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THE ACUTE EFFECT OF AN ENERGY DRINK ON THE PHYSICAL AND COGNITIVE PERFORMANCE OF MALE ATHLETES

AKUTNI UČINEK ENERGETSKEGA NAPITKA NA TELESNE IN KOGNITIVNE SPOSOBNOSTI ŠPORTNIKOV

Abstract

Energy drink consumption by athletes has become increasingly popular. Athletes believe that energy drinks can be used to enhance their performance during training and competition due to their potentially ergogenic ingredients such as carbohydrates, caffeine, sodium and taurine, among others. Therefore, the purpose of this study was to determine the effectiveness of the acute ingestion of an energy drink on physical and cognitive variables in a sample of 20 trained-male athletes recruited from a local university. A double-blind study was designed in which the participants ingested on different occasions an energy drink, a placebo beverage or nothing (control). Factorial 3 x 2 repeated measures analysis of variance were used to analyse the dependent variables of strength, power, speed, reaction time, short-term memory and mood states. Results did not indicate any significant changes in the physical and cognitive variables when comparing the energy drink, the placebo and the control condition. However, significant pre-to-post test improvements in strength and power were found regardless of the experimental condition. In conclusion, a commercially-available energy drink did not enhance physical or mental performance within the conditions and design of this study.

Keywords: energy drinks, physical tests, cognitive tests, placebo, acute supplementation

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Izvleček

Med športniki postaja uživanje energetskih napitkov čedalje bolj priljubljeno. Športniki so mnenja, da lahko z uživanjem energetskih napitkov izboljšajo svoje zmožnosti na treningu in tekmovanju, saj le-ti vsebujejo potencialno ergogene substance, med katerimi so ogljikovi hidrati, kofein, natrij in taurin. S študijo, v kateri je sodelovalo 20 treniranih športnikov lokalne univerze, smo želeli ugotoviti, kako akutno uživanje energetskega napitka vpliva na telesne in kognitivne spremenljivke. Pripravljena je bila dvojna slepa raziskava, v kateri so merjenci ob različnih časih zaužili energetski napitek, placebo napitek ali pa nič (kontrolna skupina). Za analizo odvisnih spremenljivk: vzdržljivost, moč, hitrost, reakcijski čas, kratkoročni spomin in sprememba razpoloženja, smo uporabili faktorsko 3 x 2 analizo variance za ponovljene meritve. Rezultati primerjave skupin, ki so uživale energetski napitek in placebo, ter kontrolne skupine niso pokazali pomembnih sprememb telesnih in kognitivnih spremenljivk. Vendar pa so se po testu pokazale pomembne izboljšave glede na stanje pred testom v vzdržljivosti in moči, ne glede na pogoje eksperimenta. Zaključimo lahko, da energetski napitki, ki so v prosti prodaji telesnih ali mentalnih sposobnosti športnikov niso izboljšali.

Ključne besede: energetski napitki, telesni testi, kognitivni testi, placebo, akutno uživanje dodatkov

INTRODUCTION

Energy or ‘power’ drinks (e.g., Battery®, B52®, Dark Dog®, Jess®, Red Bat®, Red Bull®, Rhino’s®) are beverages designed and consumed for purposes other than for improving athletic performance; for instance, to reduce the depressant effects of alcohol on the central nervous system (Ferreira, de Mello, Rossi, & Souza-Formigoni, 2004). On the contrary, sports and fluid-electrolyte replacement beverages (e.g., Gatorade®, Powerade®) are designed and consumed to enhance athletic performance or to reduce the deleterious effects of dehydration during athletic competitions (Dennis, Noakes, & Hawley, 1997; Maughan & Murray, 2001).

Although energy drinks have been sold worldwide for more than a decade, only a few studies have apparently been published to test the effectiveness of these beverages in physical and cognitive performance in athletes (Alford, Cox, & Wescott, 2001; Baum & Weiß, 2001; Umaña-Alvarado & Moncada-Jiménez, 2004, 2005). Studies on non-athletic populations have demonstrated moderate positive effects on cognitive variables (e.g., attention, concentration, memory, reaction time) (Alford, Cox, & Wescott, 2001; Horne & Reyner, 2001; Mucignat-Caretta, 1998; Reyner & Horne, 2002; Seidl, Peyrl, Nicham, & Hauser, 2000; Smit & Rogers, 2002; Warburton, Bersellini, & Sweeney, 2001).

