Acute effect of energy drink ingestion on Crossfit® performance: a randomized, double-blind, crossover study

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Abstract

The aim of this study was to analyze the acute effects of energy drink (ED) ingestion on CrossFit® performance in a randomized, double-blind, cross-over study, with 8 CrossFit®-trained (26.5 ± 2.7 years; 70.2 ± 13.0 kg; 1.7 ± 0.09 m; 23.0 ± 3.2 kg/m2; ∑ skinfold thickness: 34.1 ± 6.9 mm; body fat: 13.3 ± 3.0 %), that were randomly allocated to 2 groups and underwent 2 trials separated by a 7-day washout period. Participants ingested either a dose of 300 mL of ED or Placebo (soda), 30 minutes before the start of tests of muscular strength (MS), 10 and 12 maximum repetitions (MRs) in barbell bench press (BBP) and barbell squat (BS), respectively and localized muscular endurance (LME) using Workout of the Day (WOD) selected. The rating of perceived exertion (RPE) and the rating of perceived pain (RPP) were evaluated immediately after the tests. The total volume of repetitions (TVR) was evaluated to each test. The TVR was significantly higher after consuming the ED ($p = 0.012$) and of the Placebo ($p = 0.027$). There was a reduction in the rate of RPE after the consumption of both drinks ($p = 0.023$ and $p = 0.024$). The consumption of ED significantly reduced the rate of RPP ($p = 0.017$). Acute ED ingestion improved CrossFit® performance by increased the TVR and the pain tolerance.

Keywords: Exercise; Exercise movement techniques; Exercise test; Physical fitness; Physical endurance.

Introduction

Energy drinks (ED), typically formulated with a mixture of caffeine (about 32 mg), taurine (about 400 mg), glucuronolactone (about 240 mg), inositol (about 20 mg), B-complex vitamins (40%) 100% of daily requirements) and carbohydrates (about 11 g) in every 100 mL of the product[1] or any substance that acts as a central nervous system stimulant, first appeared in the U.S. in 1949, and nearly 40 years later in Europe, with claims to improve physical and cognitive performance as ergogenic resources[2].

The speculation proposed by manufacturers and physical activity/athlete consumers regarding the effects on human performance by ED, although widely consumed worldwide today, has been rarely studied[3-5], and studies performed are inconclusive, leaving gaps in the specialized literature regarding these products, including the non-approach of the subject in the current guidelines[6, 7].

In this context, such products may be sought by practitioners of vigorous physical activities, such as CrossFit® (CrossFit, Inc., Washington, DC, USA), which consists of aerobic exercise, Olympic weightlifting, gymnastic movements with high-speed repetitions, and limited or no recovery interval between sets, characteristics that have generated debate about risk of injury and overtraining[8]. Thus, CrossFit® training incorporates both, high-intensity and resistance exercises. In theory, athletes could benefit largely from the supplementation of ED. However, to date, there are no studies examining the influence of ED on performance in CrossFit®.

To address this problem, in the present study, we

proposed a acute dose ED regimen. We aimed to examine the effects of ED on CrossFit® performance by the rating of perceived exertion (RPE) and the rating of perceived pain (RPP) and the total volume of repetitions (TVR), in tests of muscular strength (MS), 10 and 12 maximum repetitions (MRs) in barbell bench press (BBP) and barbell squat (BS), respectively and localized muscular endurance (LME) using Workout of the Day (WOD) selected. The hypothesis of this study is that the ingestion of ED improves CrossFit® performance.

