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The influence of a preworkout energy drink (c4) on lower limb neuromuscular activation in healthy young adults

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ABSTRACT

Energy drinks (Edrinks) have a plethora of ingredients for the same objective, a burst of energy and improving mood among others. However, there are various Edrink brands with diverse ingredients and slightly different purposes, such as the C4 drink which is a pre-workout. This ingredient variation can provoke different neuromuscular balance and gait adaptations. Recent studies suggest that some ingredients in Edrinks can aid in muscle fatigue in lower limb musculature. To investigate the lower limb neuromuscular modification after edink (C4) consumption. Ten participants (1 male and 9 females) partaken in the study (age of 23.4 (+/- 2.95). Neuromuscular activation of leg musculature was measured during a single-legged balance test on a firm and foam surface, pre and post edrink. Balance tests were designed to engage diverse areas of the balance systems (visual, proprioceptive and vestibular) while studying the adaptations in lower limb muscles such as tibialis anterior and gastrocnemius. The main outcome of this study showed a trend towards greater onset, faster TP, and slower decay for leg muscles after edrink consumption. It seems C4 beverage provokes a faster and prolonged recruitment of the leg muscles. Future studies should look into the postural adaptations after the said drink.

Contribution/Originality: This work's primary contribution is to establish neuromuscular adaptations to balance tests after C4 pre-workout energy drinks intake in healthy young adults. Further, this investigation revealed patterns towards nerve conduction velocity changes during balance activities associated with the diverse ingredients in the aforesaid drink, such as caffeine.

1. INTRODUCTION

Energy drinks (Edrinks) have become increasingly popular worldwide, with the industry expected to grow by 7.1% by 2027 (Fontinelle, 2022). Red Bull was the first Edrink introduced to the United States in 1997, and the industry has skyrocketed. According to Statista, the United States has the most significant annual volume consumption of Edrinks per capita. Edrinks are among the most popular supplements for teens and young adults, commonly consumed between 11 and 35 (Higgins, Tuttle, & Higgins, 2010).

Edrinks are composed of stimulants and additives like caffeine, taurine, vitamin B, and sugar; all claimed to improve physical performance and increase awareness (Hajsadeghi et al., 2016). Different brands can contain between 50 and 505 mg of caffeine, with the Food and Drug Administration (FDA) recommending no more than 400 mg daily (Higgins et al., 2010). Excessive amounts of caffeine can lead to rapid heart rates, nausea, high blood pressure, headache, and nervousness (Higgins et al., 2010). Other negative concerns surrounding Edrinks include mania, epilepsy, and stroke (Hajsadeghi et al., 2016).

Red Bull, Monster, and Rockstar are the big-name Edrinks in the United States, but newer Edrinks have since surged the market, such as C4 Energy (Fontinelle, 2022). According to the C4 Energy nutrition label, the drink contains zero calories, zero sugar, and an explosive performance energy blend that comprises 200 mg of caffeine, CarnoSyn Beta-alanine, Beta power Betaine Anhydrous, N-acetyl-l-tyrosine, and Citrulline malate. Highly marketed ingredients are Caffeine and CarnoSyn, which are known to affect the neuromuscular, cardiovascular, and central nervous systems. Carnosyn is a controlled-release version of beta-alanine. Synthesis of beta-alanine and histidine in the body forms carnosine in skeletal muscle cells (Harris, Jones, & Wise, 2008). Carnosyn (beta-alanine) helps prevent muscle fatigue. Additionally, Carnosyn significantly affects fast-twitch muscle fibers in the neuromuscular system by acting as a buffer to block acid buildup in muscles, increasing the body's time to exhaustion by up to 19% (Culbertson, Kreider, Greenwood, & Cooke, 2010). Caffeine, another main ingredient in C4 Energy, significantly affects the central nervous system by acting as a psycho-stimulant. Caffeine interferes with the neuroendocrine control system to block adenosine, a sleep-promoting neurotransmitter. Although caffeine is widely used to enhance cognitive function, the benefits of caffeine are suggested to improve memory retrieval, particularly rather than a gross improvement in cognitive functions (Cappelletti, Daria, Sani, & Aromatario, 2015). Likewise, caffeine consumption through Edrinks has been shown to increase diastolic blood pressure and blood glucose but has no significant impact on systolic pressure and heart rate (Nowak, Gośliński, & Nowatkowska, 2018).

Further studies have examined the effects of Edrinks on the human body. One study by Rosario et al. shows that consuming 16oz Edrinks can provoke an increased disposition to postural instability (Rosario, Collazo, Mateo, Gonzalez-Sola, & Bayron, 2017).

