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## RESEARCH ARTICLE

# Increased static postural sway after energy drink consumption: A randomized trial [version 1; referees: 2 approved with reservations]

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## Abstract

**Background:** Energy drinks consumption continues to grow since its appearance in the United States in 1997. Available evidence indicates that caffeine, their main ingredient, can alter the central nervous system (CNS). However, it is unknown how energy drinks alter the CNS postural control mechanism. The purpose of this study was to investigate how energy drinks can affect postural control after sensory perturbations during stance.

**Methods:** 20 healthy adults, (11 males; 9 females) averaging 26.1 years of age, stood on a MatScan<sup>TM</sup> pressure mat, which measured center of pressure (CoP), anteroposterior (AP) and mediolateral (ML) postural sways during eight different balance tests (BALT's). BALT's were designed to alter or cancel the systems involved in postural control: visual, vestibular and somatosensory. Subjects were randomly assigned to a caffeine group and an energy drink group. MANOVA analysis was performed for all variables of interest.

**Results:** In the caffeine group, the AP sway of the Eyes Closed test on a stable surface was statistically significant. In the energy drinks group, we observed a general tendency of participants to increase CoP slightly, AP and ML sway in most of the BALT's after the consumption of an energy drink. However, this increase was not statistically significant. These results suggest that in healthy young adults, the sensory re-weighting mechanism can overcome postural perturbation and maintain overall postural control.

**Conclusions:** We observed an overall tendency to increase postural instability after the ingestion of energy drinks.

## Open Peer Review

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	1	2
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## Introduction

Consumption of energy drinks continues to increase since its appearance in the United States in 1997<sup>1</sup>. Energy drinks are available in more than 140 countries; and by 2006, around 500 brands of energy drinks were established, where Thailand led the world in energy drinks consumption per person and the United States in the total volume of sales<sup>2,3</sup>. The main active ingredient in energy drinks is caffeine, a central nervous system stimulant (CNS) and the most widely used psychoactive drug in the world<sup>4</sup>. In addition to their main active ingredient caffeine, of which intake in high doses can alter the CNS, they also contain other substances such as<sup>3,4</sup>: taurine, guarana, cocoa, riboflavin, pyridoxine, nicotinamide, among other derivatives of herbs, which often contain additional amounts of caffeine<sup>4</sup>. For instance, guarana, in addition to its high caffeine content, contains theobromine and theophylline, which are mild CNS stimulants, that have been proven to cause higher levels of stimulation than caffeine alone in *Dugesia tigrina*, a free-living aquatic flatworm, with a CNS comparable to those found in mammals<sup>5</sup>.

One of the biggest problems with energy drinks is that manufacturers are not required by law to label the caffeine content of these additives. Sometimes they are just simply included in what they call an “energy blend.”<sup>4,6</sup>. It is not clear whether these additional ingredients provide a physical or cognitive improvement even more than the one provided by caffeine alone or how they affect the CNS<sup>4</sup>. How energy drinks affect the postural control and which sensory system (proprioceptive, visual, vestibular) is the most affected, remains unknown. Postural control is defined as the act of maintaining or restoring the achievement of postural control in any posture or activity through a complex interaction of the neurological and musculoskeletal system<sup>7,8</sup>. Because the central nervous system is responsible for maintaining postural control we believe that energy drinks, a CNS stimulant, could cause alterations in how the body reacts to different postural perturbations during stance. Therefore, the purpose of this study was to determine the energy drinks effects in the CNS postural control mechanism after sensory disturbances.

## Methods

Trial registered at ClinicalTrials.gov: [NCT03315442](#)

Registration date: November 16, 2017

A completed CONSORT checklist can be found in [Supplementary File 1](#).

## Ethical statement

This study was approved by the Institutional Review Board of the UPR-MSCH Human Research Protection Office (A2540116). Subjects of this study were recruited through advertisements published around the University of Puerto Rico, Medical Sciences Campus and Facebook page of the physical therapy students involved in this study. The study was carried out in the Biomechanics Laboratory of the Doctoral Program in Physical Therapy at the School of Health Professions in the Medical Sciences Campus, University of Puerto Rico (UPR-MSCH).

Subjects were invited to participate in the study through word of mouth, flyers and social media announcements during May 1,

2016 to December 15, 2016 for trial and recruitment purposes. Contact information was provided and potential participants called the Principal Investigator (PI) to express their interest in participating and schedule an appointment. Subjects were instructed to assist the biomechanics laboratory at the UPR-MSCH. During the scheduled meeting, the PI explained the details of the study and when participants choose to partake there were given the informed consent. They had no specific time to finish reading informed consent, and they were encouraged to ask any questions during that process. When participants communicated to the PI that they finished reading the informed consent, the PI asked questions related to the study to ensure subjects did understand the purpose of the study and their role in the study.