Alford et al. (2001) investigated the effect of the consumption of the energy drink Red Bull® in psychomotor (i.e., reaction time, concentration, memory), anaerobic and aerobic performance. Aerobic performance was measured as the time the participants were able to maintain an exercise intensity of their 65-75% maximal heart rate. Anaerobic performance was measured by a 20 s cycle ergometer test (i.e., all-out test). Compared to the controls, the Red Bull® group improved aerobic and anaerobic performance by 9% and 24%, respectively. Performance improvements were also reported for reaction time, concentration (number cancellation) and short-term memory as measured by an immediate recall task. These investigators concluded that the physical and mental improvement is attributed to the combination of ingredients contained in the energy drink Red Bull®.

The physiological mechanisms that might explain the improvements in physical performance are not fully understood. However, Baum and Weiß (2001) suggested that increases in maximal oxygen consumption might occur due to the potential effect of the energy drink in the cardiac contractility. Barthel, Mechau, Schnittker, Liesen, and Weiß (2001) indicated that the caffeine and taurine content of energy drinks might be responsible for enhancements in motor responses. Based on the findings of their study, the consumption of an energy drink might improve the function of the cortical regions responsible for the anticipation and preparation of a movement. However, Alford et al. (2001) did not report differences in heart rate, systolic and diastolic blood pressure when comparing the Red Bull® energy drink with carbonated water and a control condition (no drink).

Recently, male runners (Umaña-Alvarado & Moncada-Jiménez, 2004) and cyclists (Umaña-Alvarado & Moncada-Jiménez, 2005) were measured in physiological and psychological constructs following the ingestion of a commercially-available energy drink. In a randomised double-blind, cross-over study, 11 athletes completed two 10 km cross-country races. The athletes ingested 6 ml / kg^{-1} body mass of an energy drink or a placebo beverage 30 min before the race. Even though the athletes did not improve their run times when consuming either beverage, the ratings of perceived exertion (RPE) were lower in the energy drink experimental condition (Umaña-Alvarado & Moncada-Jiménez, 2004). In this case, it was demonstrated that an energy drink could have a positive psychological effect not necessarily correlated to a better performance (i.e., race time).

Umaña-Alvarado and Moncada-Jiménez (2005) designed a study to determine if the consumption of a commercially-available energy drink could improve intermittent cycling performance in males when compared to a placebo beverage. In a double-blind, cross-over randomised design, 11 young trained cyclists (age: M = 17.14 yrs, SD = 1.68 yrs), participated in three-50 km intermittent cycling trials. Athletes were given 200 ml of the beverage every 20 min during each trial. In this study, four participants were unable to finish the study due to gastrointestinal symptoms (n = 3) and an injury unrelated to the study protocol (n = 1). Therefore, the statistical analysis was performed on the seven subjects who finished both experimental conditions which obviously impacted on the overall statistical power of the study. Nonetheless, no significant mean time differences were reported between the experimental conditions in these seven subjects.

Based on the previous background and since only a reduced number of studies had been performed in athletic populations; the present research was designed to evaluate the acute effect of an energy drink on the physical and cognitive performance of male athletes.

METHOD

Participants

This study was designed in a double-blind, placebo-controlled fashion (Kerlinger & Lee, 2000). The study protocol was approved by the University of Costa Rica's Institutional Ethics Review Board. The volunteers read and signed an informed consent to participate in the study.

Competitive male soccer athletes (n = 20) participated in this study. Three experimental conditions were tested: a) control (no drink); b) energy drink beverage; and c) placebo beverage. During each testing session, an experimental condition was randomly assigned to each participant. Therefore, each participant performed all three experimental conditions.

In order to be eligible to participate in the study, athletes had to meet the following inclusion criteria: a) to train for competition at least four days per week for at least a 30 min. session; b) to be a moderate coffee consumer (2-4 cups $\cdot$ d^{-1}) (Reyner & Horne, 2002); c) not being on medication or nutritional supplementation (Baum & Weiß, 2001; Warburton et al., 2001); and d) not being a regular energy drink consumer. Potential participants were excluded from the study if they: a) presented psychiatric or neurological diseases (Mucignat-Caretta, 1998; Seidl et al., 2000); b) were sensitive to any ingredient contained in the energy drink (this information was obtained by a registered dietician in an interview) (Alford et al., 2001); c) were under any nutritional supplementation regimen that included either caffeine, guarana, taurine or inositol; d) had participated in any pharmacological study in the previous three months (Warburton et al., 2001); or e) had documented cardiac problems.

Instruments

Physical performance was measured by a speed test (100 m sprint on a track), a handgrip strength test (hand dynamometer), and explosive power in the legs (standing long jump). These tests were chosen primarily due to their validity and reliability (Kirkendall, Gruber, & Johnson, 1980) and because they are known by most college students (Miller, 1998). Psychological variables measured were reaction time (eye-hand co-ordination) (Kirkendall et al., 1980), short-term memory (Verbal Script Digit Span test) (Lezak, 1995), and mood states (Profile of Mood States [POMS]) (Macnair, Lorr, & Dropplemen, 1964).

Procedure

One-week before the data collection took place, participants were instructed on how to perform each test and were allowed to have a familiarisation session as recommended by Hopkins, Hawley, and Burke (1999). Athletes were instructed to avoid alcohol, nicotine and other stimulants the night before the experiment was performed (Barthel et al., 2001). In addition, subjects were asked to maintain their regular physical activities during the days prior to the experiment; however, they were instructed to avoid strenuous activities and sudden changes in food consumption, including any nutritional supplementation products the day before the experimental measures were taken (Baum & Weiß, 2001).

In each experimental condition, the subjects arrived at the laboratory at 7:00 a.m. in a fasted state, and then a standardised breakfast was provided. The nutritional composition of the breakfast was 1580 kJ (378 kcal) of energy provided by carbohydrates (48%), protein (17%) and fat (30%). Following breakfast, the participants' height (cm) and weight (kg) were recorded by standard methods. Following anthropometric measures, the POMS, short-term memory and reaction time tests were administered individually. Then, the handgrip strength test was performed by adjusting the hand dynamometer to meet each participant's hand size.

The standing long jump test was performed three times with one minute of resting between trials before the subjects were taken to a synthetic track where the sprint test was performed (Kirkendall et al., 1980; Miller, 1998). Since the 100 m sprint test is an all-out test, the subjects warmed up for at least 25 min in order to avoid possible injuries. The warm-up was standardised for all participants and consisted of floor and standing stretching exercises (15 min), jogging (5 min) (short runs (i.e., 10, 15, and 20 m) for approximately 10 min. Sprint time, in seconds, was measured by an automatic timing photo-cell system. By 11:00 a.m., the subjects had finished their experimental session for that day and an appointment was given for them to return to the laboratory four days later.

Experimental protocol

Following baseline measures (pre-test), beverages were double-blind assigned by properly trained staff. The composition of the 250 ml energy drink is shown in Table 1. The total volume given to each participant was calculated based on their measured body weight. Each athlete consumed 6 ml of energy drink / kg body weight in the energy drink trial, and five capsules with 6 ml placebo blue coloured water / kg body weight during the placebo trial. During the control condition, the participants did not drink anything.

The placebo beverage consisted of five gelatin capsules filled with wheat flour and were given with blue-coloured water. This placebo regimen has been used by others (Seidl et al., 2000). During the experimental conditions, athletes were told that they were to consume two beverages designed to improve their physical and cognitive performance. These beverages were given cooled in opaque black plastic bottles, and the capsules were given in a transparent plastic

Table 1: Nutritional composition of the energy drink

Ingredients	Portion of 250 ml (8.3 oz)
Calories/portion	460 kJ
Fat	0 g
Protein	< 1 g
Carbohydrates	28 g
Sodium	200 mg
Caffeine	80 mg
Taurine	1000 mg
Glucuronolactone	600 mg
Inositol	50 mg

bag. The staff ensured that the athletes consumed all the fluid and capsules given during the experimental session.

Thirty-minutes after the beverages were given; the athletes performed the post-test physical and cognitive measurements in the same order as they were measured before. In the control condition, athletes sat in a room until the post-test measures were performed.

Statistical analysis

The Statistical Package for the Social Sciences was used to compute descriptives. Inferential analysis included 3 x 2 repeated measures analysis of variance (ANOVA) for the dependent variables strength, speed, power, POMS, reaction time, and short-term memory. Simple effect analyses were performed when significant interactions were obtained at a pre-determined $p < 0.05$ significance value.

In addition, percentage changes (Δ%) and omega squared (ω^2) were computed in order to detect potential tendencies in the data (Keppel, 1982; Vincent, 1999). According to Keppel (1982), ω^2 is an effect size indicator that allows the comparing of F values in the absence of statistic significance. This statistic is not affected by sample size. The statistic Δ% allows for a comparison of pre- and post-test scores relative to their baseline values, and was computed as follows (Vincent, 1999): [(post-test mean – pre-test mean) / pre-test mean] x 100.

RESULTS

Twenty male athletes from the University of Costa Rica completed the study protocol. The mean age and height were 20.2 years (SD = 2.24 yrs) and 1.75 m (SD = 0.06 m), respectively. The initial mean body weights in the energy drink, control and placebo sessions were 68.43 kg (SD = 8.4 kg), 65.04 kg (SD = 17.45 kg), and 68.39 kg (SD = 8.29 kg), respectively (see Table 2). Since no statistically significant body weight differences were found in the experimental sessions ($p = 0.38$), the beverage volume consumed was similar among athletes ($p = 0.94$). Athletes consumed a mean volume of 411 ml in the energy drink condition and 410 ml in the placebo condition.

Table 2: Descriptive Statistics (M ± SD) for body weight, physical and cognitive variables in male athletes (n = 20)

Variables	*Energy Drink*		*Control*		*Placebo*	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Weight (kg)	68.43 ± 8.45	◊	65.04 ± 17.45	◊	68.39 ± 8.29	◊
Power (m)	2.20 ± 0.18	2.24 ± 0.17	2.20 ± 0.17	2.21 ± 0.16	2.19 ± 0.18	2.18 ± 0.14
Strength (kg)	43.77 ± 8.53	45.45 ± 8.42	44.77 ± 5.25	45.17 ± 6.75	43.27 ± 7.37	44.35 ± 7.71
Speed (s)	13.49 ± 0.64	13.15 ± 0.57	13.72 ± 0.63	13.62 ± 0.81	13.56 ± 0.72	13.46 ± 0.75
Reaction time (s)	0.16 ± 0.02	0.17 ± 0.06	0.16 ± 0.00	0.152 ± 0.01	0.17 ± 0.01	0.16 ± 0.01
Short-term memory	4.30 ± 1.49	4.30 ± 1.03	4.30 ± 0.86	4.40 ± 1.49	4.00 ± 1.12	4.20 ± 0.89
POMS subscales						
Tension-Anxiety	4.00 ± 3.13	4.75 ± 3.60	3.80 ± 2.85	4.90 ± 3.12	4.55 ± 3.03	4.10 ± 2.55
Depression	2.85 ± 3.28	2.80 ± 3.16	3.10 ± 3.17	3.60 ± 4.09	3.15 ± 3.91	3.10 ± 2.78
Anger	1.55 ± 3.66	1.20 ± 2.82	1.20 ± 1.88	3.20 ± 4.80	1.95 ± 3.53	1.30 ± 3.34
Vigour	16.90 ± 4.42	16.50 ± 4.33	16.30 ± 5.85	14.05 ± 4.81	16.15 ± 3.49	17.20 ± 6.46
Fatigue	4.90 ± 4.02	6.55 ± 4.64	6.20 ± 4.57	7.50 ± 5.76	5.15 ± 3.74	4.95 ± 3.17
Confusion	2.65 ± 2.16	3.15 ± 2.45	3.15 ± 2.25	4.55 ± 3.61	3.20 ± 2.70	2.90 ± 2.17

◊*Note*: The study design did not include post-test body weight measurements.