Methods

Participants

The sample size calculation was based on an alpha value of 5%, and power of 80% and effect size of 0.5 using crossover ANOVA. These parameters generated a sample size of 12 subjects. Fifteen participants were initially enrolled in this study. However, 8 (3 women, 5 men; mean ± SD: age: 26.5 ± 2.7 years; baseline values of body mass: 70.2 ± 13.0 kg; body height: 1.7 ± 0.09 m; Body Mass Index [BMI]: 23.0 ± 3.2 kg/m^2; ∑ skinfold thickness: 34.1 ± 6.9 mm; body fat: 13.3 ± 3.0 %) completed the entire study protocol and were included in analyses. The participants were recreationally and regularly training CrossFit® at the CrossFit® Alaia (6 participants) and CrossFit® Blumenau (2 participants) clubs in Blumenau, Brazil, chosen for convenience from prior institutional ties and considering the availability of personnel and materials. The criteria for qualifying for the study, among others, included good health condition[9], a valid and up-to-date medical certificate confirming the athlete's ability to practice sports, at least three months of CrossFit® training experience, and a minimum of 3 workout sessions a week in the practiced CrossFit® discipline.

The studies were conducted from May to June 2016. All athletes declared that they had not introduced any changes in their lifestyles, elements of training, nutrition or supplementation, and that they had not been using any medications and supplements with potential ergogenic effects, other than those supplied by the authors of this study.

Those who did not meet the inclusion criteria asked to withdraw their participation in the research, and did not show physical or intellectual conditions to meet the evaluation protocol were excluded from the analysis. Therefore, of the 15 recruited subjects, 7 did not meet the inclusion criteria, 4 did not have a medical certificate and 3 did not have the required practice time.

Ethical aspects

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki[10], and has been approved by the Committee of Ethics and Research on Human of the Catarinense Federal Institute under opinion No. 1.768.851/2016. Informed consent has been obtained from all individuals included in this study.

Procedures

FIGURE 1 show the study protocol, that consisted of two 15-day experimental trials separated by a 7-day washout period in a randomized double-blind Placebo-controlled cross-over manner. Anthropometric measures were obtained on the preliminary visit (1st session). The participants were familiarized with the testing procedures, protocols, and equipment used before beginning the study (2nd and 3rd sessions). After being qualified for the study, participants were subjected to a randomization procedure and assigned either to the group receiving first a ED preparation or to the group receiving Placebo. The randomization of participants was obtained by computer-generated numbers, and the allocation and administration of products centrally generated by an independent person (nutritionist) who was not responsible for determining participants eligibility, had no information about participants and did not participate of the other stages of the research.

The main study protocol involved another 6 sessions (4th to 9th) in tests of MS, 10 and 12 MRs in BBP and BS, respectively and LME using WOD selected, after consensus of the CrossFit® coaches certificates the of two clubs, previously on the begin to the study, with verbal command stimulus and with the technique and form of execution for each exercise standardized

and continuously monitored in an attempt to ensure the quality of execution. During trials, the participants ingested at a dose of 300 mL either ED (Mormaii EnerGETico®), supplied by Wild+Amazon Flavors, or Placebo (Guarana Antarctica Black®), supplied by the Americas Beverage Company (AMBEV S/A), 30 minutes before the start of standardized exercises. Both drinks have a similar amount of sugar.

The participants were instructed to complete the anthropometric measurements and testing sessions between 5.30 and 9.00 PM and avoid strenuous exercise for the 24 hours prior to each test session. However, three hours before the tests, participants consumed standardized small meals. In addition, the participants were asked to maintain the same dietary intake and training load throughout the study protocol.