## Inclusion criteria

The inclusion criteria for the study were designed to ensure a homogenous sample among the participants. 1) subjects between 21 to 40 years of age, 2) functional flexibility in the lower extremities, 3) functional muscular strength in the lower extremities, 4) completing the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire, 5) a Body Mass Index of 18.5 to 29.9, 6) arterial blood pressure less than or equal to 140/90 mmHg, 7) pulse at rest between 45–90 beats per minute (BPM), and 8) 95% or more of oxygen saturation (spO2).

## Exclusion criteria

The exclusion criteria were designed to identify any factor that could alter postural control, other than energy drinks, or endanger the participant's safety. 1) subjects under the age of 21 and/or over the age of 40, 2) answering any questions affirmative on the pre-participation questionnaire, 3) cardiovascular problems, 4) severe balance problems, 5) taking any sedative or stimulant medications, 6) medical history of any neurological condition, 7) a fall in the last 3 months, 8) having undergone a surgical procedure in the past 6 months, 9) pain in the lower extremities and / or lower back, 10) have suffered a lower back injury and/or in the lower extremities in the last 6 months, 11) is pregnant or suspecting pregnancy, 12) have experienced adverse effects after caffeine consumption, 13) caffeine consumption 12 hours prior to the study intervention, 14) allergies to one of the energy drink ingredients, and 15) people unable to consent.

## General protocol

After signing the informed consent and reviewing the inclusion and exclusion criteria, participants were subjected to a preliminary screening of participation using a list of questions and the AHA / ACSM Health / Fitness Facility Questionnaire<sup>9</sup>. This questionnaire's purpose is to ensure the safety of the participants to engage in physical activity by assessing the subjects and family history of cardiovascular diseases. Afterwards, we assessed subjects' vital signs, blood pressure, pulse, and spO2, to ensure subjects were able to participate in physical activity safely ingest a moderate intake of caffeine without complications. Since postural control is negatively correlated with increased adiposity, weight and height data were measured to obtain a classification according to the Body Mass Index. A range of 18.5 to 29.9 was required to participate<sup>10,11</sup>. During the physical examinations the subjects also performed a Romberg test to rule out any obvious impairment in static balance, a modified Sit and Reach Test for the evaluation of functional flexibility, Sit to Stand Test (30 Seconds) for the

assessment of lower limb functional strength, and a Tecumseh Step Test to evaluate the response of the cardiovascular system to a submaximal cardio test<sup>12–15</sup>. After the physical examination, the participants had a rest period between 10–20 minutes before starting the balance tests protocol of (BALT's).

### Subjects

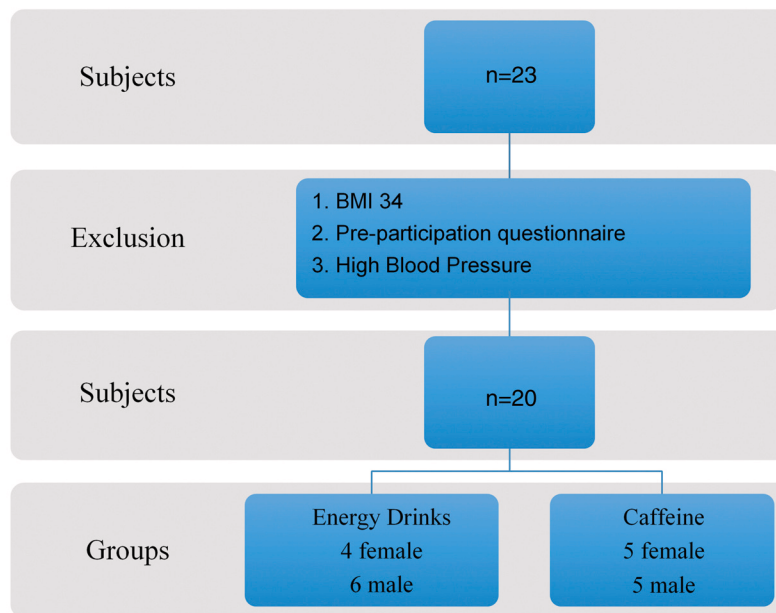
Twenty-three people contacted the researchers to participate in the study (see [Supplementary File 2](#)). We excluded 3 subjects from participating in the study for the following: 1) BMI of 34 (male), 2) did not pass pre-participation questionnaire for reporting adverse effects after ingesting caffeine (female) and 3) high blood pressure (male). Of the twenty participants, eleven (55%) were men and 9 (45%) women, with an average of 170.73 pounds, 26.1 years of age and 67.1 inches of height. The caffeine group consisted of 5 (50%) male participants and 5 (50%) female participants,

while the energy drink group consisted of 6 (60%) female and 4 (40%) male participants ([Figure 1](#)).

