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The Effect of Energy Drinks on the Cognitive Function in Medical Students: Randomised Controlled Trial

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Abstract

Energy drinks can be defined as any non-alcoholic beverage that primarily contains caffeine, taurine, glucose derivatives, vitamin B and some herbal ingredients. Energy drinks have become a popular drink especially among the adolescent to young adult population. This randomised controlled study was conducted to determine the effect of energy drinks on the cognitive function among medical students. A randomised controlled trial was carried out in a private medical college in Malaysia from June 2019 to July 2019. The participants were randomized into two groups: an intervention group (energy drinks) and a control group (non-caffeinated carbonated beverages) with 26 participants in each group respectively. They were asked to perform short term memory, attention, and reaction time tests, along with assessing their alertness and anxiety levels. They were given 250ml of either an energy drink (Monster) or control drink (Sprite). After 30-45 minutes, they were once again evaluated for their cognitive performance, alertness, anxiety levels and immediate adverse effects were asked. The changes in the cognitive performance, alertness and anxiety level were analysed using unpaired t test and paired t test. The immediate adverse effects after consuming the beverages were analysed using Chi-square test and Fisher exact test. The results showed that there were significant differences in the levels of alertness but no significant differences were observed in short term memory, reaction time and selective attention while comparing intervention and control groups after consumption of the drinks. There was a significant difference however, in reaction time ($p=0.020$), selective attention ($p=0.023$), and levels of alertness ($p<0.001$) and anxiety ($p=0.010$) after consuming the energy drinks in comparison to the performance prior to the intervention. There was no significant difference in the immediate adverse effects and the consumption of both beverages. In conclusion, energy drinks can improve reaction time, selective attention and the levels of alertness but the participants experience an average increase in anxiety level after consumption of these popular drinks. On the contrary however, energy drinks have no effect on short term memory.

Keywords

Energy Drinks, Cognitive Function, Medical Students, Randomised Controlled Trial

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1. Introduction

"Energy drinks" can be considered as any non-alcoholic beverage that usually contains caffeine (a psychostimulant), as well as sugar and often additional supplements, that are perceived to improve alertness and physical performance [1]. The sales of energy drinks have grown into a global billion-dollar industry. For instance, since Red bull®

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launched their products into the markets of Austria in 1987 and into the United States in 1997, the company's growth was astounding due to their marketing strategy in promotion of its sales among the younger generation [2]. The content of these energy drinks are mainly caffeine, taurine, glucose derivatives, riboflavin, pyridoxine, nicotinamide, and other vitamin B and other herbal ingredients such as ginseng guarana and gingko biloba [1]. According to Zenith International [3], the consumption of energy drinks worldwide has increased since 2007 by 14%, reaching 4.8 billion litres in 2011, from a previous value of 3.3 billion litres. In a study done in the European Union in 2012, the prevalence of consumption of energy drinks is 68% among young adults, 30% in adults and 18% in the paediatric age group [1]. Bulut et al. [4] noted that 46.5% of university students in Turkey have a history of consuming energy drinks at least once. Park et al. found that 1.4% of students among the 800 students sampled consumed energy drinks more than 5 times a week, whereas 10.5% drank it at least once a week in South Korea [5]. This is supported by the 665% growth spurt in the energy drink industry in South Korea between the years of 2010 to 2012 [6]. In a study done in Malaysia among university students, 83.3% consume energy drinks, 31.7% take it weekly and 5.8% daily, in which the common energy drink brands are Red bull®, Livita® and Power root® [7].

Many studies have been done to determine the active ingredient in energy drinks that enhance cognitive function. Giles et al. [8] states that caffeine is the active ingredient in energy drinks that bring about improvements in mental performance, drives away lethargy and increases attention and reaction time. However, some studies state that it might be due to the withdrawal effect of caffeine that results in these improvements [9]. On the other hand, Hewlett et al. [10] found that mood and cognitive function were not affected by overnight caffeine withdrawal and caffeine helps people stay awake and remain vigilant. This is further supported by Warburton et al. [11] as information processing, attention and verbal reasoning has been greatly enhanced by moderate intake of caffeine and taurine. Scholey et al. found that there might be a synergistic effect between glucose and caffeine resulting in the enhancement of cognitive performance [12].

In addition, consuming energy drinks resulted in significant improvement in alertness, thus enhancing physical endurance and cognitive function [13]. This is supported by Lara et al. [14] as the physical performance of athletes improved greatly in a simulated soccer game. Furthermore, energy drinks can be used as a stimulant to increase alertness in a sleep deprived person to prevent the driver from dozing off [15].

Mixing energy drinks and alcohol however, further affects behavioural inhibition and mask signs of intoxication, thus endangering their lives especially while driving as it may lead to road traffic accidents [16]. Excessive energy drink intake might precipitate seizure attacks [17]. Energy drink consumption has a negative relationship with the number of hours of sleep someone attains after consuming the beverage, resulting in insomnia, and is also associated with depressive mood [5]. Furthermore, obese individuals should be cautious during the intake of energy drinks as it might lead to adverse cardiovascular effects [18]. Pettit et al. [19] also established a negative relationship between academic performance and the intake of energy drinks. This might be due to latent sleep onset, insomnia and increased daytime sleepiness [20].

In previous intervention studies, Alford et al. [13] found that there was marked improvement in cognitive functions such as reaction time, memory and concentration, which was evident by the elevated alertness demonstrated by the subjects. In addition, according to the results attained by Kennedy et al. [21], combining caffeine and glucose can enhance cognitive function and circumstantial fatigue during lengthy periods where increase cognitive demand is required. This is also supported by Adan et al. that caffeine and glucose help in improving attention and consolidation of verbal memory [22]. However, in another study, short term memory is not improved by the combination of caffeine and taurine which are the assumed active ingredients of energy drinks [23]. Warburton et al. [11] also found that taurine containing energy drinks had no effect on verbal memory compared to placebos.

According to Euromonitor International 2014 [24], the growth rate of sales of energy drinks in Malaysia from the year 2008-2013 is 24.5%. This indicates that the industry of energy drinks in Malaysia has increased exponentially and energy drinks are becoming more popular among the citizens. Previous research has been done in Malaysia on the effect of energy drinks on cardiology parameters and they found out that energy drinks can raise systolic blood pressure and there was a significant improvement in mental alertness subjectively [25]. On the other hand, another study done among a local university found that there was no significant difference between the academic performance of students who consume energy drinks and those who do not [7]. Therefore, this randomised controlled study is being conducted to determine the effect of energy drinks on the cognitive performance among medical students.

The main objective of this study is to determine the effect of energy drinks (Monster®) compared to a control drink on cognitive function (short term memory, attention and reaction time). Furthermore, we would like to find out the

immediate adverse effects of energy drinks. Our research questions are:

A. Do energy drinks (Monster®) affect the cognitive function (short term memory, attention and reaction time) of medical students?

B. Do energy drinks have any immediate adverse effects?

From this research, we would hypothesize that the consumption of energy drinks will improve short term memory, attention and reaction time in medical students.

2. Methodology

2.1. Study Design, Study Setting and Study Population

We conducted a randomised controlled trial to determine the effect of energy drinks on cognitive function in which short term memory, reaction time and attention were assessed. This study was conducted among medical students of Melaka Manipal Medical College (MMMC), Muar campus, Malaysia.

MMMC has two campuses (Melaka and Muar) in Malaysia which cater for students from Foundation in Science (FIS), Bachelor of Dental Surgery (BDS) and Bachelor of Medicine and Bachelor of Surgery (MBBS).

Our study was conducted in the month of June 2019 till July 2019, in MMMC in Muar, Johor, Malaysia where semester 6 and 7 MBBS students with a population estimated to be around 280 students were situated.

2.2. Sample Size and Sampling

Out of the estimated 280 population in Muar campus, we conducted a non-probability sampling where we invited volunteers to obtain a sufficient sample for our study. The sample size was calculated using the below formula where 0.05 precision (α=0.05) was accepted.