Another study analyzed muscular adaptations, specifically in the ankle, inferring that reduced blood flow caused by Edrinks could increase fatigue, modifying balance (Rosario, Clare, Lauren, & Ashley, 2021). Moreover, Edrinks have been shown to create neuromuscular adaptations in lower limb musculature (Rosario, Jamison, & Hyder, 2020; Rosario, Hogle, & Williams, 2021) with no significant modifications in gait (Rosario, Versemann, Bowman, & Orozco, 2021). Recently, Rosario, Costet, and Berlof (2022) studied the effects of muscle fatigue after consuming a Celsius energy drink. This study investigates the influence of Celsius energy drinks on neuromuscular adaptations during muscle fatigue and balance. Researchers found minimal muscle fatigue based on preserved muscle activity and balance after an ankle pump test.

Based on the above, the current study aims to determine neuromuscular activation patterns after consuming a pre/workout energy drink (C4). C4 would likely recruit neuromuscular modifications after fatigue-inducing activity in young, healthy adults.

2. METHODS

2.1. Participants

Using convenience sampling, participants were recruited at Texas Woman's University-Dallas campus (TWU). Ten total participants (1 male and 9 females) participated in the study, with a mean age of 23.4 (+/- 2.95) and a mean body mass index (BMI) of 23.54 (+/- 3.97).

2.2. Study Criteria

Inclusion criteria: Healthy participants of both genders between 21 and 31 at TWU were recruited. According to Fontinelle (2022) most Edrinks are consumed between 18 and 34. Exclusion criteria: Participants who had any allergies to C4 ingredients or reported undesirable effects from drinking C4 in the past were excluded from the study.

2.3. Procedures

The institutional review board (IRB) approved the study, and all participants signed informed consent before participating. Subjects were asked not to consume any coffee, energy drinks, or other form of caffeine in the 12 hours leading up to their time of data collection. Upon arrival, all participants had their vitals taken and demographic information recorded. Participants' dominant leg was determined by stepping behind them and applying a posterior perturbation. Whichever leg the participant used during their stepping strategy to correct their posture was determined as their dominant leg. The Delsys, Inc surface electromyography (EMG) system collected the muscle activation data. EMG surface electrodes were placed on the participants' Tibialis Anterior (TA) and Gastrocnemius (GA) muscles based on previously published protocols by Orozco, Joslin, Blumenthal, and Rosario (2022) and Rosario, et al. (2021). Subjects were randomly assigned which leg to place the first surface electrodes to minimize participants from biasing their dominant leg first.

Pre-Energy Drink Consumption: Participant's vitals (heart rate, blood pressure, and SPO2) were collected pre and post Edrink consumption. After, EMG surface electrodes were placed following the previously published protocol by Rosario and Jose (2021) to the leg musculature, tibialis anterior and gastrocnemius. A single-leg balance test protocol entailed stance on a firm surface with their eyes open for 10 seconds followed. To further involve other balance systems such as proprioceptive, a single-leg stance (same limb) on a foam surface for 10 seconds with their eyes open was performed by all subjects.

Energy Drink Protocol: All participants drank a 16 fl oz C4 energy drink within 5 minutes. Subsequently, after 30-minutes, the previously gathered vitals were re-taken. The 30-minute timeframe was suggested and employed in Rosario et al (2021-22) studies to ensure maximal impact of the drink confirmed by a difference in the heart rate pre and post-E-drink.

Post-Energy Drink Consumption: EMG sensors were used on the opposite leg following the same above-mentioned protocol. Also, the balance test was repeated identically to the Pre-Energy Drink Consumption section.

3. DATA ANALYSIS

In the current study Statistical Package for the Social Sciences (SPSS) Version 28 was employed. A multivariate analysis of variance (MANOVA) with post hoc comparisons was completed pre and post energy drink with all data points. The electromyographic data collected and compared was the initiation of muscle activation (onset), the point of maximal activation (time to peak), duration of muscle activity and the time of activity completion (decay). All data points were collected in time (seconds) parameters and a P value equal to or less than 0.05 was acknowledged as statistically significant.