### Procedure

The 20 healthy young subjects selected, were randomly assigned (simple randomization, flipping a coin 3 times, heads was energy drink, tails was caffeine) to control (caffeine) group (n = 10) and experimental (energy drinks) group (n = 10). Vital signs were retaken before the balance test protocol to ensure that the subjects remained within the previously established inclusion values.

Each participant from both groups performed 8 balance tests (BALT's) which alter or cancel, individually or combined, sensory input from the sensory systems involved in postural control ([Table 1](#)). The order of the tests was changed systematically between subjects; therefore, they did not perform the tests



**Figure 1.** Characteristics of the study subjects.

**Table 1. Protocol of balance tests and the systems assessed or altered by each test.** Assessed= (+); Altered= (-). HUD\*= Head up/down movements using a metronome 2/4, 60 BPM.

BALT's	Postural Control System		
	Visual	Vestibular	Somatosensory
1. Eyes Open	+	+	+
2. Eyes Closed	-	+	+
3. Eyes Open HUD*	+	-	+
4. Eyes Closed HUD*	-	-	+
5. Mat Eyes Open	+	+	-
6. Mat Eyes Closed	-	+	-
7. Mat Eyes Open HUD*	+	-	-
8. Mat Eyes closed HUD*	-	-	-

in the same order to eliminate external factors such as fatigue or accommodation to the BALT's, which could alter the results. The BALT's were conducted on the MatScan,<sup>TM</sup> (TekScan, Boston, MA) a pressure platform containing sensors that measure a displacement of the center of pressure in centimeters square (cm<sup>2</sup>) (CoP), anteroposterior (AP), and mediolateral (ML) sway in centimeters (cm)<sup>16</sup>. The data collected from the pressure mat was analyzed with Tekscan Sway Analysis Module (SAM) software designed for this purpose. The subjects stood for 30 seconds on the pressure platform during each test.

The first 4 BALT's were carried out by placing the pressure platform on the floor, a stable surface. These tests were: 1) Open Eyes (EO) with a fixed point to evaluate all the systems involved in the postural control (visual, vestibular, somatosensory); 2) Eyes Closed (EC) to evaluate the vestibular and somatosensory system, while eliminating the visual sensory input; 3) Eyes Open while actively moving the head up and down (HUD) to evaluate the visual and somatosensory system, while altering the vestibular system with head movements (EO HUD) (For HUD movements a metronome 2/4 60 BPM was used to maintain a fixed frequency of about one spin per second in motion); 4) Eyes closed and actively moving the head up and down (EC HUD) to assess the effect of removing the visual input, in combination of an alteration of the vestibular system with the head up and down movements.

The remaining 4 BALT's were the same as the 4 previously mentioned tests with the difference that the subject stood on an unstable surface (foam mat) that was placed on top of the pressure platform to alter the somatosensory (proprioceptive) system. The BALT's on the unstable surface were: 1) Open Eyes (MAT EO), standing on the unstable surface to evaluate the visual and vestibular system while the somatosensory is altered; 2) Eyes Closed (MAT EO), standing on the unstable surface to evaluate the vestibular system (the somatosensory was modified and the visual system removed); 3) Eyes Open (MAT EO HUD) while actively moving the head up and down to evaluate the visual system, while altering the vestibular and somatosensory system; 4) Eyes Closed (MAT EC HUD) while actively moving the head up and down (in this test all three systems were altered). The same frequency of motion used for BALT's 3 and 4 in the stable surface (1 spin per second, 60 BPM) was maintained for the BALT's with HUD movements on the unstable surface.

After the initial 8 pre BALT's, to the experimental group, 160 mg of caffeine was given through one energy drink (16 ounces). Monster energy drink was chosen because, unlike Redbull previously used by Enriquez, the label of Monster Energy drink exhibits the guarana additive, a potential CNS stimulant, in its nutritional label<sup>17,18</sup>. To the control group, we gave a caffeine pill of 200mg, a moderate dose in healthy adults which has been used in numerous studies on different topics and has not been associated with adverse effects such as toxicity, cardiovascular effects, behavior changes, among other things<sup>18</sup>. Because peak absorption of caffeine is reached within 30–45 minutes after the ingestion of caffeine/energy drink, there was a rest period of 30 minutes<sup>19,20</sup>. Vital signs were measured after the rest period, for the third time. The same 8 BALT's were then performed, for post ingestion results.

## Statistics

We used the statistical package for the social sciences (SPSS) version 19 for all the data analysis. In this study, we used "Tekscan Sway Analysis Module (SAM)" software for our data collection. For data analysis, we first did a Shapiro-Wilks test to determine normality and to eliminate atypical values, or outliers for the CoP and sway data. Then, a paired Student's T-test was used to compare values of weight, age, height and BMI of both groups and to determine homogeneity between the two groups. Concerning sway and CoP data, we used a MANOVA for all the variables of interest. A comparison Pre Caffeine/energy drink between groups (CoP and Sway) during all task was performed to ensure similarities between groups. Subsequently, a comparison between groups (MANOVA) was performed post Caffeine/energy drink consumption to assess the role of both substances. The test results were adjusted using a Bonferroni correction to identify the different parameters with a significant difference. In this study, a P value of 0.05 or lower was considered statistically significant.