To compare the quantitative outcome between energy drinks (Monster) and a control drink, a formula comparing two means (using mean and standard deviation) in Statistics and Sample Size Pro app was used as shown below:

$$n \geq \frac{\left(Z_{1-\alpha/2} + Z_{1-\beta}\right)^2 \left(\sigma_1^2 + \sigma_2^2/r\right)}{(\mu_1 - \mu_2)^2}$$

The minimum sample size was calculated with the help of previous study

Where,

Type 1 error rate (α)=0.05

Type 2 error rate (β)=0.2

Mean in group 1 (μ_1)=89.62

Standard deviation in group 1 (σ_1)=2.49

Mean in group 2 (μ_2)=86.43

Standard deviation in group 2 (σ_2)=5.15

Ratio (Group 2/Group 1)=1

With reference to a previous similar study, the mean percentage of getting the right answer of spatial memory is 89.32% and 86.43% for energy drinks and placebo's respectively [12]. The minimum sample size needed for each group was 26 (per intervention group).

$$_{n}final = \frac{n}{[1-(dropout\%)]} \quad (1)$$

$$_{n}final = \frac{26}{1-0.1} \quad (2)$$

$$_{n}final = 28.89 \quad (3)$$

$$_{n}final \approx 29 \quad (4)$$

Dropout percentage=0.1

n=26

With 10% as attrition, the final sample size, n_{final} calculated from the formula above was 29 per group. Therefore, the total minimum sample size needed was 58. However, we recruited 52 students as our final total sample size. We randomized 52 students into 2 groups, which included 26 students in the intervention group and 26 students in the control group.

The sampling method used was the non-probability sampling method. Our inclusion criteria were medical students from semester 6 and 7 of any age, gender, ethnicity and who were willing to provide informed consent. The exclusion criteria consisted of significant medical illnesses or mental disorders, use of specific medication, signs and symptoms of dysmenorrhea (for females), alcohol consumption in the last 24 hours and caffeinated drink consumption within the last 10 hours. Volunteers were selected based on fixed inclusion and exclusion criteria.

2.3. Randomization

We recruited 52 volunteers to participate in this study, in which 26 volunteers were allocated to the intervention group and 26 volunteers were allocated to the control group. The block randomization method was done to randomize equal numbers of participants into the respective intervention group and control group. Therefore, a block size of 2 was used to classify the participants into an intervention group and control group. We used Randomizer. org website to carry out the randomization.

2.4. Procedure and Intervention

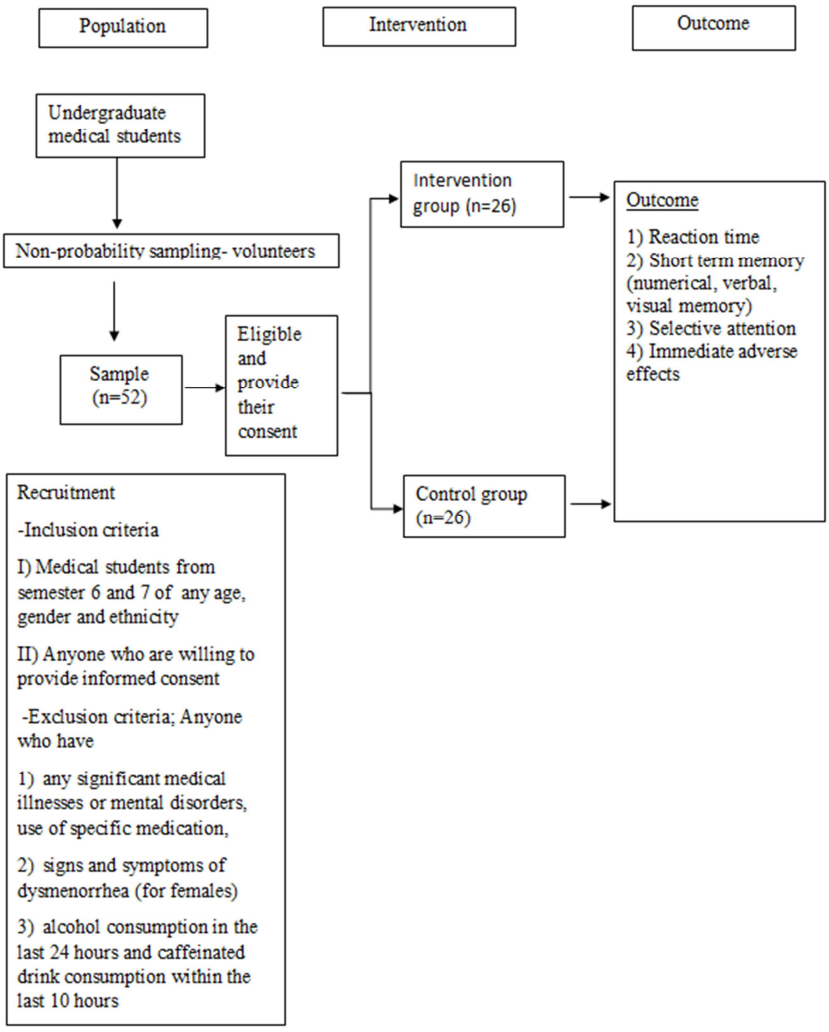

Figure 1. Flow chart of the randomised controlled trial.

Participants were then be divided into a control group and an intervention group. All of the participants were given a questionnaire prior to the commencement of the tests to assess their validity in terms of exclusion criteria, which was applied to exclude participants who consumed alcohol in the last twenty-four hours, consumed caffeinated drinks in the last ten hours, had significant medical illnesses and mental disorders, used specific medication, and exhibited signs and symptoms of dysmenorrhea for females. Then, a self-administered questionnaire was distributed to assess the participant's sleeping pattern, nutritional status, caffeine intake, energy drink intake, exercise tolerance and practices of self-meditation. The participants were also asked to rate how energetic, awake, anxious and alert they were feeling from a scale of 1-10 prior to the commencement of any tests. After the questionnaires were analysed for their validity for partaking in the tests, a pre-test was conducted prior to the consumption of the control and intervention drinks to assess the simple reaction time, selective attention and short-term memory of the individual participants. The individual scores were then documented and used for later comparison with the results attained after the intervention.

For the intervention group, they were assigned to drink an energy drink (Monster®, in which every 100ml contained 47kcal calories, 0g protein, 0g fat, 12.2g carbohydrate, 11.3g total sugar, 77mg sodium, 19mg caffeine, 400mg taurine) 30 to 45 minutes prior to the initiation of the test and the control group was provided a non-caffeinated carbonated beverage (Sprite®, in which every 100ml contained 22kcal calories, 0g protein, 0g fat, 5.5g carbohydrate, 5.5g total sugar, 16mg sodium) to drink at the same time as the intervention group. The amount to be consumed was kept constant for all participants regardless of the drink, at an estimated 250ml. Therefore, each participant assigned to the intervention group consumed an energy drink containing 47.5mg caffeine and 28.25g total sugar, whereas the control group consumed a

non-caffeinated carbonated drink which contained 13.75g total sugar. 30-45 minutes after consuming the drinks, all the participants were once again asked to take the same tests to assess their simple reaction time, selective attention and short-term memory. The individual scores were once again documented for analysis. Once the tests were completed, all the participants were provided another questionnaire to once again assess and enquire about the presence of any adverse effects after the intervention was completed. The specific adverse effect of insomnia was asked about the following morning. The participants were also asked to rate how energetic, awake, anxious and alert they were feeling from a scale of 1-10 after the completion of the tests. To ensure a non-biased result, our intervention was held in the computer lab at the same time for all participants with no outside interference.