4. RESULTS

Table 1 shows the demographics of the research participants, including age, gender, height, weight, and BMI. Table 2 presents the participants' cardiovascular data before and after energy drink consumption (EDC). The participants' average blood pressure increased after EDC, while the average heart rate decreased after EDC. The average oxygen saturation slightly increased post-EDC, but the changes were insignificant. Table 3 presents the neuromuscular activity data for the Tibialis Anterior (TA) and Gastrocnemius (GA) muscles, pre- and post-energy drink consumption during the balance tests. The TA and GA muscles experienced a decreased time to peak (TP) post-EDC, but the GA muscle had a more substantial difference from pre- to post-EDC than the TA muscle. The GA muscle was also recruited for a more extended period, while the TA muscle generally remained the same. The GA and TA muscles both presented a quicker onset of muscle activation pre- to post-EDC, with similar differences between the two. Lastly, both muscles exhibited a prolonged time until muscle decay, with the GA showing a greater increase in time until muscle decay than the TA.

Table 1. Results of paired sample t-tests performed between pre energy drink and post energy drink cardiovascular data.

Characteristics of participants	
Characteristics	C4 (n=10)
Age	m= 23.4 +/- 2.9
Male	n= 1
Female	n= 9
Height	m = 65.8 +/- 2.4 inches
Weight	m = 144.6 +/- 22.6 pounds
BMI	m= 23.5 +/- 4.0

Note: Significance level set at p≤0.05.

Table 2. Results of paired sample t-tests performed between pre energy drink and post energy drink cardiovascular data.

Cardiovascular data			
	Pre Edrink	**Post Edrink**	**P value**
Systolic (mmHg)	118.8 +/- 12.6	124.7 +/- 11.0	0.78
Diastolic (mmHg)	76.49 +/- 7.6	83.9 +/- 8.3	0.67
Heart rate (Beats per minute)	79.3 +/- 10.6	75.5 +/- 9.2	0.77
Oxygen saturation (%)	98.3 +/- 0.01	98.5 +/- 0.007	0.97
Time for cardio change (Minutes)	30		

Note: Significance level set at p≤0.05.

Table 3. EMG data for GA and TA muscle during balance task. Results of MANOVA between pre-energy drink and post-energy drink.

GA	**Pre Edrink**	**Post Edrink**	**P value**
Onset	36.8 +/- 17.7	37.8 +/- 15.9	0.90
Time to peak	0.77 +/- 0.28	0.66 +/- 0.20	0.37
Duration	1.83 +/- 0.26	1.78 +/- 0.34	0.69
Decay	1.07 +/- 0.24	1.12 +/- 0.35	0.74
TA	Pre Edrink	Post Edrink	P value
Onset	37.27 +/- 17.40	38.29 +/- 15.43	0.89
Time to peak	0.68 +/- 0.23	0.67 +/- 0.25	0.93
Duration	1.60 +/- 0.47	1.59 +/- 0.36	0.96
Decay	0.92 +/- 0.34	0.93 +/- 0.34	0.99

Note: Significance level set at p≤0.05.

5. DISCUSSION

This study aimed to evaluate the effects of C4 energy drinks on the ankle musculature among healthy young adults during various balance tasks. C4 would modify neuromuscular recruitment after fatigue-inducing activity in young, healthy adults. Based on previous studies reporting similarities on leg musculature standing balance regardless of dominance (Bowman & Rosario, 2021) and TA and GA neuromuscular activity on both limbs in young healthy adults (Rosario & Jose, 2021) the current research identifies modifications related to consumption of C4 Energy in ankle musculature. Specifically, the findings of this investigation present different muscle activation patterns before and after C4 energy consumption; accordingly, we partially accept our assumption.

The main finding of this study showed a trend towards a more significant onset, faster TP, and slower decay after EDC. The above outcome illustrates that after C4 consumption, leg musculature was recruited faster and extended during the balance activities. This increase in activity suggests that C4 or some ingredients in the drink can promote neuromuscular adaptations to leg musculature.

Previous studies have found a similar change in the activation of TA and GA during balance activities due to various Edrinks other than C4 (Rosario, et al., 2021). Authors found that the consumption of Red Bull or Bang led to an increased posterior sway of individuals, resulting in faster activation of TA and prolonged activation of GA to compensate for this response. The study also found that the consumption of Rockstar led to increased anterior movements, causing a quicker response from the GA to compensate. Similarly to Redbull, Bang, and Rockstar, C4 Energy seems to increase muscle activation onset of TA and GA muscles. The consumption of C4 also provoked decreased TP and prolonged muscle decay, which could promote lesser muscle fatigue and lead to balance alterations in lower leg musculature.