## Results

### Subject comparison

A Paired Student T-test (Table 2) was used to compare values of weight, age, height and BMI of both groups. None of the variables showed statistically significant results, evidencing homogeneity in the characteristics of subjects between the groups.

### Caffeine pre and post

In the comparison of the caffeine group (Table 3), a significant increase ( $p \leq 0.05$ ) was found only in the AP sway in the eyes closed test while standing on a stable surface. The AP sways before caffeine ingestion was  $1.65 \pm 0.41$ , and 30 minutes after the ingestion it was  $2.85 \pm 1.1$ . For CoP in any of the BALT's, including the EO test, the results were statistically significant.

### Energy drinks pre and post

When comparing pre and post average of AP sway, ML sway and COP in the energy drinks group (Table 4), no statistically significant results were found in any of the variables measured in any of the BALT's.

### Caffeine versus energy drinks

No statistically significant results were found for the comparison of the average of AP sway, ML sway, and COP of energy drinks and caffeine post BALT's (Table 5).

**Table 2. T-Test of the variables (BMI, weight, age, and height) between subjects of both groups.**

	Caffeine	Energy Drinks	P value
<b>BMI</b>	23.86 + 2.85	25.45 + 2.56	.286
<b>Weight (pounds)</b>	155.90 + 28.42	161.72 + 25.64	.650
<b>Age</b>	25.80 + 2.44	27.20 + 3.55	.363
<b>Height (inches)</b>	67.50 + 2.74	66.70 + 3.09	.462

**Table 3.** Average of the center of pressure in centimeter squared (CoP), anteroposterior sways (AP Sways) and medial-lateral sways (ML Sways) in centimeters for each balance test condition before and after the caffeine tablet intake.

BALT's	CoP (cm <sup>2</sup> )			AP Sways (cm)			ML Sways (cm)		
	Pre test	Post test	Sig	Pre test	Post test	Sig	Pre test	Post test	Sig
EO	0.862 ± 0.47	0.923 ± 0.52	0.79	1.72 ± 0.65	1.69 ± 0.53	0.92	1.14 ± 0.29	1.16 ± 0.42	0.87
EC	0.777 ± 0.53	1.58 ± 1.1	0.55	1.65 ± 0.41	2.85 ± 1.1	0.05	1.18 ± 0.54	1.45 ± 0.81	0.41
EO HUD	2.33 ± 1.6	1.35 ± 0.78	0.09	2.99 ± 1.1	2.33 ± 0.85	0.15	1.60 ± 0.66	1.28 ± 0.52	0.24
EC HUD	1.48 ± 0.79	2.06 ± 1.2	0.22	2.48 ± 0.90	2.92 ± 0.97	0.32	1.23 ± 0.36	1.53 ± 0.67	0.22
EO Mat	9.81 ± 4.9	1.56 ± 9.4	0.1	4.06 ± 1.1	5.52 ± 2.6	0.12	4.39 ± 0.93	5.81 ± 2.3	0.09
EC Mat	26.9 ± 14	29.1 ± 24	0.8	7.77 ± 2.9	7.27 ± 3.5	0.73	7.82 ± 2.4	8.44 ± 3.3	0.64
EO HUD Mat	18.5 ± 6.2	16.3 ± 7.5	0.48	7.01 ± 1.9	6.45 ± 2.8	0.61	5.90 ± 1.2	5.72 ± 1.8	0.79
EC HUD Mat	53.4 ± 21	52.6 ± 26	0.94	10.3 ± 3.7	10.6 ± 3.9	0.86	12.5 ± 3.1	10.7 ± 2.5	0.18

**Table 4.** Average of the center of pressure in centimeter squared (CoP), anteroposterior sways (AP Sways) and medial-lateral sways (ML Sways) in centimeters for each balance test condition before and after the energy drink intake.