2.5. Cognitive Function Test

1) Simple reaction time [26]

This test can assess response speed and accuracy. The participant was instructed to click on the screen once the screen changes colour from red to green. The reaction time was recorded in milliseconds. The average score of 5 trials was documented.

2) Forward Digit span (numerical memory) [26]

This test measured short term memory span. The participant was asked to memorise the sequence of numbers which appeared on the screen and type out the number after the numbers disappear. The number of digits increased with each correct answer and the performance was documented by the average number of digits correctly remembered.

3) Verbal short-term memory [26]

This test assessed short term memory in which the participants had to remember the previous words shown on the screen and decide whether or not the word projected had already been shown or was a new word. The marks are calculated based on the number of correct answers and the participants were given 3 chances.

4) Visual memory test [26]

This test measured spatial short-term memory where it assessed the participant's ability to remember relationships between objects in space. The participant had to pay attention and memorise the sequence of the boxes while they start to flash and click the correct order of previously flashing boxes. The performance was measured by the average number of boxes remembered during the task.

5) Stroop effect [27]

This test assessed the selective attention and their processing speed ability. A video was played to assess the Stroop effect in which there was a mismatch between the ink colour and the word. The participant had to write down the colour of the ink of the word. The performance was assessed based on the number of correct answers.

2.6. Data Collection and Data Processing

On the day of data collection, the participants were called to the computer lab and they were seated according to the group they belonged to. At the beginning, the participants were briefed about the aim and their role in the experiment. They were informed that they were allowed to withdraw from the study at any time they wanted.

The participants were given the questionnaire to assess their mental alertness subjectively and the cognitive function was assessed through online cognitive tests (https://www.humanbenchmark.com/). The baseline variables were BMI (Body Mass Index), number of hours of sleep the day before, caffeinated drink intake, consumption of energy drinks, self-meditation and nutritional status.

Then, they were given the respective intervention and control drinks allocated to them and the participants reassembled at the computer lab after a duration of 30-45 minutes in which they were not allowed to do any form of strenuous activity. Their cognitive function (simple reaction time, selective attention and short-term memory, which included verbal, numerical and visual memory) was assessed again post-intervention.

2.7. Data Analysis

For the data analysis, it was tabulated by using Microsoft Excel version 2013 and the values entered were double checked to prevent any duplication and prevent missing data. From Microsoft Excel, the information was then used for statistical calculation using analytical software Epi info version 7.2 and Graph pad.

For descriptive statistical analysis, we included mean, standard deviation (SD), frequency and percentage. Mean and standard deviation were used to analyse age, BMI, alertness scale and average hours of sleep. Frequency and percentage were calculated for categorical data which included gender, ethnicity, caffeinated drink consumption, energy drink intake, average hours of exercise per week and adverse effects of energy drinks. A table was drawn for the demographic details to describe frequency and its percentage between the intervention group and control group.

For hypothesis testing, a parametric test known as unpaired t test was used to determine the difference between the intervention group and control group on cognitive performance, alertness and anxiety levels. The level of

significance was set at P<0.05, in which any value more than 0.05 was considered not statistically significant. Paired t test, another parametric test, was used to find the difference in cognitive performance, alertness and anxiety levels before and after consumption of the drinks. Mean plot was used to represent the numerical data obtained from the scores of cognitive performance, alertness and anxiety levels.

For measurement of association, the relative risk of adverse effects after drinking the beverages between the intervention and control groups was calculated along with 95%CI. Chi-square test and Fisher exact test were used to determine the level of significance.

2.8. Ethical Consideration

The participants that joined the study were volunteers and were not forced into partaking in the randomised controlled trial. An informed consent form which mentioned all the important necessary and relevant details of the study was provided to each participant with a brief statement of reassurance that there would be no academic or occupational penalty on those who refused to volunteer for the study. Once given the consent, each participant was given the free choice to either partake or not, depending on how comfortable they were with the tests to be conducted. The participants were also notified well in advance, that all the data and information gathered throughout the duration of the study would be kept completely private and confidential. The participants were also informed that they were allowed to withdraw from the study at any time without reason. The study was approved by the Research Ethics Committee, Faculty of Medicine, Melaka Manipal Medical College (MMMC).

3. Results

Table 1. Baseline characteristics between the intervention (energy drink) group (n=26) and control (non-caffeinated carbonated beverage) group (n=26).

Variables		Energy drink Intervention group (n=26) n (%)	Control group (n=26) n (%)	Total (n=52) N (%)
Age (years)[a]		22.7 (1.01)	22.9 (1.75)	22.8 (1.42)
Gender	Male	11 (42.31)	15 (57.69)	26 (50)
	Female	15 (57.69)	11 (42.31)	26 (50)
Ethnicity	Malay	1 (3.85)	2 (7.69)	3 (5.77)
	Chinese	11 (42.31)	10 (38.46)	21 (40.38)
	Indian	8 (30.77)	8 (30.77)	16 (30.77)
	Others	6 (23.08)	6 (23.08)	12 (23.08)
BMI (kg/m^2)[a]		23.69 (6.55)	22.88 (5.21)	23.29 (5.87)
Duration of sleep last night (hours)[a]		5.62 (1.57)	5.77 (1.93)	5.69 (1.74)
Meal before test	Yes	23 (88.46)	21 (80.77)	44 (84.62)
	No	3 (11.54)	5 (19.23)	8 (15.38)
Regular caffeinated drink consumer	Yes	15 (57.69)	11 (42.31)	26 (50)
	No	11 (42.31)	15 (57.69)	26 (50)
Frequency of consuming caffeinated drinks	Less than once a week	12 (46.15)	12 (46.15)	24 (46.15)
	2-3 times a week	7 (26.92)	9 (34.62)	16 (30.77)
	4-6 times a week	3 (11.54)	4 (15.38)	7 (13.46)
	7-9times a week	2 (7.69)	1 (3.85)	3 (5.77)
	More than 10 times a week	2 (7.69)	0 (0)	2 (3.85)
Energy drink consumer	Yes	18 (69.23)	13 (50)	31 (59.62)
	No	8 (30.77)	13 (50)	21 (40.38)
Duration of exercise per week	Less than 1 hour	10 (38.46)	11 (42.31)	21 (40.38)
	1-2hour	8 (30.77)	6 (23.08)	14 (26.92)
	3-4 hours	2 (7.69)	2 (7.69)	4 (7.69)
	5-6 hours	4 (15.38)	3 (11.54)	7 (13.46)
	7 hours and above	2 (7.69)	4 (15.38)	6 (11.54)
Self-meditation	Yes	7 (26.92)	7 (26.92)	14 (26.92)
	No	19 (73.08)	19 (73.08)	38 (73.08)

[a]Mean (SD).

A total of 52 students participated in this study and were randomised into two groups, which was the energy drink intervention group (n=26) and control group (n=26). Table 1 shows baseline characteristics between the intervention group (energy drinks) and control group (non-caffeinated carbonated beverages). The mean age of participants in the intervention group was 22.7 (SD=1.01), while in the control group, the mean age was 22.9 (SD=1.75). For gender, female participants were the majority (57.69%) in the intervention group, however males were the majority (57.69%) in the control group. The majority of participants were Chinese, which was represented by 42.31% in the intervention group and 38.46% in the control group. The average BMI in the intervention group is 23.69 kg/m^2 (SD=6.55) and 22.88

kg/m^2 (SD=5.21) in the control group. Participants in the control group had more hours of sleep which was 5.77 hours (SD=1.93), compared to 5.62 hours (SD=1.57) in the intervention group. Majority of the participants (84.62%) had their meal before joining the study. 50% of the participants were regular caffeinated drink consumers, in which 57.69% are in the intervention group and 42.31% in the control group. However, 46.15% of the participants consumed caffeinated drinks less than once a week. The majority (59.62%) of the participants have consumed energy drinks, which was 69.23% and 50% in the intervention group and control group respectively. Majority of the participants (40.38%) exercised less than 1 hour per week and 14% of the participants performed self- meditation.

Table 2. Energy drink intake among energy drink consumers (n=31) between the intervention group (energy drink) and control group (non-caffeinated carbonated beverage).

Variables			Energy drink Intervention group (n=18) n (%)	Control group (n=13) n (%)	Total (n=31) n (%)
Consumed more than 1 energy drink per month	Yes		5 (27.78)	4 (30.77)	9 (29.03)
	No		13 (72.22)	9 (69.23)	22 (70.97)
Brand of Energy Drink	Livita	Yes	1 (5.56)	1 (7.69)	2 (3.85)
		No	17 (94.44)	12 (92.31)	50 (96.15)
	Power Root	Yes	1 (5.56)	0 (0.00)	1 (1.92)
		No	17 (94.44)	13 (100.00)	51 (98.08)
	Monster	Yes	1 (5.56)	1 (7.69)	2 (3.85)
		No	17 (94.44)	12 (92.31)	50 (96.15)
	Red Bull	Yes	18 (100.00)	13 (100.00)	31 (59.62)
		No	0 (0.00)	0 (0.00)	21 (40.38)
Amount of energy drinks consumed at once	1		17 (94.44)	13 (100.00)	30 (96.77)
	2		1 (5.56)	0 (0.00)	1 (3.23)
Maximum amount of energy drinks consumed in a day [a]			1.94 (1.73)	2.38 (1.26)	2.13 (1.54)
Amount of energy drinks consumed per week	0 times		15 (83.33)	8 (61.54)	23 (74.19)
	1-2 times		3 (16.67)	3 (23.08)	6 (19.35)
	3-4 times		0 (0.00)	2 (15.38)	2 (6.45)

[a]Mean (SD).

Table 2 shows the energy drink intake among energy drink consumers between the intervention and control groups. The sample size obtained for the study was 52 medical students. However, only 31 of them reported that they had consumed energy drinks prior to the study, therefore, the subset obtained was 31 medical students. 18 of which belonged to the intervention group (energy drinks) and 13 of them belonged to the control group (non-caffeinated beverages).

Among the intervention group, 5 (27.78%) of them had consumed more than one energy drink a month prior to the study as compared to the 4 (30.77%) in the control group. 13 (72.22%) had never consumed more than one energy drink a month among the intervention group whereas 9 (69.23%) had never drank more than one energy drink per month in the control group.

The four energy drinks enquired about here, were the four main popular brands of energy drinks among Malaysian medical students; Red Bull®, Monster®, Power Root® and Livita®. Among the intervention group, only 1 (5.56%) participant had reported drinking Monster® or Livita® before as compared to the 17 (94.44%) participants who have never consumed it. Among the control group, 1 (7.79%) participant had consumed Livita® and Monster® before as opposed to the 12 (92.31%) who had never. In the intervention group, 1 (5.56) participant had taken Power Root® before and 17 (94.44%) had never as compared to the control group where all 13 (100.00%) participants reported never consuming Power Root® before. The most popular energy drink among the four enquired about is Red Bull®. In the intervention and control groups, all 18 (100.00%) and 13 (100.00%) students respectively had consumed Red Bull® before.

The amount of energy drinks consumed at once was also asked among the volunteers in the study. In the intervention group, 17 (94.44%) of them reported that they had only taken 1 energy drink at a time whereas 1 (5.56%) participant had reported to take 2 energy drinks at once. In the control group however, all 13 (100.00%) students said to have consumed only one energy drink at once.

The amount of energy drinks taken a week was subdivided into 0 times, 1-2 times and 3-4 times a week. In the intervention group, 15 (83.33%) did not take energy drinks quantified to per week, 3 (16.67%) students had taken energy drinks 1-2 times a week and no one reported to have taken it 3-4 times a week. As compared to the control group, 8 (61.54%) students did not take energy drinks quantified to per week, 3 (23.08%) students took it 1-2 times a week and 2 (15.38%) took it 3-4 times a week.

Finally, the mean and standard deviation was calculated to compare the maximum amount of energy drinks consumed in a day between the intervention and control groups. For the intervention group, the mean was 1.94 with a SD of 1.73 and the control group had a mean of 2.38 with a SD of 1.26. The

overall mean and SD for the intervention and control groups was 2.13 and 1.54 respectively.

Table 3. Comparison of simple reaction time, short term memory, selective attention, alertness and anxiety between intervention group (energy drink) and control group (non-caffeinated carbonated beverage) before intervention.

Outcome variables		Mean (SD)		Mean difference (95%CI)	*t*-statistics (df)	P-value
		Intervention group (n=26)	Control group (n=26)			
Cognitive performance	Reaction time (ms)	296.96 (53.66)	331.00 (100.81)	-34.04 (-79.02, 10.95)	-1.52 (50)	0.135
	Numerical memory (score)	10.31 (1.83)	9.00 (1.67)	1.31 (0.33, 2.28)	2.69 (50)	0.010
	Verbal memory (Score)	33.69 (24.20)	35.65 (26.36)	-1.96 (-16.05, 12.13)	-0.28 (50)	0.781
	Visual memory (score)	9.69 (2.68)	9.04 (1.66)	0.65 (-0.59, 1.90)	1.06 (50)	0.295
	Selective attention (score)	26.62 (8.20)	28.46 (4.94)	-1.85 (-5.62, 1.93)	-0.98 (50)	0.330
Alertness & anxiety	Alert (scale)	6.62 (1.88)	6.35 (1.74)	0.27 (-0.74, 1.28)	0.54 (50)	0.594
	Awake (scale)	6.77 (2.01)	6.23 (1.88)	0.54 (-0.55, 1.62)	1 (50)	0.323
	Energetic (scale)	6.15 (1.89)	5.58 (2.12)	0.58 (-0.54, 1.70)	1.04 (50)	0.305
	Anxious (scale)	4.00 (2.61)	3.15 (2.11)	0.85 (-0.48, 2.17)	1.29 (50)	0.204

[b]Unpaired t-test.

Table 3 shows the comparison of simple reaction time, short term memory, selective attention, alertness and anxiety between the intervention and control groups before the commencement of the intervention.

The mean of the participants' reaction time in the intervention group (energy drinks) was 296.96ms with standard deviation (SD) of 53.66, while in the control group, the mean was 331ms with SD of 100.81. The mean difference (95% CI) and t-statistics of reaction time between the intervention group and control group were -34.04 (-79.02, 10.95) and -1.52 respectively. The P value obtained for reaction time is 0.135. Hence, there is no significant difference in the reaction time between the intervention group and control group before the consumption of the drinks.

The mean of the participants' numerical memory score in the intervention group (energy drink) was 10.31 with a SD of 1.83, while in the control group, the mean was 9.00 with a SD of 1.67. The mean difference (95% CI) and t-statistics of the numerical memory score between the intervention group and control group was 1.31 (0.33, 2.28) and 2.69 respectively. The P value computed for numerical memory was 0.010. Hence, there is significant difference in the numerical memory between the two groups before consumption of the drinks.

The mean of the participants' verbal memory score in the intervention group (energy drinks) was 33.69 with a SD of 24.20, while in the control group, the mean was 35.65 with a SD of 26.36. The mean difference (95% CI) and t-statistics of verbal memory score between the intervention group and control group was -1.96 (-16.05, 12.13) and -0.28 respectively. The P value computed for verbal memory was 0.781, which suggested that there is no significant difference in the verbal memory between the intervention group and control group before the intervention ended.

The mean of the participants' visual memory score in the intervention group (energy drink) was 9.69 with a SD of 2.68, while in the control group, the mean was 9.04 with a SD of 1.66. The mean difference (95% CI) and t-statistics of the visual memory score between the intervention group and control group was 0.65 (-0.59, 1.90) and 1.06 respectively. The P value obtained for visual memory was 0.295, which suggested that there is no significant difference in the visual memory between the intervention group and control group before consumption of the drinks.

The mean of the participants' selective attention score in the intervention group (energy drinks) was 26.62 with SD of 8.20, while in the control group, the mean was 28.46 with SD of 4.94. The mean difference (95% CI) and t-statistics of the selective attention score between the intervention group and control group was -1.85 (-5.62, 1.93) and -0.98 respectively. The P value gained for selective attention score was 0.330. Thus, there is no significant difference in the selective attention score between the intervention group and control group before the intervention.

The mean score of the participants' level of alertness in the intervention group (energy drink) was 6.62 (out of 10) with a SD of 1.88, while in the control group, the mean was 6.35 with a SD of 1.74. The mean difference (95% CI) and t-statistics of alertness between the intervention group and control group was 0.27 (-0.74, 1.28) and 0.54 respectively. The P value obtained for alertness was 0.594. Hence, there is no significant difference in how alert the participants felt between the intervention group and control group before consumption of the drinks.

The mean score of how awake the participants felt in the intervention group (energy drinks) was 6.77 (out of 10) with a SD of 2.01, while in the control group, the mean was 6.23 with a SD of 1.88. The mean difference (95% CI) and t-statistics of wakefulness between the intervention group and control group was 0.54 (-0.55, 1.62) and 1 respectively. The P value obtained for wakefulness was 0.305. Hence, this indicates that there is no significant difference in the how

awake the participants felt between the intervention and control group before consumption of the drinks.

The mean score of how energetic the participants felt in the intervention group (energy drinks) was 6.15 (out of 10) with a SD of 1.89, while in the control group, the mean was 5.58 with a SD of 2.12. The mean difference (95% CI) and t-statistics of how energetic the participants felt between the intervention group and control group was 0.58 (-0.54, 1.70) and 1.04 respectively. The P value obtained was 0.305. Hence, there is no significant difference in how energetic the participants felt between the intervention group and control group before the intervention.

The mean score of participants' anxiety level in the intervention group (energy drinks) was 4.00 (out of 10) with a SD of 2.61, while in the control group, the mean was 3.15 with a SD of 2.11. The mean difference (95% CI) and t-statistics of anxiety levels between the intervention group and control group was 0.85 (-0.48, 2.17) and 1.29 respectively. The P value obtained for the anxiety level was 0.204. This suggests that there is no significant difference in the anxiety levels between the intervention group and control group before consumption of the drinks.

Table 4. Comparison of simple reaction time, short term memory, selective attention, alertness and anxiety between intervention group (energy drink) and control group (non-caffeinated carbonated beverage) after intervention.

Outcome variables		Mean (SD)		Mean difference (95%CI)	*t*-statistics (df)	P-value
		Intervention group (n=26)	Control group (n=26)			
Cognitive performance	Reaction time (ms)	266.46 (64.50)	294.19 (49.95)	-27.73 (-59.87, 4.40)	-1.73 (50)	0.089
	Numerical memory (score)	10.15 (1.46)	9.46 (1.10)	0.69 (-0.03, 1.41)	1.93 (50)	0.060
	Verbal memory (score)	44.88 (29.06)	38.23 (21.71)	6.65 (-7.64, 20.94)	0.94 (50)	0.354
	Visual memory (score)	9.81 (1.74)	9.77 (1.73)	0.03 (-0.93, 1.01)	0.08 (50)	0.937
	Selective attention (score)	30.27 (2.63)	29.81 (3.51)	0.46 (-1.27, 2.19)	0.54 (50)	0.594
Alertness & anxiety	Alert (scale)	8.23 (1.21)	6.42 (1.98)	1.81 (0.89, 2.72)	3.97 (50)	<0.001
	Awake (scale)	8.27 (1.19)	6.46 (1.86)	1.81 (0.94, 2.67)	4.18 (50)	<0.001
	Energetic (scale)	8.27 (1.22)	6.04 (2.58)	2.23 (1.11, 3.36)	3.98 (50)	<0.001
	Anxious (scale)	5.42 (2.89)	3.81 (2.93)	1.61 (-0.003, 3.235)	2 (50)	0.051

[b]Unpaired t-test.

Table 4 shows the comparison of simple reaction time, short term memory, selective attention, alertness and anxiety between the intervention group (energy drinks) and control group (non-caffeinated carbonated beverages) after the intervention.

The mean of the participants' reaction time in the intervention group (energy drinks) was 266.46ms with standard deviation (SD) of 64.50, while in the control group, the mean was 294.19ms with SD of 49.95. The mean difference (95% CI) and t-statistics of reaction time between the intervention group and control group were -27.73 (-59.87, 4.40) and -1.73 respectively. The P value obtained for reaction time is 0.089. Hence, there is no significant difference in the reaction time between the intervention group and control group after the consumption of the drinks.

The mean of the participants' numerical memory score in the intervention group (energy drink) was 10.15 with a SD of 1.46, while in the control group, the mean was 9.46 with a SD of 1.10. The mean difference (95% CI) and t-statistics of the numerical memory score between the intervention group and control group was 0.69 (-0.03, 1.41) and 1.93 respectively. The P value computed for numerical memory was 0.060. Hence, there is no significant difference in the numerical memory between the two groups after consumption of the drinks.

The mean of the participants' verbal memory score in the intervention group (energy drinks) was 44.88 with a SD of 29.06, while in the control group, the mean was 38.23 with a SD of 21.71. The mean difference (95% CI) and t-statistics of verbal memory score between the intervention group and control group was 6.65 (-7.64, 20.94) and 0.94 respectively. The P value computed for verbal memory was 0.354, which suggested that there is no significant difference in the verbal memory between the intervention group and control group after the intervention ended.

The mean of the participants' visual memory score in the intervention group (energy drink) was 9.81 with a SD of 1.74, while in the control group, the mean was 9.77 with a SD of 1.73. The mean difference (95% CI) and t-statistics of the visual memory score between the intervention group and control group was 0.04 (-0.93, 1.01) and 0.08 respectively. The P value obtained for visual memory was 0.937, which suggested that there is no significant difference in the visual memory between the intervention group and control group after consumption of the drinks.

The mean of the participants' selective attention score in the intervention group (energy drinks) was 30.27 with SD of 2.63, while in the control group, the mean was 29.81 with SD of 3.51. The mean difference (95% CI) and t-statistics of the selective attention score between the intervention group and control group was 0.46 (-1.27, 2.19) and 0.54 respectively. The P value gained for selective attention score was 0.594. Thus, there is no significant difference in the selective attention score between the intervention group and control

group after the intervention.

The mean score of the participants' level of alertness in the intervention group (energy drink) was 8.23 (out of 10) with a SD of 1.21, while in the control group, the mean was 6.42 with a SD of 1.98. The mean difference (95% CI) and t-statistics of alertness between the intervention group and control group was 1.81 (0.89, 2.27) and 3.97 respectively. The P value obtained for alertness was <0.001. Hence, there is a significant difference in how alert the participants felt between the intervention group and control group after consumption of the drinks.

The mean score of how awake the participants felt in the intervention group (energy drinks) was 8.27 (out of 10) with a SD of 1.19, while in the control group, the mean was 6.46 with a SD of 1.86. The mean difference (95% CI) and t-statistics of wakefulness between the intervention group and control group was 1.81 (0.94, 2.67) and 4.18 respectively. The P value obtained for wakefulness was <0.001. Hence, this indicates that there is a significant difference in the how awake the participants felt between the intervention and control group after consumption of the drinks.

The mean score of how energetic the participants felt in the intervention group (energy drinks) was 8.27 (out of 10) with a SD of 1.22, while in the control group, the mean was 6.04 with a SD of 2.58. The mean difference (95% CI) and t-statistics of how energetic the participants felt between the intervention group and control group was 2.23 (1.11, 3.36) and 3.98 respectively. The P value obtained was <0.001. Hence, there is a significant difference in how energetic the participants felt between the intervention group and control group after the intervention.

The mean score of participants' anxiety level in the intervention group (energy drinks) was 5.42 (out of 10) with a SD of 2.89, while in the control group, the mean was 3.81 with a SD of 2.93. The mean difference (95% CI) and t-statistics of anxiety levels between the intervention group and control group was 1.615 (-0.003, 3.235) and 2 respectively. The P value obtained for the anxiety level was 0.051. This suggests that there is no significant difference in the anxiety levels between the intervention group and control group after consumption of the drinks.

Table 5. Comparison of simple reaction time, short term memory, selective attention, alertness and anxiety in the intervention group (energy drink) before and after consuming the energy drink.

Outcome variables		Mean (SD) (n=26)		Mean difference (95%CI)	*t*-statistics (df)	P-value
		Before	After			
Cognitive performance	Reaction time (ms)	296.96 (53.66)	266.46 (64.50)	30.50 (5.20, 55.80)	2.48 (25)	0.020
	Numerical memory (score)	10.31 (1.83)	10.15 (1.46)	0.15 (-0.41, 0.72)	0.56 (25)	0.582
	Verbal memory (Score)	33.69 (24.20)	44.88 (29.06)	-11.19 (-22.46, 0.07)	2.05 (25)	0.051
	Visual memory (score)	9.69 (2.68)	9.81 (1.74)	-0.12 (-0.99, 0.76)	0.27 (25)	0.424
	Selective attention (score)	26.62 (8.20)	30.27 (2.63)	-3.65 (-6.75, -0.55)	2.42 (25)	0.023
Alertness & anxiety	Alert (scale)	6.62 (1.88)	8.23 (1.21)	-1.62 (-2.18, -1.05)	5.94 (25)	<0.001
	Awake (scale)	6.77 (2.01)	8.27 (1.19)	-1.50 (-2.17, -0.83)	4.62 (25)	<0.001
	Energetic (scale)	6.15 (1.89)	8.27 (1.22)	-2.12 (-2.74, -1.49)	6.93 (25)	<0.001
	Anxious (scale)	4.00 (2.61)	5.81 (1.39)	-1.81 (-3.12, -0.50)	2.84 (25)	0.010

[c]Paired t-test.

Table 5 shows the comparison of reaction time, numerical memory, verbal memory, visual memory, selective attention, alertness, and how awake, energetic and anxious the participants felt before and after consuming the energy drinks.

The mean (SD) of the reaction time before and after consumption of the energy drinks was 296.96ms (53.66) and 266.46ms (64.50) respectively. The mean difference (95% CI) and t-statistics of reaction time calculated before and after consumption was 30.50 (5.20, 55.80) and 2.48 respectively. There was a decrease of reaction time after the drinks were consumed with the magnitude of 30.50 mean difference. The P value of reaction time computed was 0.020. Hence, there is significant difference in the reaction time of the participants before and after the intervention.

The mean (SD) of the numerical memory before and after consumption of the energy drinks was 10.31 (1.83) and 10.15 (1.46) respectively. The mean difference (95% CI) and t-statistics of numerical memory calculated before and after the drinks were consumed was 0.15 (-0.41, 0.72) and 0.56 respectively. There was a decrease of numerical memory after drinking the energy drink with the magnitude of 0.15 mean difference. The P value of numerical memory computed was 0.582. Hence, there is no significant difference in the numerical memory of the participants before and after drinking the energy drinks.

The mean (SD) of the verbal memory before and after consumption of the drink was 33.69 (24.20) and 44.88 (29.06) respectively. The mean difference (95% CI) and t-statistics of verbal memory calculated before and after consumption was -11.19 (-22.46, 0.07) and 2.05 respectively. There was an increase of verbal memory after consuming the energy drinks with the magnitude of -11.19 mean difference. The P value of verbal memory computed was 0.051. Hence, there is no

significant difference in the verbal memory of the participants before and after energy drink consumption.

The mean (SD) of the visual memory before and after consumption of the intervention drink was 9.69 (2.68) and 9.81 (1.74) respectively. The mean difference (95% CI) and t-statistics of visual memory calculated before and after the intervention was -0.12 (-0.99, 0.76) and 0.27 respectively. There was an increase of visual memory after energy drink consumption with the magnitude of -0.12 mean difference. The P value of visual memory computed was 0.424. Hence, there is no significant difference in the visual memory of the participants before and after the intervention.

The mean (SD) of the selective attention before and after the intervention was 26.62 (8.20) and 30.27 (2.63) respectively. The mean difference (95% CI) and t-statistics of selective attention calculated before and after the intervention was -3.65 (-6.75, -0.55) and 2.42 respectively. There was an increase of selective attention after consumption of the energy drinks with the magnitude of -3.65 mean difference. The P value of selective attention computed was 0.023. Hence, there is a significant difference in the selective attention of the participants before and after the intervention.

The mean (SD) of the alert before and after the intervention was 6.62 (1.88) and 8.23 (1.21) respectively. The mean difference (95% CI) and t-statistics of alertness calculated before and after intervention was -1.62 (-2.18, -1.05) and 5.94 respectively. There was an increase in alertness after energy drink consumption with the magnitude of -1.62 mean difference. The P value of alert computed was <0.001. Hence, there is a significant difference in the levels of alertness of the participants before and after the intervention.

The mean (SD) of how awake the participants felt before and after the intervention was 6.77 (2.01) and 8.27 (1.19) respectively. The mean difference (95% CI) and t-statistics of how awake they felt calculated before and after energy drink consumption was -1.50 (-2.17, -0.83) and 4.62 respectively. There was an increase of how awake they felt after consuming the energy drinks with the magnitude of -1.50 mean difference. The P value of awake computed was <0.001. Hence, there is a significant difference in how awake the participants felt before the after the intervention.

The mean (SD) of the energetic levels before and after energy drink consumption was 6.15 (1.89) and 8.27 (1.22) respectively. The mean difference (95% CI) and t-statistics of the energetic levels calculated before and after the intervention was -2.12 (-2.74, -1.49) and 6.93 respectively. There was an increase of how energetic the participants felt after consuming the energy drinks with the magnitude of -2.12 mean difference. The P value of energetic computed was <0.001. Hence, there is a significant difference in the energetic levels of the participants before the after the intervention.

The mean (SD) of the anxiety levels before and after the intervention was 4.00 (2.61) and 5.81 (1.39) respectively. The mean difference (95% CI) and t-statistics of the anxiety levels calculated before and after energy drink consumption was -1.81 (-3.12, -0.50) and 2.84 respectively. There was an increase of anxiety felt by the participants after consuming the energy drinks with the magnitude of -1.81 mean difference. The P value of anxious computed was 0.010. Hence, there is a significant difference in the anxiety levels of the participants before and after treatment.

Table 6. Comparison of simple reaction time, short term memory, selective attention, alertness and anxiety in the control group (non-caffeinated carbonated beverage) before and after consuming the non-caffeinated carbonated beverage.

Outcome variables		Mean (SD) (n=26)		Mean difference (95%CI)	*t*-statistics (df)	P-value
		Before	After			
Cognitive performance	Reaction time (ms)	331.00 (100.81)	294.19 (49.95)	36.81 (-0.51, 74.12)	2.03 (25)	0.053
	Numerical memory (score)	9.00 (1.67)	9.46 (1.10)	-0.46 (-1.24, 0.32)	1.22 (25)	0.233
	Verbal memory (Score)	35.65 (26.36)	38.23 (21.72)	-2.58 (-13.62, 8.47)	0.48 (25)	0.635
	Visual memory (score)	9.04 (1.66)	9.77 (1.73)	-0.73 (-1.32, -0.14)	2.56 (25)	0.017
	Selective attention (score)	28.46 (4.94)	29.81 (3.51)	-1.35 (-3.53, 0.84)	0.22 (25)	0.217
Alertness & anxiety	Alert (scale)	6.35 (1.74)	6.42 (1.98)	-0.08 (-0.82, 0.66)	0.21 (25)	0.832
	Awake (scale)	6.23 (1.88)	6.46 (1.86)	-0.23 (-0.83, 0.37)	0.80 (25)	0.434
	Energetic (scale)	5.58 (2.12)	6.04 (2.58)	-0.46 (-1.20, 0.28)	1.28 (25)	0.212
	Anxious (scale)	3.15 (2.11)	3.81 (2.93)	-0.65 (-1.51, 0.20)	1.58 (25)	0.128

[c]Paired t-test.

Table 6 shows the comparison of reaction time, numerical memory, verbal memory, visual memory, selective attention, alertness, and how awake, energetic and anxious the participants feel before and after drinking the control drink.

The mean (SD) of the reaction time before and after the intervention was 331.00ms (100.81) and 294.19ms (49.95) respectively. The mean difference (95% CI) and t-statistics of the reaction time calculated before and after the intervention was 36.81 (-0.51, 74.12) and 2.03 respectively. There was a decrease of reaction time after control drink consumption with the magnitude of 36.81 mean difference. The P value of reaction time computed was 0.053. Hence, there is no significant difference in the reaction time of the participants

before and after consuming the control drink.

The mean (SD) of the numerical memory before and after the intervention was 9.00 (1.67) and9.46 (1.10) respectively. The mean difference (95% CI) and t-statistics of numerical memory calculated before and after the intervention was-0.46 (-1.24, 0.32) and 1.22 respectively. There was an increase in numerical memory after consumption of the control drink with the magnitude of -0.46 mean difference. The P value of numerical memory computed was 0.233. Hence, there is no significant difference in the numerical memory of the participants before and after the intervention.

The mean (SD) of the verbal memory before and after the intervention was 35.65 (26.36) and 38.23 (21.72) respectively. The mean difference (95% CI) and t-statistics of verbal memory calculated before and after the intervention was – 2.58 (-13.62, 8.47) and 0.48 respectively. There was an increase of verbal memory after control drink consumption with the magnitude of -2.58 mean difference. The P value of verbal memory computed was 0.635. Hence, there is no significant difference in the verbal memory of the participants before and after the intervention.

The mean (SD) of the visual memory before and after the intervention was 9.04 (1.66) and 9.77 (1.73) respectively. The mean difference (95% CI) and t-statistics of visual memory calculated before and after the intervention was-0.73 (-1.32, -0.14) and 2.56 respectively. There was an increase of visual memory after consumption of the control drink with the magnitude of -0.73 mean difference. The P value of visual memory computed was 0.017. Hence, there is a significant difference in the visual memory of the participants before and after the intervention.

The mean (SD) of the selective attention before and after the intervention was 28.46 (4.94) and 29.81 (3.51) respectively. The mean difference (95% CI) and t-statistics of selective attention calculated before and after the intervention was -1.35 (-3.53, 0.84) and 0.22 respectively. There was an increase of selective attention after consumption of the control drink with the magnitude of -1.35 mean difference. The P value of selective attention computed was 0.217. Hence, there is no significant difference in the selective attention of the participants before and after the intervention.

The mean (SD) of the alertness before and after the intervention was 6.35 (1.74) and 6.42 (1.98) respectively. The mean difference (95% CI) and t-statistics of alertness calculated before and after the intervention was -0.08 (-0.82, 0.66) and 0.21 respectively. There was an increase of alert after drinking the control drink with the magnitude of -0.08 mean difference. The P value of alert computed was 0.832. Hence, there is no significant difference in the alertness of the participants before and after the intervention.

The mean (SD) of how awake the participants felt before and after the intervention was 6.23 (1.88) and 6.46 (1.86) respectively. The mean difference (95% CI) and t-statistics of awake calculated before and after the intervention was -0.23 (-0.83, 0.37) and 0.80 respectively. There was an increase of how awake they felt after drinking the control drink with the magnitude of -0.23 mean difference. The P value of how awake they felt computed was 0.434. Hence, there is no significant difference in how awake the participants felt before and after the intervention.

The mean (SD) of the energetic levels before and after the intervention was 5.58 (2.12) and 6.04 (2.58) respectively. The mean difference (95% CI) and t-statistics of energetic calculated before and after the intervention was -0.46 (-1.20, 0.28) and 1.28 respectively. There was an increase in the energy levels after drinking the control drink with the magnitude of -0.46 mean difference. The P value of energetic levels computed was 0.212. Hence, there is no significant difference in the energetic levels of the participants before and after the intervention.

The mean (SD) of the anxiety levels before and after the intervention was 3.15 (2.11) and 3.81 (2.93) respectively. The mean difference (95% CI) and t-statistics of anxious calculated before and after the intervention was -0.65 (-1.51, 0.20) and 1.58 respectively. There was an increase in anxiety felt after consuming the control drinks with the magnitude of -0.65 mean difference. The P value of anxiety levels computed was 0.128. Hence, there is no significant difference in the anxiety levels of the participants before and after the intervention.

Table 7. Comparison of adverse effects experienced by participants 30 minutes after consuming the beverage and insomnia between intervention (energy drink) group (n=26) and control (non-caffeinated carbonated beverage) group (n=26) after intervention.

Variable (Adverse effects)	Intervention group n (%)		Control group n (%)		RR (95%CI)	x^2	P-value
	Yes	No	Yes	No			
Palpitations	9 (34.62)	17 (65.38)	3 (11.54)	23 (88.46)	3 (0.91, 9.84)	3.9	0.048[d]
Tremors/shaking hands[e]	4 (15.18)	22 (84.62)	5 (19.23)	21 (80.77)	0.8 (0.24, 2.65)	-	0.999
Restlessness[e]	6 (23.08)	20 (76.92)	3 (11.54)	23 (88.46)	2 (0.56, 7.15)	-	0.465
Dizziness[e]	0 (0)	26 (100)	3 (11.54)	23 (88.46)	Undefined	-	0.235
Syncope	0 (0)	26 (100)	0 (0)	26 (100)	-	-	-
Stomach-ache[e]	1 (3.85)	25 (96.15)	1 (3.85)	25 (96.15)	1 (0.07, 15.15)	-	0.999
Paraesthesia (tingling or numbness of skin)	0 (0)	26 (100)	0 (0)	26 (100)	-	-	-
Headache[e]	2 (7.69)	24 (92.31)	3 (11.54)	23 (88.46)	0.67 (0.12, 3.67)	-	0.999

Variable (Adverse effects)	Intervention group n (%)		Control group n (%)		RR (95%CI)	x^2	P-value
	Yes	No	Yes	No			
Dehydration[e]	2 (7.69)	24 (92.31)	2 (7.69)	24 (92.31)	1 (0.15, 6.57)	-	0.999
Increased urination[e]	4 (15.38)	22 (84.62)	4 (15.38)	22 (84.62)	1 (0.28, 3.58)	-	0.999
Nausea[e]	0 (0)	26 (100)	1 (3.85)	25 (96.15)	Undefined	-	0.999
Chest pain	0 (0)	26 (100)	0 (0)	26 (100)	-	-	-
Insomnia[e]	4 (15.38)	22 (84.62)	1 (3.85)	25 (96.15)	4 (0.48, 33.42)	-	0.350

[d]Chi-square [e] Fisher exact.

Table 7 shows the adverse effects experienced by participants in the intervention group (energy drink) 30 to 60 minutes after consuming the beverage and insomnia in comparison to the control group (non-caffeinated carbonated beverage).

Participants who drank the energy drink are 3 times more likely to experienced palpitations compared to those who drank the control drink (non-caffeinated carbonated beverage). The P value obtained and Chi square value were 0.048 and 3.9 respectively. However, according to relative risk (95% CI), the value obtained was 3 (0.91, 9.84). Hence, there is no statistically significant difference in the participants having palpitations after consuming energy drink compared to the control group.