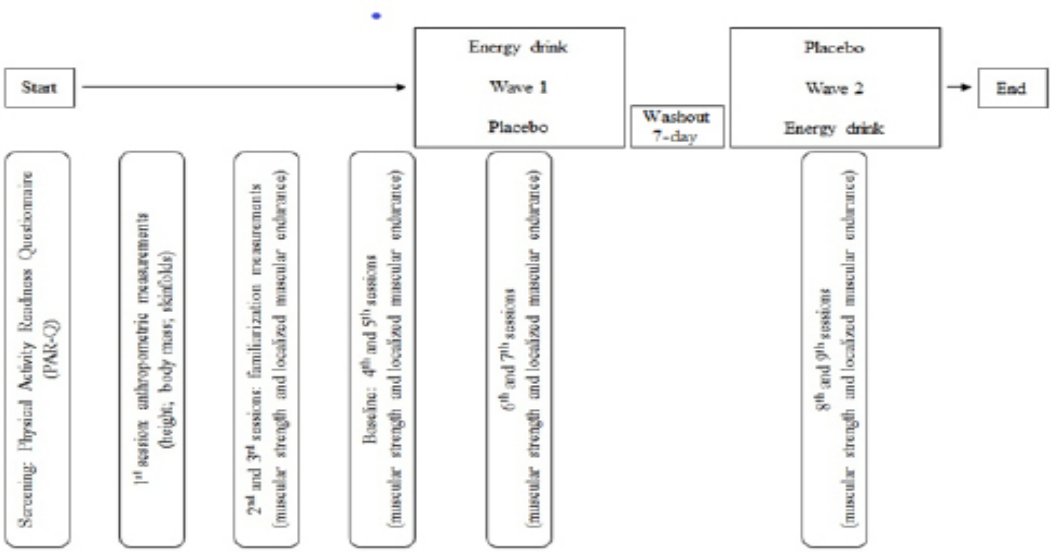
Immediately after each test, RPE and RPP were measured using the Borg scale[11], adapted by Foster et al.[12] and the visual analogue scale for pain[13], respectively.

Supplementation

Four participants were randomly allocated to the "Energy drink - Placebo" group and four to the "Placebo - Energy drink" group.

Placebo and ED were administered in similar containers preventing visual recognition and always immediately after consumption of one extra-strong menthol (Halls® mini) artificial hard taste drop supplied by Cadbury Adams Brazil, to hinder identification of the drinks, according to the nutritionist, with no chance that it can have any effect on the performance results. For the purpose of double blinding, neither the researchers nor the participants knew whether ED or Placebo was administered. Only the nutritionist had access to information on randomization, which was revealed only after cessation of the protocol.

FIGURE 1 - Experimental design.



Anthropometric measurements

Participants underwent anthropometric assessment individually at an appropriate location in each CrossFit® club between 5.30 and 9.00 PM. Height was measured with a stadiometer at an accuracy of 0.1 cm (Sanny®, São Paulo, Brazil). Body mass was determined with a mechanical scale at an accuracy of 100 g (Welmy®, São Paulo, Brazil). Subscapular (SS), triceps (TR), supra-iliac (SI), and medial calf (MC) skinfolds were measured with an adipometer at an accuracy of 0.1 mm (Sanny®, São Paulo, Brazil). Body density was estimated through Petroski[14]. Once the body density was determined, fat percentage was calculated using the Siri equation[15]. BMI was defined as the body mass in kilograms divided by the square of height in meters and used according to the cutoff points of the classification adapted by the World Health Organization[16]. All anthropometric measurements were collected by a level 3 anthropometry-certified physical education teacher from the International Society for the Advancement of Kinanthropometry (ISAK), three times by (non-consecutive) rotation, and the mean was used as the measure, with an intra-evaluative estimated technical error of measurement (TEM) for skinfold thickness of up to 5%, and 1% for other measurements, according to ISAK recommendations[17].

Exercise tests

All participants were submitted to the in tests of MS, 10 and 12 MRs in BBP and BS, respectively, and LME using WODs selected, with techniques and executions, following the procedures of Rodrigues and Rocha[18] and CrossFit®[19], respectively, by the total number of repetitions with no interval between exercises, separated in categories by training time: Beginner (3-6 months) [WOD-A: Overhead Lunge (OL), 20 kg; Abmat Sit-up (AS); and Burpee (B)]; Intermediate (7-18 months) [WOD-B: Wall Climbing (WC); Wall Ball (WB), 10 lb for Women; 20 lb, for men; and Box Jump (BJ)]; Advanced (19 months or more) [WOD-C: Handstand Push-up (HP); Overhead Squat (OS), 40 kg; and Kipping Pull-up (KP)]. In each test of MS, a maximum of three attempts were allowed to reach the load for 10 and 12 MRs with an interval of 5 minutes between attempts and 20 minutes between exercises. The load used in the first attempt in each test of MS was determined by the subject (subjective) based on their training experience, the increase in load between attempts was at least 1 kg and 2.25 kg for BBP and BS exercises, respectively. The subjects were instructed to perform a maximum of 10 and 12 repetitions per attempt even if the load allowed more, the attempt in which the volunteer performed 10 and 12 repetitions with the maximum load possible, when concentric or eccentric failure occurs, before the twelfth and twelfth retry to be achieved, the attempt was discarded. All tests were video recorded to allow precise counting of all technically-well performed repetitions. Coaches, with CrossFit® certificates, verbally counted repetitions (WODs), but only if the participant completed a full range of motion required for each exercise. Repetitions that did not meet movement standards were not counted, and participants were provided with feedback to meet the movement standards.