Another study examined the effects of Edrinks on the gait parameters and found that Edrinks, such as Rockstar and Bang, may alter gait by increasing the variable, time, or speed (Rosario, et al., 2021). While this study did not measure muscle activation of the lower leg, said study observed a difference in the gait cycle after EDC. This research discovered several trends: gait cycle duration symmetry, lumbar range of motion (ROM) measured in the coronal plane, double support asymmetry, and arm ROM. Further research is warranted to determine if C4 consumption affects the gait cycle, but differences in lower leg efficiency were evident in both studies after EDC. Nevertheless, the differences in lower leg performance post-C4 consumption also suggest differences in gait cycle performance.

Rosario et al. (2022) examined the influence of Celcius energy drinks on lower limb muscle fatigue and recovery. This study found that Celsius prevented neuromuscular timing changes caused by muscle fatigue during balance tasks by extending muscle activation. Participants were able to do more calf raise repetitions after consuming Celcius, which the authors noted could be interpreted as a proactive neurological response and pre-movement facilitation after consuming the Edrink. These findings were consistent with the previous studies mentioned by Correa, Hanrahan, Basye, and Rosario (2021) and Rosario, et al. (2021) showing that the consumption of Red Bull, Rockstar, and Bang prolongs muscle activation, along with the current study showing C4 extends muscle activation.

Another assumption is that caffeine provokes neuromuscular variations, explaining the difference between pre and post-Edrink consumption. Caffeine is a popular dietary supplement extensively studied for its effects on muscle activation, performance, and exercise tolerance. Kalmar et al. researched the influence of caffeine on voluntary muscle activation, finding an increase in neuromuscular activation following caffeine intake. Similarly, Walton, Kalmar, and Cafarelli (2003) found that caffeine ingestion leads to increased spinal excitability in humans, leading to enhanced neuromuscular activation. Bowtell et al. (2018) noted improved exercise tolerance with caffeine ingestion and modulation of peripheral and central neural processes. Studies found a variation in standing balance after caffeine consumption (Cildir, Altin, & Aksoy, 2021) or EDC (Rosario et al., 2017). Since edrinks have caffeine, this leads to the assumption that caffeine could be the ingredient that provokes these posture changes. A systematic review and meta-analysis examined the effects of caffeine on muscle strength and power in healthy individuals. The results suggest caffeine may enhance maximal voluntary muscular strength and muscle power output (Grgic, Trexler, Lazinica, & Pedisic, 2018). According to the International Society of Sports Nutrition, caffeine can improve sports performance, including muscle strength and power (Goldstein et al., 2010). Another study examined the acute effects of caffeine supplementation on muscle activation and anaerobic power in elite taekwondo athletes. The results suggest caffeine ingestion can enhance muscle activation and anaerobic power output (Ouergui et al., 2023).

Other researchers have shown that caffeine may also impact muscle activation. In one study, Stebbins and Tobias (1994) analyzed the effects of caffeine on tibialis anterior activity during submaximal isometric contractions. Their results suggest caffeine may enhance motor unit recruitment and firing rates during these contractions. De Ruiter, Van Leeuwen, Kruithof, and Savelberg (2010) explored the effects of caffeine on tibialis anterior activation during gait in habitual caffeine consumers. Their findings showed that caffeine consumption was associated with altered tibialis anterior activation patterns during standing and walking. However, the exact mechanism behind the effects of caffeine on muscle fatigue remains unclear. Thompson, Dzubur, Wade, and Tomaszycki (2011) proposed that the bitter taste of caffeine might influence the perception of muscle fatigue rather than the chemical properties of caffeine itself. The results suggest that the bitter taste of caffeine is not responsible for its effect on muscle fatigue. These studies indicate that caffeine may have a complex relationship with muscle activation and fatigue. Further research is needed to fully understand the impact of caffeine on muscle function and develop targeted interventions for athletes and individuals seeking to improve their performance.

6. CONCLUSION

The current analysis was intended to investigate the neuromuscular adaptations of leg musculature during a balance test after C4 consumption. This research helps determine a tendency towards quicker and greater recruitment of TA and GA. The authors reveal that caffeine could be responsible for the aforementioned muscular modification changes. Forthcoming considerations should correlate the use of caffeine and C4 in lower limb musculature to the discoveries of this research. Additionally, an assessment of muscle activation and stability after consuming caffeine or C4 in those experiencing mild to moderate neuromuscular weakness or issues should be examined. The clinical significance of this contemporary inquiry is that C4 or some ingredients, such as caffeine, can aid in proper neuromuscular adaptation during balance activities.

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Institutional Review Board Statement: The Ethical Committee of the Texas Woman's University, USA has granted approval for this study on 27 April 2022 (Ref. No. 20107).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
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