Participants who consumed energy drink are less likely to have tremors compared to those who drank the control drink. The P value obtained by Fisher exact test was 0.999. According to relative risk (95% CI), the value obtained was 0.8 (0.24, 2.65). Hence, there is no statistically significant difference in the participants having tremors after consuming the energy drink compared to the control group.

Participants who consumed energy drinks are 2 times more likely to experienced restlessness compared to those who drank the control drink. The P value obtained by Fisher exact test was 0.465. According to relative risk (95% CI), the value obtained was 2 (0.56, 7.15). Hence, there is no statistically significant difference in the participants being restless after consuming energy drinks compared to the control group.

11.54% of the participants who drank the control drink have dizziness whereas 0% of participants who consumed the energy drink developed dizziness. The P value obtained by Fisher exact test was 0.235. Hence, there is no significant difference in the participants having dizziness after consuming energy drinks compared to the control group.

There is no association between stomach-ache and consumption of energy drink as 3.85% of the participants from both the intervention and control groups respectively developed stomach-ache. The P value obtained by Fisher exact test was 0.999. According to relative risk (95% CI), the value obtained was 1 (0.07, 15.15). Hence, there is no statistically significant difference in the participants having stomach-ache after consuming energy drinks compared to the control group.

Participants who consumed energy drink are less likely to experienced headaches compared to those who drank the control drink. The P value obtained by Fisher exact test was 0.999. According to relative risk (95% CI), the value obtained was 0.67 (0.12, 3.67). Hence, there is no statistically significant difference in the participants having headache after consuming energy drinks compared to the control group.

There is no association between dehydration and consumption of energy drink as 7.69% of the participants from both intervention and control groups respectively felt dehydrated. The P value obtained by Fisher exact test was 0.999. According to relative risk (95% CI), the value obtained was 1 (0.15, 6.57). Hence, there is no statistically significant difference in the participants feeling dehydrated after consuming energy drinks compared to the control group.

There is no association between increased urination and consumption of energy drink as 15.38% of the participant from both intervention and control groups respectively have increased urination. The P value obtained by Fisher exact test was 0.999. According to relative risk (95% CI), the value obtained was 1 (0.28, 3.58). Hence, there is no statistically significant difference in the participants having increased urination after consuming energy drinks compared to the control group.

3.85% of the participants who drank the control drink have nausea whereas 0% of the participants who consumed the energy drink developed nausea. The P value obtained by Fisher exact test was 0.999. Hence, there is no significant difference in the participants having nausea after consuming energy drinks compared to the control group

Participants who consumed energy drink are 4 times more likely to have insomnia compared to those who drank the control drink. The P value obtained by Fisher exact test was 0.350. According to relative risk (95% CI), the value obtained was 4 (0.48, 33.42). Hence, there is no statistically significant difference in the participants having insomnia after consuming energy drinks compared to the control group.

4. Discussion

The purpose of this randomised controlled trial was to determine the effects of energy drink consumption on the

cognitive performance of medical students, namely the reaction time, selective attention, short term memory in terms of numerical, verbal and visual, and to determine the immediate adverse effects. A total of 52 medical students were randomised into an intervention group (26 students) to whom we gave an energy drink and a control group (26 students) to whom we gave a non-caffeinated carbonated beverage.

Based on our study, although the results suggested that the intervention group performed better on the cognitive performance tests such as reaction time, numerical memory, verbal memory, visual memory and selective attention than those who were in the control group, we found that there was no significant difference between the two groups. The results were consistent with a study done in Columbia, where the results obtained from consuming energy drinks showed no significant difference in immediate memory and concentration as compared to the placebo drinks [28]. This is further supported by Warburton et al. who found no significant improvement in memory between caffeinated taurine drinks and the placebo drink as well [11]. However, these findings contradicted with one study which found a significant improvement in reaction time, concentration and memory after consumption of energy drinks [13].

On the other hand, regarding alertness and anxiety, the intervention group demonstrated increased alertness, but they noted to experience higher levels of anxiety than those who were in the control group. The results for alertness showed that there was a significant difference among the two groups. The findings corresponded with a study carried out in United Kingdom which found an increase in subjective alertness in the energy drink group [13]. However, there was no significant difference between the intervention group and control group in terms of their anxiety levels. This was supported by a study carried out in Tunisia which found that there was no significant difference for anxiety levels in the participants who consumed either energy drinks or the placebo drink [29].

The comparison of cognitive performance in the intervention group before and after consuming the drinks showed that they had increased reaction time and better selective attention, which is of statistically significant difference. However, numerical, verbal and visual memory indicated no significant difference. The improved performance in reaction time and attention goes along with the study conducted by Scholey et al. [12]. The intervention group showed to be more anxious post-intervention, although they indicated that they felt more alert, awake and energetic which is of significant difference. The improvement in alertness was justified by Hendrik et al. who found significant improvements on task performance and self-assessed mood after consuming energy drinks as the participants in this group felt more alert, revitalised and awakened [30]. Moreover, Stasio et al. found that energy drink consumption had a positive effect on anxiety scores and sleep disturbances [31].

The participants were required to fill in a questionnaire regarding any side effects they encountered after consuming the drinks. The main side effects enquired about were palpitations, tremors, restlessness, dizziness, syncope, stomach-ache, paraesthesia, headache, dehydration, increased urination, nausea, chest pain and insomnia, out of which syncope, paraesthesia and chest pain were not experienced by any of the participants, thus indicating these outcomes were of no significant difference regarding consumption of energy drinks in this present study. Occurrence of palpitations, restlessness and insomnia were more common among the intervention group whereas tremors, dizziness, headache and nausea were more common among the control group. The occurrence of stomach-ache, dehydration and increased urination were equivalent between the two groups, thus indicating no significant difference between these adverse effects and intake of the drinks. Overall, in this present study, there was no significant difference between the adverse effects and the consumption of beverages. This is supported by similar studies as no immediate side effects were reported by the participants after drinking these beverages [28, 29]. However, energy drinks have been associated with caffeine overdose resulting in insomnia, restlessness, tachycardia and even fatality [2].

The response rate was 100% with no drop-outs in between the study. However, we have a few limitations. As this study was conducted among healthy undergraduate medical students of young adult age, the findings cannot be generalised to larger demographic population. Furthermore, it is not possible to identify the specific active ingredients in energy drinks that contribute to the improvement in certain cognitive performance. Glucose, an ingredient present in both drinks, could have possibly contributed to the outcome of the cognitive performance however. Another limitation is not all the confounding variables could be controlled such as duration of sleep and amount of exercise carried out a day before the study was conducted. Participants might have been familiar with the way the cognitive performance was being assessed as the cognitive function tests were evaluated twice, once before and after consuming the drinks. Therefore, the improvement in cognitive performance may have been due to practice. In addition, blinding was not included in our randomised controlled trial and this might have led to bias as the participants could identify the drink that they were consuming, thus influencing or eliminating the subjectivity assessed such as alertness and anxiety level.

Further experiments may consider assessing the active ingredient of energy drinks individually which may enhance

cognitive performance. Adverse effects of energy drinks among regular energy drink consumers can be investigated more deliberately. Further studies may consider using a blinding design to avoid occurrence of bias as well as obtaining a larger sample size.

5. Conclusion

Consumption of energy drinks has been a weekly routine in many teenagers and young adults as the beverages are easily accessible. Evident improvement in the reaction time, selective attention and alertness among the intervention group after consumption of the energy drinks in comparison to their performance prior to the intake of the beverage have been demonstrated in our present study. However, according to our study results, energy drink intake has shown no beneficial effect on short term memory. The levels of alertness is enhanced significantly among the participants who consume energy drinks compared to the control group (non-caffeinated carbonated beverages). Furthermore, there was no significant difference in immediate adverse effects between the intervention and control groups.

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