Physical performance

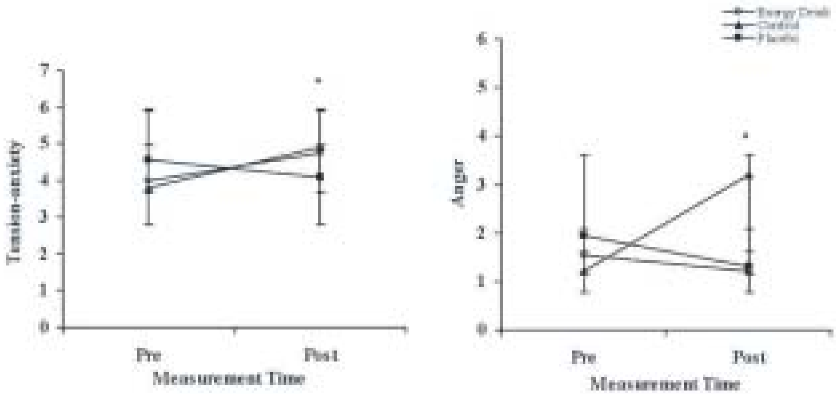
For the statistical analysis of the dependent variables power and speed in the control condition only the results of 19 participants were used because one participant suffered an injury unrelated to the study protocol. ANOVA results showed that there were no significant interactions in power (see Table 3). However, the analysis showed significant main measurement time effects (i.e., pre- to post-test) in strength and speed. The follow-up analysis indicated that both strength and speed improved from pre to post-test regardless of the experimental condition, from 43.94 to 45.00 kg and from 13.58 to 13.39 s, respectively.

Table 3: ANOVA summary table and explained variance for physical and cognitive variables

Variables	**Experimental Condition (A)**			**Measurement Time (B)**			**Interaction (A x B)**		
	F	*p*	*ω2 (%)*	*F*	*p*	*ω2 (%)*	*F*	*p*	*ω2 (%)*
Power (m)	1.88	0.17	46.0	2.78	0.11	1.5	1.68	0.20	1.0
Strength (kg)	1.09	0.35	52.3	7.20	0.02	3.2	0.68	0.52	-
Speed (s)	2.08	0.14	63.0	9.55	0.01	5.5	1.52	0.23	13.1
Reaction time (s)	1.71	0.20	1.4	0.00	0.98	-	0.79	0.46	-
Short-term memory	0.82	0.45	-	0.41	0.53	-	0.13	0.88	-
POMS subscales									
Tension-Anxiety	0.01	0.99	-	0.85	0.37	-	4.53	0.02	3.0
Depression	1.03	0.37	30.0	0.16	0.70	-	0.27	0.77	-
Anger	1.97	0.15	1.6	1.14	0.30	0.1	4.82	0.01	7.8
Vigour	2.00	0.15	2.1	0.64	0.43	-	2.20	0.13	2.0
Fatigue	2.19	0.13	3.0	1.77	0.20	0.9	1.72	0.19	0.7
Confusion	2.94	0.07	4.0	2.14	0.14	1.5	2.85	0.07	2.7

Cognitive performance

The ANOVA did not show significant interactions in reaction time and short-term memory (see Table 3). Two statistically significant interactions were found in the POMS subscales: tension-anxiety ($p = 0.02$) and anger ($p = 0.01$). Simple effect analysis indicated that for both subscales the participants reported higher post-test scores ($p < 0.05$) (Figure 1).

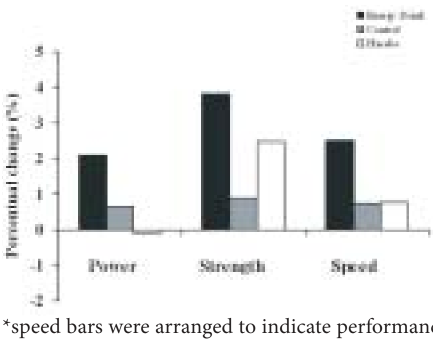


* p < 0.05 pre vs. post

Figure 1: Interaction between experimental conditions and measurement time in the POMS subscales tension-anxiety and anger

Effect size estimations

As shown in Table 4, energy drink consumption revealed a trend towards an improvement in power and speed compared to the placebo and control experimental conditions. Indeed, for power there was a small nocebo effect (Figure 2). A nocebo refers to negative thoughts, feelings or expectations about a treatment that eventually lead to negative outcomes in the dependent variable (Hahn, 1997). A nocebo effect has also been defined as a negative outcome in a dependent variable that is attributable to a placebo (Beltranena, Aragón-Vargas, & Salazar, 1998). The ω^2 shown in Table 3 indicated that the treatments accounted for at least 46% of the variance in the physical performance variables, meaning the high influence of the experimental conditions in this variable (Keppel, 1982). This was not the case of the measurement times (i.e., pre to post-test), which only showed small ω^2 from 0.1% to 5.5%.



*speed bars were arranged to indicate performance improvement in spite of the negative sign shown in table 4.