Statistics

Descriptive statistical analysis was used adopting the frequency and percentage for categorical variables and mean ± standard deviation (SD) for continuous variables. The nine exercises were aggregated into a single variable (WOD Z score) to reduce type I error and allow comparison of WOD exercise performance, as follows: the number of repetitions of each participant in each WOD exercise was added; thus, each participant had one result per assessment day, and then each participant received a Z score for their performance. A negative score meant performance below their mean performance, while a positive score reflected performance above their mean performance. Data normality was tested using the Shapiro-Wilk test. Student's t-test for independent samples was employed to assess the appropriateness of participant randomization in the baseline Placebo and ED groups.

Standard methods for two-period two-treatment crossover designs were used to evaluate the effect of supplementation[20]. The mixed linear regression model for longitudinal data, together with the restricted maximum probability method, was used to assess the impact of ED on the variables analyzed during the experimental protocol. The correlated random effects model was used for the evaluated participants, and the assessment period as a repeated effect in a model with correlated residuals within random effects, given the possibility of the correlation between repeated measures decreasing in strength in the most distant periods (weeks) over time, an autoregressive residual covariance structure was adopted. When the significant result was found the Cohen's D was used for the effect size calculation and classified as "trivial" (<0.19), "small" (0.20–0.49), "moderate" (0.50–0.79), and "large" (>0.80)[21].

The significance level was $p \leq 0.05$ for the training effect and $p \leq 0.10$ for the carry-over effect, and all statistical analyses were performed using Statistical Package for the Social Sciences® (SPSS) (PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.).

Results

TABLE 1 shows the results as mean and SD for the variables RPE, RPP, and TVR in the nine exercises of the three WODs, in Z score, RPE, RPP, and the lifted loads (kg) in exercises BBP and BS, during the experimental protocol. Adequacy of randomization and wash-out period was demonstrated, since the former showed no significant differences in baseline between the analyzed variables (age, anthropometric characteristics, RPE, RPP, and TVR in the nine WOD exercises, RPE, RPP and the loads raised in kg in BBP and BS) ($p > 0.05$), and in the latter, the carry-over effect was not significant in any of the analyses ($p > 0.10$).

TABLE 1 - Mean ± standard deviation of the results of the Workout of the Day and the lifted loads (kilogram) in the barbell bench press and barbell squat, n = 8.

		Energy drink - Placebo			Placebo - Energy drink		
		Baseline	**Wave 1**	**Wave 2**	**Baseline**	**Wave 1**	**Wave 2**
BBP	RPE	7.7±2.2	9.1±0.6	8.7±0.9	9.0±0.8	8.2±1.5	7.8±1.1
	RPP	6.1±1.9	7.3±0.4	7.5±0.5	6.1±2.9	6.3±1.0	6.6±3.2
	10MRs	56.5±26.2	54.5±28.3	54.5±29.7	53.0±32.2	54.0±31.1	55.0±31.3
BS	RPE	7.7±0.5	8.2±1.7	8.5±1.0	9.2±0.9	9.0±0.8	9.0±0.8
	RPP	5.8±1.4	6.5±1.5	6.2±0.9	6.7±2.2	7.5±1.4	6.7±2.2
	12MRs	64.5±30.1	62.5±36.2	67.0±36.5	57.5±32.1	62.5±29.5	62.0±27.9
WOD	RPE	-0.07±1.0	-0.1±0.6	0.2±1.0	-1.1±0.03	0.6±0.1	0.5±0.2
	RPP	-1.0±0.1	0.3±0.5	0.6±0.5	-0.3±0.8	0.7±0.4	-0.4±0.7
	TVR	-0.7±0.5	0.4±0.9	0.3±0.5	-0.3±0.8	-0.1±0.9	0.4±0.8

BBP = barbell bench press;
BS = barbell squat;
MRs = maximum repetitions;
RPE = rating of perceived exertion;
RPP = rating of perceived pain;
TVR = total volume of repetitions;
WOD = Workout of the Day.