BALT's	CoP (cm <sup>2</sup> )			AP Sways (cm)			ML Sways (cm)		
	Pre test	Post test	Sig	Pre test	Post test	Sig	Pre test	Post test	Sig
EO	0.944 ± 0.51	1.08 ± 0.80	0.65	1.90 ± 0.47	1.95 ± 0.81	0.87	0.969 ± 0.27	1.15 ± 0.44	0.27
EC	0.989 ± 0.66	1.64 ± 0.92	0.08	2.43 ± 0.72	2.99 ± 0.90	0.14	1.10 ± 0.33	1.38 ± 0.52	0.17
EO HUD	1.40 ± 0.30	1.75 ± 0.69	0.16	2.39 ± 0.59	2.87 ± 0.73	0.13	1.30 ± 0.29	1.32 ± 0.28	0.87
EC HUD	2.17 ± 1.1	2.61 ± 1.3	0.43	3.41 ± 1.3	3.47 ± 1.3	0.91	1.54 ± 0.77	1.73 ± 0.66	0.56
EO Mat	9.76 ± 4.5	9.20 ± 4.6	0.79	4.50 ± 1.5	4.09 ± 1.1	0.49	4.55 ± 1.0	4.54 ± 1.6	0.99
EC Mat	19.7 ± 7.3	24.2 ± 12	0.31	6.09 ± 1.9	7.26 ± 2.5	0.25	7.16 ± 1.6	7.75 ± 1.1	0.35
EO HUD Mat	18.4 ± 8.7	14.4 ± 10	0.36	8.10 ± 3.9	6.17 ± 4.4	0.31	6.30 ± 2.0	6.33 ± 3.3	0.98
EC HUD Mat	48.9 ± 19	49.9 ± 26	0.93	10.9 ± 3.1	10.3 ± 3.5	0.7	11.7 ± 4.1	10.6 ± 3.4	0.52

**Table 5.** Average of the center of pressure in centimeter squared (CoP), anteroposterior sways (AP Sways) and medial-lateral sways (ML Sways) in centimeters for each test comparing after the intake of energy drinks and caffeine.

BALT's	CoP (cm <sup>2</sup> )			AP Sways (cm)			ML Sways (cm)		
	Energy Drink	Caffeine	Sig	Energy Drink	Caffeine	Sig	Energy Drink	Caffeine	Sig
EO	1.08 ± 0.80	0.923 ± 0.52	0.6	1.95 ± 0.81	1.69 ± 0.53	0.41	1.15 ± 0.44	1.16 ± 0.42	0.96
EC	1.64 ± 0.92	1.58 ± 1.1	0.88	2.99 ± 0.90	2.85 ± 1.1	0.82	1.38 ± 0.52	1.45 ± 0.81	0.82
EO HUD	1.75 ± 0.69	1.35 ± 0.78	0.25	2.87 ± 0.73	2.33 ± 0.85	0.15	1.32 ± 0.28	1.28 ± 0.52	0.85
EC HUD	2.61 ± 1.3	2.06 ± 1.2	0.34	3.47 ± 1.3	2.92 ± 0.97	0.29	1.73 ± 0.66	1.53 ± 0.67	0.57
EO Mat	9.20 ± 4.6	1.56 ± 9.4	0.07	4.09 ± 1.1	5.52 ± 2.6	0.12	4.54 ± 1.6	5.81 ± 2.3	0.18
EC Mat	24.2 ± 12	29.1 ± 24	0.57	7.26 ± 2.5	7.27 ± 3.5	0.99	7.75 ± 1.1	8.44 ± 3.3	0.54
EO HUD Mat	14.4 ± 10	16.3 ± 7.5	0.65	6.17 ± 4.4	6.45 ± 2.8	0.87	6.33 ± 3.3	5.72 ± 1.8	0.61
EC HUD Mat	49.9 ± 26	52.6 ± 26	0.82	10.3 ± 3.5	10.6 ± 3.9	0.85	10.6 ± 3.4	10.7 ± 2.5	0.95



In a secondary analysis, a comparison of the data over time (0, 15, 30 seconds) of each balance test was performed. In this analysis, we also observed a tendency of the energy drinks to alter the postural control, more significantly in the middle of the test and before subjects were able to recover overall postural control at the end of the test.

#### Dataset 1. Postural control dataset

<http://dx.doi.org/10.5256/f1000research.12565.d184744>

## Discussion

Postural control is a complex and dynamic interaction in which the CNS continuously receives afferent information from the vestibular, somatosensory, and visual systems. Once received by the CNS a relative weight is placed in these sensory inputs depending on the environment and goal of the task, resulting in a motor outcome required for postural control<sup>21</sup>. Different studies have found that weight or contribution of the 3 systems changes depending on the perturbation during stance<sup>22</sup>.

This shift in input and adjusting process, required to maintain control of the body, is referred as sensory re-weighting<sup>23</sup>. Several studies have demonstrated that sensory re-weighting is a major contributor to limiting body sway amplitudes when postural control is perturbed<sup>22</sup>. The purpose of this study was to assess the interaction of energy drinks on standing postural control. To determine the effects of energy drinks in the CNS postural control mechanism after sensory perturbations, we divided our analysis into several components.

### Caffeine pre and post

First, we assessed postural stability (pre and post average) and compared the effects of caffeine and energy drinks in the individual groups to determine the effects of consumption individually during eight sensory conditions.

In the caffeine pre and post comparison, 5/8 of the BALT's results showed an increase in the average of CoP. However, none of the results were statistically significant. A statistically significant difference ( $P \leq 0.05$ ) was found only in AP sways values in the EC test in the stable surface. Nevertheless, the average of CoP in the same test did not show statistically significant difference suggesting that overall postural control was maintained. Even though in the present study the consumption of caffeine alone did not have a significant effect in altering the postural control, available evidence is inconsistent with this conclusion. In their study, Kim *et al.*<sup>24</sup> measured postural control during EO, EC and a changed base of support after an approximate intake of 73 mg of caffeine. They concluded that after 40 minutes of caffeine intake, there was not a significant alteration to postural control in the healthy subjects. Compared with our study, they gave an amount of caffeine which was significantly less than the caffeine administered in our study (200mg); but overall results were similar. Meanwhile, following the present study, Mcnerney *et al.*<sup>25</sup> measured postural control after altering the system's associate to postural control after the ingestion of 300mg of caffeine and found a significant difference in the

eyes closed, platform sway-referenced test. However, authors made a general conclusion that caffeine did not produce a clinically significant effect in healthy young participants. Furthermore, Franks *et al.*<sup>26</sup> measured body sway of young subjects during stance with EO and EC after ingesting 300mg of caffeine per 70 kg of weight. The researchers observed a significant increase in body sway (eyes open) after 40 minutes, but subjects recovered stability at later times (100, 160 minutes). A similar behavior was observed with the eyes closed test of this study; but it was not significant, evidencing a tendency of the subjects to improve postural stability with time. It is important to note that in Franks *et al.* study, subjects' weight was considerate to determine the amount of caffeine administered, which should be taken into consideration for the comparison of the results of our study, and for the design of future studies assessing the effect of caffeine in postural control.

### Energy drinks pre and post

In the energy drinks pre and post comparison, 6/8 of the BALT's showed an increased average of COP, 5/8 BALT's in the AP sway and 6/8 BALT's in the ML sway 30 minutes after the consumption of the energy drink. The previous results suggest a negative effect on the postural control mechanism due to a possible stimulatory effect of the energy drinks in the CNS. The BALT's EO, EC, EO HUD, EC HUD, EC MAT were affected in the three measurements (CoP, AP sway, ML sway), while EC HUD MAT was only affected in the CoP, and EO HUD MAT in the ML sway only. EO MAT was the only BALT's not altered in any of the three measurements. Even though we observed a tendency of an increased postural instability after the energy drinks consumption, none of the results were statistically significant. No association between the systems altered, and the results could be established since there was not a pattern of the altered/canceled system and the increased instability observed in the BALT's. Enriquez *et al.*<sup>17</sup> also measured body sway with the eyes closed and eyes open only 1 hour after the ingestion of energy drinks (160 mg of caffeine). In the study, 23 young subjects presented an increased sway in both conditions, but none of the results were statistically significant which correlates with our findings. Available evidence at the moment seems to indicate that energy drinks appear to make small increases in body sway. However, it does not impair the postural control mechanism significantly, at least in healthy subjects with a dose of 160 mg of caffeine given through energy drinks. How the postural control mechanism responds to an even higher dose of energy drinks or in other populations at risk for falls such as older adults remains unknown, however a stepping stone for future studies.

### Energy drinks versus caffeine

Secondly, we compared the effects of caffeine versus energy drinks, to determine any differences in post test results regarding postural instability between the subjects of both groups, even though there was a difference of 40 mg of caffeine between the energy drink (160 mg) and caffeine group (200 mg). The average of CoP, AP sway and ML sway in the caffeine group seems to be more affected in the BALT's performed on the unstable surface (foam mat), while the energy drinks showed more instability in the stable surface. Albeit, an association or correlation between the system altered/canceled (specific BALT's) and the effect between both groups could not be

established, as the results were not consistent. Although, the energy drinks, in addition to the 160 mg of caffeine, contain potential stimulating ingredients. However, the difference of 40 mg of caffeine between groups was not a major factor as none of the post test results (CoP, AP sway, and ML sway) were statistically significant in the comparison between subjects of both groups. The results of this comparison show that the sensory re-weighting system of the twenty healthy young subjects in both groups was able to adjust and re-adjust the sensory inputs appropriately to maintain overall postural control despite the postural perturbations during the BALT's and the stimulatory effect of the intake of the CNS stimulants caffeine and energy drinks.

## Conclusion

We concluded that consumption of one 16 ounces energy drink does not impair the postural control mechanism significantly in healthy young adults. However, we observed an overall tendency to increase postural instability after the ingestion of one (16 ounces) energy drinks. We believe that our study adds to the working literature related to the effect of energy drinks and caffeine on posture balance and clarifies some of the inconsistencies related to this topic. Also, this study is a stepping stone for future studies related to motor control and the effects of external substance like energy drinks and caffeine. For instances, investigate postural control with a greater amount (ounces) of energy drink. Secondly, the habitual energy drink or caffeine consumption of the subjects prior the study was not measured; thus, we recommend adding this factor for future research as well. Thirdly, assess the effects on dynamic or gait balance control after caffeine or energy drink ingestion. Fourthly, future studies could consider taking

balance measurements at earlier times, and more than once post consumption of energy drinks and caffeine. Fifth, we only included healthy young people. Additional studies can investigate the effects of the protocol of this study in other populations at fall risk: for instance elderly and subjects with sensory impairment or neurologic conditions. One final note, we did not assess the impact of caffeine or energy drinks in the different balance test using, as a baseline or control, the EO test compared to the other BALT's on a firm surface and the same for eyes on an unstable surface. We believed this information could tell us the impact of energy drink/caffeine on the different sensory systems.

## Data availability

Dataset 1: Postural control dataset. doi, [10.5256/f1000research.12565.d184744](https://doi.org/10.5256/f1000research.12565.d184744)<sup>27</sup>

## Competing interests

No competing interests were disclosed.

## Grant information

The author(s) declared that no grants were involved in supporting this work.

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## Supplementary material

Supplementary File 1: CONSORT Checklist.

[Click here to access the data.](#)

Supplementary File 2: CONSORT Flow Diagram.

[Click here to access the data.](#)

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[Data Source](#)

# Open Peer Review

Current Referee Status:



Version 1

Referee Report 25 January 2018

doi:[10.5256/f1000research.13608.r29888](https://doi.org/10.5256/f1000research.13608.r29888)



**Evelyn B. Voura**

School of Science, Technology and Health Studies, Morrisville State College (SUNY), Morrisville, NY, USA

In this interesting article Martin G. Rosario *et al.* examined the effect of caffeine on postural control via a pressure mat when a 'system' involved in this physiological reflex was compromised. The findings led the investigators to conclude that caffeine caused the study participants – all young healthy adults – to be less stable following caffeine injection. The motivation behind the study was the ever-increasing consumption of caffeinated energy drinks, leading researchers to help build an increased understanding of how these beverages might affect physiology – particularly since caffeine content is typically not fully disclosed on the packaging.

## Study-Related Considerations:

The tests used by the investigators to assess postural control seem rigorous, and carefully considered. However, this reviewer is not familiar with the specifics of the data collected by these pressure platforms. To help readers fully appreciate these details, it might be beneficial to elaborate on the measurements taken by the device.

The primary drawback of such studies is often the sample size, and this is the case here as well. It would be ideal to canvas more participants, which of course would require more time for the study, given that the search was limited to the investigating campus. With the small sample size, however, meaningful data can be collected – the statistical analysis of choice should be the Student's T-test for the before and after treatment comparison. The fact that the study participants were more similar than they were different, despite their gender as evidenced by the analysis of the homogeneity of the samples, lends more credence to the use of the Student's T-test as a method of analysis – a Bonferroni correction is helpful, as was reported by the authors. Using the T-Test, however, to assess how similar the participants were, seems out of place – this reads like it would be more appropriate for the analysis of variance. So to this reviewer, the statistical choices were reversed. Comparing the participants as their own controls (before and after) instead of a pool of 'treated and untreated' unrelated individuals is helpful. However, the drawback is the low level of significance reported in Table 3. To really understand the effect of the caffeine in these measurements, a clearer level of significance is needed. It would be of interest, therefore, to determine the findings with the other statistical test. A larger sample size, of course, can also help, but that might not be possible for the investigators to consider at this time. In the end, it may be that energy drinks and caffeine at these concentrations does not have any effect on postural control as the other publications referenced by the authors note. However, given that these studies are still underway by this and other groups, despite other corroborating evidence, there does seem to be some question into

these conclusions. Indeed, despite statistics, which show the contrary in almost all cases, the authors still believe that their study subjects were less stable following the supplementation. As such, it is worth ensuring that the statistics are rigorous to settle the discussion.

The authors might also consider presenting their data – the significance levels - in a histogram format – so that the reader can more quickly identify those tests providing the greatest effect – and also directly compare caffeine versus energy drink. This is particularly helpful when the significance values themselves are not considerable.

The other point worth noting is the difference in the level of caffeine used for the energy drink group and the caffeine pill group. It is understandable that the authors desired to have their findings be comparable to previous studies using the 200 mg level, but it is also difficult to compare the effect of 160 mg with 200 mg. This reviewer also wonders if the form of the solution – water or an energy drink formulation – pill matrix versus soluble, might also affect the absorption of caffeine. Was the fact that the only significant effect measured by the investigators in Table 3 due to the caffeine level, or due to the formulation of a pill versus an energy drink? Using the same concentration might help to eliminate this confounding factor. The authors do make note of other studies that use weight as a determining factor toward how much caffeine should be administered, however, since the idea is to study the effect of energy drinks (which are consumed by individuals regardless of weight), and because the control for each individual is the subject's own reactions without the supplementation, this reviewer does not find the method of dosing the subjects of particular concern.

Another idea worth considering is the time to effect. The authors mention this interest as well in their discussion. It would be interesting for this reviewer, for example, to see what the effect would be if the participants were also tested one hour or so afterward as well. Is there an effect due to the 'let down' of the caffeine that could be detected for example – a 'crash' effect? The investigators observed, in their secondary analysis, mentioned prior to the final Dataset 1 link, that there were detectable differences in postural control between the caffeine and energy drink groups during the test, and that the subjects recovered control by 30-second end time. This implies a difference between these two groups that is speculated upon, but not documented – and perhaps would lend more information to the entire story of how caffeine and energy drinks affect physiology. Since the authors have the data, why not report the results at different intervals during the test and not only from those numbers collected at the end? This might provide a better picture of the effect of a) caffeine in general, and b) the energy drink formulation where more than just the caffeine may be at play. Even if the findings from different times prove to also not be statistically significant by the standards given, the trends in the data with time, if shown graphically, might be particularly informative for future studies - and aid the reader with a means to gain a complete 'picture' of what the authors observed while running their study, and why they arrived at their conclusions, despite their statistical analysis.

#### Grammatical Considerations:

There are a few textual items to be corrected in an updated version of the work. While cosmetic, these minor corrections will improve the overall quality of the document. By way of example:

Under Ethical statement:

- 1) "...choose to partake there were given..." should read "...chose to partake they were given..."
- 2) "...asked questions related to the study to ensure subjects did understand..." should read "asked questions related to the study to ensure subjects understood..."

The authors should have a careful read of the text to ensure these or other grammatical issues do not distract the reader from their findings.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

Partly

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Partly

**Competing Interests:** No competing interests were disclosed.

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Referee Report 08 December 2017

doi:10.5256/f1000research.13608.r28251



**Ann Hallemans**

University of Antwerp, Antwerp, Belgium

The authors performed a study on the effect of caffeine intake on postural sway. They compared two situations: intake of caffeine by a pill (200 mg) and intake of caffeine (160 mg) by an energy drink containing additional ingredients with caffeine of which the amount of additional caffeine and modulating effects are unknown. They want to investigate whether the "energy blend" in energy drinks has a different effect on postural sway in different sensory modalities, compared to intake of pure caffeine.

Given the frequent consumption of energy drinks, this seems like a valid question. What I would have expected, though, is a stronger motivation for why exactly postural control/ postural sway should be investigated. Do you expect an increased risk of falling or is it related to safety issues?

The study design is appropriate, although the sample size is relatively small. Subjects are their own controls, which makes the study stronger. It should be motivated, however, why the dose of caffeine in the energy drink (160 mg) is lower than the dose in the pill (200 mg). Why was the pill not dosed at 160 mg as well?

Regarding the methodology, some additional details should be provided. Resolution and measurement frequency of the MatScan should be provided. Furthermore, did you analyse the entire 30s or leave out

the first 10 s to eliminate start-up effects? Also provide size and density of the foam pad.

You report that COP and sway data are outcome parameters. This is not specific enough. The reader would require to know which outcome parameters (amplitude, range, path, speed, area, ...) were used. Furthermore, information should be provided on preprocessing of the COP trajectory, e.g. filtering (which filter type, cut-off frequency, ...) as well as the formulas used to calculate the outcome parameters. Units of measurement should definitely be included when reporting outcome measurements.

Statistical analysis is only partly appropriate. It is not clear whether the quality of data was checked and whether outliers were removed. The database contains some strange values. Furthermore, it is not correct to perform a paired t-test to compare two groups. This would require an independent samples t-test. The main statistical analysis was a MANOVA, which seems appropriate to answer the research question. Please define the model: which variables were dependents? which were factors? What main effects and possible interaction effects were investigated?

I do not feel conclusions are very well supported by the data, which partially might relate to uncertainty about what parameters are actually investigated. In the tables it is unclear whether reported p-values are subject to Bonferonni correction or not. Furthermore, in the discussion results are reported as an increase in postural sway (p. 7/10) although results are not significant. If the difference is not significant, you cannot report it as an increase. The conclusion is reported correctly in that the data are not able to indicate a significant increase in postural sway after the consumption of caffeine. However, the title of the manuscript makes a very strong statement that suggests otherwise and this creates confusion.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Partly

**If applicable, is the statistical analysis and its interpretation appropriate?**

Partly

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

No

**Competing Interests:** No competing interests were disclosed.

**Referee Expertise:** biomechanics, movement science, balance control, gait

**I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**



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