Figure 2: Percentage changes (Δ%) for power, strength and speed*

In the case of the cognitive variables, the data suggested that reaction time showed a tendency towards impairment when athletes consumed the energy drink (Δ = 5.29%). The ω^2 indicated that only 1.4% of the total variance was explained by the experimental treatments (Table 3). No interaction or measurement time influenced the outcome in this dependent variable. Similarly, the energy drink did not affect short-term memory (Δ = 0%); ironically, there was a positive effect in the control (Δ = 2.32%) and placebo (Δ = 5%) conditions (Table 4).

Table 4 shows that in the three experimental conditions there was inconsistent behaviour of the Δ% in the sub-scales of the POMS. In the case of the tension-anxiety subscale, there was a tendency towards an increased score between the pre-test and post-test in the energy drink (Δ = 18.75%) and control (Δ = 28.94%) conditions. In addition, there was tendency towards reduction in the energy drink and placebo conditions for the subscales of depression and anger. The anger subscale in the control condition presented the highest change (Δ = 166.66%) among all the cognitive variables. A placebo effect tendency was found for the subscales vigour (Δ = 6.50%), fatigue (Δ = – 3.88%) and confusion (Δ = – 9.37%). Finally, the cognitive variable in which the treatments had the highest effect was in the depression subscale (ω^2 = 30.33%).

Table 4: Percentage changes in physical and cognitive variables

Variables	Δ% Energy Drink	Δ% Control	Δ% Placebo
Power (m)	+2.08	+0.67	-0.10
Strength (kg)	+3.83	+0.89	+2.48
Speed (s)	-2.51*	-0.73*	-0.75*
Reaction time (s)	+5.29	-5.04*	-0.01*
Short-term memory	0.00	+2.32	+5.00
POMS subscales			
Tension-Anxiety	+18.75	+28.94	-9.89
Depression	-1.75	+16.12	-1.58
Anger	-22.58	+166.60	-33.33
Vigour	-2.36	-13.80	+6.50
Fatigue	+33.67	+20.96	-3.88
Confusion	+18.86	+44.44	-9.37

Note: * in these particular variables, the negative sign represents a performance improvement.

DISCUSSION

It has been suggested that the consumption of an energy drink improves psychological, aerobic and anaerobic performance (Alford et al., 2001). In this study we measured three important components of physical performance, strength, speed and power. We further studied the psychological variables reaction time, short-term memory and mood state.

Alford et al. (2001) found that the energy drink Red Bull® improved anaerobic performance in 24% when compared to a placebo. In the present study, we did not find significant changes in strength, power and speed performance when athletes consumed an energy drink, a placebo or when athletes did not drink at all (i.e., control). Further, strength and speed improved from pre to post-test measurements regardless of the beverage consumed (see Figure 1). This could be interpreted as a learning effect; however, the research design used in this study allowed for the minimising of that effect due to the randomisation of the subjects to the experimental conditions and also to the fact that the subjects and investigators were blind to the experimental conditions (Kerlinger & Lee, 2000). Nevertheless, the potential mechanism responsible for the improvements in strength and speed remains unknown.

Contrary to the positive effects reported in the literature following the consumption of an energy drink on reaction time, memory and mood (Alford et al., 2001; Horne & Reyner, 2001; Mucignat-Caretta, 1998; Smit & Rogers, 2002; Warburton et al., 2001), in this study we did not find such benefits. Further, the effect sizes (i.e., Δ% and ω^2) computed following the consumption of the energy drink indicated small positive changes in power, strength, speed, depression and anger. Those changes were similar in magnitude to those obtained in the placebo and control conditions. The highest Δ% obtained was in the anger subscale in the control condition. The subjects expressed their dissatisfaction (i.e., anger) for not being able to drink any liquid during the performance tests; an expected outcome which is clearly reflected in the interaction effect observed (see Figure 1).

The conclusions drawn from previous studies (Alford et al., 2001; Horne & Reyner, 2001; Mucignat-Caretta, 1998; Smit & Rogers, 2002; Warburton et al., 2001) might have been confounded by the different methodologies used, including the types of placebos being used and the nutritional habits of the participants. According to Yaremko, Harari, Harrison and Lynn (1982), a placebo must be inert, meaning that it does not have in its ingredients the substance that is being tested in the study. This kind of placebo is referred to as a pure placebo. However, there are also placebos created with smaller quantities of the substances or nutritional supplements being tested and/or other substances claimed to be inert. This kind of placebo, manufactured with a similar chemical or physical structure of the nutritional supplement tested is called an active placebo (Steward-Williams & Podd, 2004). Active placebos have included liquid solutions (Mucignat-Caretta, 1998; Warburton et al., 2001), and capsules (Seidl et al., 2000).

We have found that the preparation of a placebo condition can be a limitation for this line of study. Active placebos, as opposed to pure placebos, have been used in most studies; meaning that a low concentration of the same ingredients found in energy drinks (e.g., caffeine, taurine) has been used, which makes it almost impossible to compare the effects of these beverages across studies. Only Seidl et al. (2000) formulated, in our opinion, a reasonable placebo condition (wheat-bran capsules and water), which we tried to mimic in the present study (wheat-flour and blue-coloured water). Therefore, before any conclusion regarding the effect of energy drinks is made, it is necessary to standardise placebos in order to discard any placebo effect.

Another methodological concern arising from previous studies relates to caffeine consumption. Habitual and non-habitual (i.e., caffeine-naive) caffeine consumers have participated in these studies, and it has been found that physical and cognitive performance are enhanced following a caffeine-abstinence period (Warburton et al., 2001). Therefore, the caffeine-abstinence issue might have impacted on previous research. For instance, beneficial energy drink effects on cognitive parameters have been reported when participants have refrained from consuming caffeine (Smit & Rogers, 2002; Warburton et al., 2001). Alford et al. (2001) did not report whether the subjects refrained from consuming caffeine or not. In the present study the subjects did not avoid consuming caffeine commonly found in foods such as chocolate or coffee. It is reasonable to believe that the abstinence period allowed previous studies to realise the positive effects of the energy drinks (Smit & Rogers, 2002; Warburton et al., 2001).

Another methodological aspect that might account for the inconsistent results reported across studies is the amount of active substances given to the participants. For instance, Robelin and Rogers (1998) administered a caffeine dose of 1.2 mg / kg of body weight; whereas Alford et al. (2001) provided a can of energy drink to each subject; therefore the dose per kilogram of body mass was unknown and different for each participant. In the present study a caffeine dose of 2.04 mg / kg of body weight was given to the athletes.

In other studies (Smit & Rogers, 2002; Umaña-Alvarado & Moncada-Jiménez, 2005; Warburton et al., 2001), a specific volume (e.g., 150 – 250 ml) has been administered to the participants. Again, the exact dose of the active ingredients of the energy drink is unknown, which does not allow drawing valid comparisons between studies. In the study by Umaña-Alvarado and Moncada-Jiménez (2004) and in the present study, the energy drink volume was standardized to 6 ml / kg of body weight. In this way, all the subjects received the same amount of active ingredients, allowing for the higher internal consistency of the study (Campbell & Stanley, 1963; Kerlinger & Lee, 2000).

Finally, the sample sizes and the diversity of compositions (e.g., male, female, athletes, non-athletes) have varied in previous studies (Alford et al., 2001; Seidl et al., 2000; Smit & Rogers, 2002; Umaña-Alvarado & Moncada-Jiménez, 2004; Warburton et al., 2001). In the present study 20 trained soccer male athletes participated in a within-subjects design. This design has been shown to be more appropriate to study variability within a subject compared to the between-subjects designs where a subject only completes one of the experimental conditions and is compared against others (Campbell & Stanley, 1963; Kerlinger & Lee, 2000). Only Barthel et al. (2001), Baum and Weiß (2001), and Umaña-Alvarado and Moncada-Jiménez (2004) have used repeated measures designs, with samples sizes of 13, 15 and 11 participants, respectively.

Based on the results of this study and from our previous research, we believe that any clear recommendation for athletes regarding the consumption of energy drinks as an ergogenic aid is inappropriate at this time. In Ireland, the death of a basketball player during competition was related to the excessive consumption of energy drinks (Stimulant Drinks Committee, 2002). In Denmark and France, it is prohibited to distribute beverages with a caffeine content higher than 150 mg / L; therefore, energy drinks are banned (Stimulant Drinks Committee, 2002). In spite of these reports, more research is needed before any statements are issued regarding the safety and efficacy of these beverages in the athletic population.

In conclusion, the present study does not support the beneficial acute effect of an energy drink in physical and cognitive variables in male athletes. More research is warranted to settle the inconsistencies found in the literature on the effects of energy drinks in athletic populations.

Acknowledgments

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