FIGURES 2, 3 and 4 shows the effects on RPP, TVR, and RPE in Z-score for the nine exercises of the three WODs when compared to the baseline in all experimental sessions.

ED consumption ($p = 0.017$) and baseline ($p < 0.001$) resulted in significantly lower RPP values when compared to Placebo consumption. However, ED consumption compared to baseline showed no significant differences in RPP ($p = 0.218$).

ED and Placebo showed significantly higher results when compared to baseline in TVR and RPE ($p = 0.012$ and $p = 0.023$; $p = 0.027$ and $p = 0.024$, respectively), although no significant differences were found when comparing the consumption of ED with Placebo to TVR ($p = 0.745$) and RPE ($p = 0.982$).

All significant results, whether comparing groups or baseline, show an effect size between 0.5 and 0.7, that's means a medium effect size.

The results of the mixed linear model indicate that ED consumption had no significant effects on the other variables analyzed ($p > 0.05$).

FIGURE 2 - Ergogenic effect of energy drink (ED) on rating of perceived pain (RPP), Z-score, Workout of the Day (WOD) exercises in all experimental sessions. *p < 0.05. **p < 0.001.

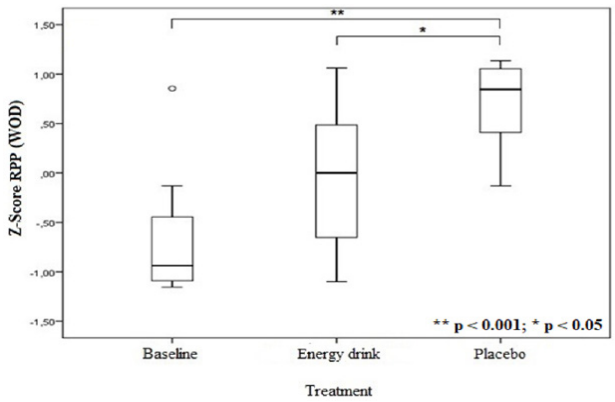


FIGURE 3 - Ergogenic effect of energy drink (ED) on total volume of repetitions (TVR), Z-score, Workout of the Day (WOD) exercises in all experimental sessions. *p < 0.05.

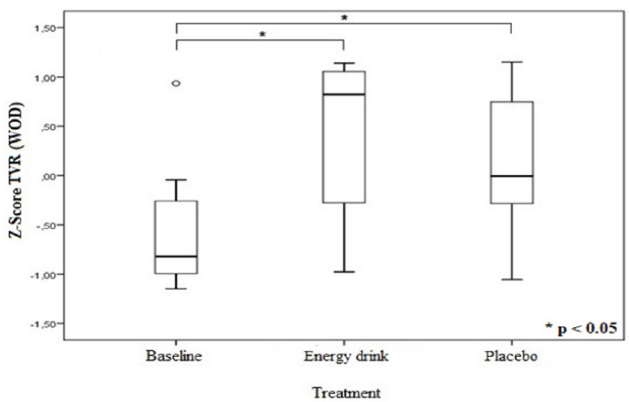
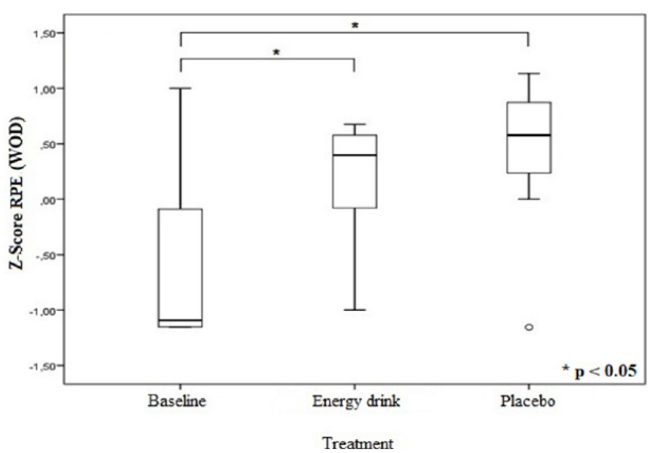


FIGURE 4 - Ergogenic effect of energy drink (ED) on rating of perceived exertion (RPE), Z-score, Workout of the Day (WOD) exercises in all experimental sessions. *p < 0.05.



Discussion

This study aimed to analyze the acute effects of ED on CrossFit® performance by the RPE and RPP and the TVR, in tests of MS, 10 and 12 MRs in BBP and BS, respectively and LME using nine selected exercises proposed by CrossFit® (WOD-A: OL, AS, B; WOD-B: WC, WB, BJ; and WOD-C: HP, OS, KP).

The hypothesis of this study was partially confirmed, as there were effects on RPP, TVR, and RPE, in Z-score, for the nine exercises of the three WODs in all experimental sessions, with the consumption of the ED and baseline, showing significantly lower RPP results when compared to Placebo consumption, and both drinks showing significantly higher TVR and RPE results when compared to baseline, probably partly due to the stimulating action of caffeine, taurine, and B vitamins, the first two for their synergistic action on mood and alertness modulation, and the other for playing an essential role in metabolism[22,23].

The effects of ED, or of its isolated ingredients, on performance during high-volume muscular endurance workouts that tax multiple muscle groups with limited recovery (e.g., CrossFit®) remains unknown. However, the caffeine, one of the main ingredients in ED, with "good evidence" establishing its ergogenicity across a variety of exercise protocols and muscle groups, was analyzed in two randomized, double-blind, crossover studies[24,25], but caffeine's ergogenic effect were not present during the CrossFit® workout, performanced by CrossFit®-trained men CrossFit®. Fundamentally, the limited evidence from the sports nutrition community exists regarding the utility of dietary supplementation for CrossFit® performance.

The results of studies related to the use of ED are controversial, with variations in experimental designs and sample characteristics, pointing from the promotion of positive effects on cognition and mood[26], level of optimism negatively correlated with the frequency of consuming[27], to the association with unhealthy behaviors[28,29], including excessive or alcohol consumption[30], which may exert ergolytic effect (decreased physical performance)[7], also contributing to commendations for safer use of energy drinks[1,31].

The mechanism of the effect of ED on human performance is not yet clear. Although cyclists showed improved performance after ingestion of this type of drink[22,32], however, the ergogenic effect was not proven in the set of sprint repetitions, changes in heart rate and RPE, in female field soccer players[33]. Moreover, so far, no national or international studies that investigated the acute ergogenic effect by RPE and RPP and TVR due to the administration of ED and Placebo on human performance in tests of participants recreationally and regularly training CrossFit® have been found.

CrossFit® is part of functional training, with demands on motor skills such as balance, coordination, gait, agility and proprioception, aimed at improving the strength and stability of the muscles of the central region of the body[34]. A tendency of the fitness segment in the world over the last decade[35], characterized as another variant of sports performance (training the body as required in competition), as well as recreational and general training (performing movements that mimic those in daily living)[9]. The method has increasingly more adherents around the world, despite the scarce scientific evidence concerning its efficacy or harm[8], and its practitioners may consume indiscriminately ergogenic substances, mainly with nutritional inadequacy concerning micronutrients and macronutrients[36], such as ED, to improve recovery, as occurs for dietary supplements[37], offered as the only response to better performance in various sports modalities and practices, since insufficient rest periods can promote high levels of exercise-induced stress[38,39].

The results of this study did not show significant effects of treatment (ED) when compared with Placebo, except in RPP, in most of the analyzed variables, in participants recreationally and regularly training CrossFit®, in MS and LME tests, with experimental design and strict methodological control, with adequate randomization and wash-out period. But the tonnage increased with ED and Placebo. It is speculated that the improvements in RPE and TVR, in Placebo, may have happened due to the verbal command stimulus.

However, further specific studies are required to investigate the BBP and BS tonnage responses (BBP volume x load lifted + BS volume x load lifted) as different TVRs have been associated with distinct acute responses[40,41]. Furthermore, the RPE is dependent on the overload used[42,43], however, no consensus on the RPP.

Methodological limitations focus on the results of this study, especially regarding the small sample size of the analyzed volunteers, the cross-sectional design, which does not allow cause-and-effect interpretation, the application of the results to other exercises, extrapolation to other populations, the lack of testing isolated components of ED and Placebo, collection of biochemical markers of fatigue and greater controls on daily routines throughout the study, including diet, recovery rate between sessions and stress analysis of athletes that may have influenced different RPE/RPP, and the use of the three Z-score WODs for the analysis of RPE, RPP and TVR. Another limiting factor is the rare scientific evidence on CrossFit® training[44] and investigations that sought to prove the effectiveness of supplementation in practitioners of this sport[45,46].

The results of this study evidence that 300 mL dosages of ED (Mormaii EnerGETico®) and Placebo (Guaraná Antarctica Black®) 30 minutes before the start of the standardized exercises, in experimental sessions with an interval of a minimum of seven days of the same test and 24-48h of the different tests, did not significantly improve the production of isotonic strength of the upper and lower limbs, but participants recreationally and regularly training CrossFit®, aiming for as many repetitions as possible in WOD exercises without intervals and recovery between each other, may have higher pain tolerance and tonnage increase, with distinct training time.

Resumo

Efeito agudo da ingestão de bebida energética no desempenho do Crossfit®: um estudo cruzado, randomizado, duplo-cego.

O objetivo deste estudo foi analisar os efeitos agudos da ingestão de bebida energética (BE) no desempenho do CrossFit® em um estudo cruzado, randomizado, duplo-cego, com 8 treinados no CrossFit® (26,5 ± 2,7 anos; 70,2 ± 13,0 kg; 1,7 ± 0,09 m; 23,0 ± 3,2 kg/m2; ∑ espessura de dobras cutâneas: 34,1 ± 6,9 mm; gordura corporal: 13,3 ± 3,0 %), que foram alocados aleatoriamente em 2 grupos e foram submetidos a 2 ensaios separados por um período de washout de 7 dias. Os participantes ingeriram uma dose de 300 mL de BE ou Placebo (refrigerante), 30 minutos antes do início dos testes de força muscular (FM), 10 e 12 repetições máximas (RMs) no supino reto (SR) e agachamento com barra (A), respectivamente, e resistência muscular localizada (RML) usando o Workout of the Day (WOD) selecionado. A percepção subjetiva de esforço (PSE) e a percepção subjetiva de dor (PSD) foram avaliadas imediatamente após os testes. O volume total de repetições (VTR) foi avaliado para cada teste. O VTR foi significativamente maior após consumir a BE (p = 0,012) e o Placebo (p = 0,027). Houve redução da taxa de PSE após o consumo de ambas as bebidas (p = 0,023 e p = 0,024). O consumo de BE reduziu significativamente a taxa de PSD (p = 0,017). A ingestão aguda de BE melhorou o desempenho do CrossFit® por aumentar o VTR e a tolerância à dor.

Palavras-chave: Aptidão física; Exercício físico; Resistência física; Técnicas de exercício e de movimento; Teste de esforço.

References

1. Alsunni AA. Energy drink consumption: beneficial and adverse health effects. Int J Health Sci (Qassim). 2015;9(4):468-74.
2. Malinauskas BM, Aeby VG, Overton RF, Carpenter-Aeby T, Barber-Heidal, K. A survey of energy drink consumption patterns among college students. