unsafe for adolescents. This is why consumers need to understand the various neurophysiological impacts that the consumption of caffeine, in such a high dosage, can have.

As has already been stated, alkaloids have marked physiological impacts. Due to its widespread, these detrimental effects may often go unnoticed. To provide context, let us take a look at how the human body responds to caffeine ingestion. Firstly, caffeine is absorbed and metabolised by the body very quickly and peaks in the bloodstream anywhere between 15 minutes to 2 hours after consumption. It is mainly broken down in the liver and can remain in one's system for up to 15 hours (Harvard School of Public Health, 2020). It also acts majorly on the Central Nervous System (CNS) (Brusie, 2017) which consists of the brain and the spinal cord (Healthdirect, 2021) and serves as an explanation for the myriad of neurophysiological impacts it brings on.

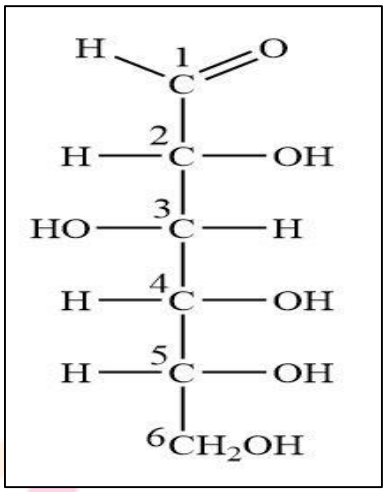
"Caffeine Tolerance" has posed a big concern in terms of unsafe consumption. Due to its fast digestion, when consumed regularly, people can gain a tolerance to it. Their body gets acclimatised to the "wake-up" effect it produces (Hilliard, 2019), this reduces the impact it has on their cognitive functioning and attention span forcing them to consume a higher quantity to be able to reap its benefits (Harvard School of Public Health, 2020). This phenomenon is also responsible for caffeine addiction or dependency. A tell-tale sign of caffeine addiction is the inability to perform daily chores without it. When those dependent on coffee try to cut back on consumption, as with any other addictive drug, they experience withdrawal symptoms (Brusie, 2017). For caffeine specifically, these include drowsiness, fatigue, irritability, muscle pain and a plethora more (Sajadi-Ernazarova et al., 2022).

Another prominent impact of high caffeine consumption is anxiety and panic attacks. Caffeine stimulates the secretion of adrenaline in the body, a hormone known to trigger the "fight or flight response." As a result of this, the body responds to caffeine the same way it would to a traumatic event. This gives rise to caffeine-induced anxiety and jitteriness which is where caffeine mimics the symptoms of clinical anxiety. These include increased heart rate, restlessness and insomnia. In severe circumstances, this can eventually lead to anxiety and panic attacks - those with underlying anxiety and panic disorders are especially susceptible to this reaction (Brusie, 2017).

If the consumption of caffeine is so dangerous to one's body, why is it that energy drinks are still sold in the market and people still consume them? Well, studies have found that caffeine intake can improve cognitive performance, particularly in tasks that require sustained attention, memory, and learning. Additionally, caffeine has been shown to enhance the consolidation of long-term memory and improve the recall of information (Borota et al., 2014). It exerts its effects by blocking adenosine receptors in the brain (Lazarus et al., 2011), which normally

promote sleep and reduce arousal levels (Mandal, 2010). By inhibiting adenosine, caffeine increases the release of several neurotransmitters, including dopamine, norepinephrine and acetylcholine which are involved in attention, alertness, and memory (PowerOnPowerOff, 2020).

The Neurophysiological Impacts of Glucose Consumption



Now coming to the biochemical structure of glucose, it is a simple sugar, also known as a monosaccharide, and is the primary source of energy for the body's cells. Its molecular formula is $C_6H_{12}O_6$ and it has a six-carbon structure consisting of a ring of carbon atoms with hydroxyl (-OH) groups attached to it. The hydroxyl groups make glucose a highly polar molecule, which enables it to dissolve in water and participate in various biochemical reactions in the body (Blanco & Blanco, 2022). Additionally, the presence of the carbonyl (-C=O) group in glucose makes it an aldehyde sugar, which gives it unique chemical properties and reactivity in metabolic processes.

It is one of the most abundant and widely distributed carbohydrates found in nature, occurring in fruits, vegetables, and grains, as well as in the bloodstream of animals. It is essential for providing energy to cells and maintaining normal bodily functions. Glucose was first discovered in 1831 by the French chemist Anselme Payen, who isolated it from honey and named it "glucose" after the Greek word for "sweet" (Britannica, 2019). Payen's discovery of glucose led to further studies on the chemical composition of carbohydrates, which eventually led to the identification of other monosaccharides and the development of carbohydrate chemistry as a field of study. Today, glucose continues to play a critical role in our understanding of metabolism and biochemistry, with numerous applications in medical research and clinical practice.

It has a wide range of applications in various industries, including food and beverage, pharmaceuticals, and energy. In the food industry, glucose is commonly used as a sweetener, a thickening agent, and a preservative, among other things (Grand View Research, 2023). It is also a primary ingredient in confectionery products such as candy and chewing gum. In the pharmaceutical industry, glucose is used as a source of energy in intravenous fluids and as a component in diagnostic tests for diseases such as diabetes (Mathew & Tadi, 2022). In the energy sector, glucose can be converted into biofuels such as ethanol through fermentation. Additionally, glucose is used in laboratory settings for various biochemical experiments and tests.

When glucose is consumed, it enters the bloodstream and triggers the release of insulin from the pancreas. Insulin is a hormone that helps to regulate blood sugar levels by promoting the uptake of glucose into cells and tissues throughout the body. The cells use glucose as a primary source of energy for various metabolic processes, such

as respiration and cellular growth. If glucose levels in the bloodstream exceed the body's immediate energy needs, the excess glucose is stored as glycogen in the liver and muscles for later use. However, if glycogen stores are full, excess glucose is converted into fat and stored in adipose tissue.

The safe amount of glucose consumption varies depending on an individual's age, sex, and level of physical activity. However, according to the American Heart Association (2019), the recommended daily intake of added sugars, which includes glucose, should not exceed 6 teaspoons (or 24 grams) for women and 9 teaspoons (or 36 grams) for men. Energy drinks can contain high amounts of added sugars, including glucose, which can exceed the recommended daily intake. A study published in the Journal of the American Pharmacists Association found that energy drinks contain an average of 27 grams of added sugars per 8-ounce serving (Clauson et al., 2008), which is more than the recommended daily intake for women and nearly equivalent to the recommended daily intake for men. Most people tend to consume at least a 16-ounce can which doubles the amount of glucose making it unsafe for both males and females. Excessive glucose intake can lead to adverse health effects, including obesity, diabetes, and cardiovascular disease.

One positive neurophysiological impact of glucose is when consumed in the right amount, it can improve cognitive functioning. A study found that the consumption of glucose is associated with enhanced memory performance and attention span (Owen et al., 2011). Glucose has also been found to enhance neural activity in areas of the brain involved in cognitive processing, such as the prefrontal cortex and hippocampus (Weinstein et al., 2015). Another positive impact of glucose is its role in regulating mood and emotional processing. It has been associated with reduced anxiety and enhanced emotional regulation (Schöpf et al., 2013).

However, while glucose is essential for normal brain function, excess levels of glucose can have negative neurophysiological impacts. One negative impact of glucose is its association with impaired cognitive function. A study found that acute hyperglycaemia, or high blood sugar levels, is associated with decreased cognitive performance, particularly in memory and attention tasks (Kodl & Seaquist, 2008). Another negative impact of glucose is its role in neurodegenerative diseases such as Alzheimer's disease. It has been found that high levels of glucose can contribute to the accumulation of amyloid-beta plaques, which are characteristic of Alzheimer's disease and can impair neuronal function and survival (Ho et al., 2004).

Conclusion

The energy drinks market has been growing at an unprecedented rate for many years. The aforementioned is predominately triggered by increasing demand for the products, especially from individuals aged 13-17 or those looking for a quick energy fix to cope with their busy days. Whilst the consumption of such drinks may have some positive impacts - the presence of caffeine and glucose can increase alertness, enhance memory and increase

attention span - the dosage in which one consumes specific ingredients can be detrimental to their neurophysiological well-being.

Most energy drinks in the market currently contain unsafe amounts of stimulants and the lack of regulatory overview on their advertisements leads to consumers being misled and not considering the effects that daily consumption may have. High caffeine intake has been associated with increased anxiety and panic attacks as well as building a "caffeine tolerance" which elicits higher consumption leaving consumers in a vicious cycle. After having daily caffeine intake, a sudden stop results in one dealing with withdrawal symptoms like drowsiness and fatigue which are quite contradictory to the main reason for caffeine consumption in the first place. Consuming glucose in excessive amounts also leads to a spike in blood sugar levels giving rise to several diseases such as diabetes and Alzheimer's which can impair cognitive functioning and reduce attention span, again a contradiction to the role of energy drinks.

Considering all the above, it can be said that *energy drinks negatively impact neurophysiological well-being to a great extent*. While these harms have been coming to the surface more amidst an increasing number of adolescents consuming energy drinks, strict and definitive measures to combat them are yet to be put in place. If immediate action is not taken to reduce the amount of caffeine and glucose in energy drinks or restrain their consumption, the severity of the dangerous neurophysiological impacts they pose is sure to rise. Conducting more research to meet the required energy boost without surpassing the recommended amount of stimulants is imperative.

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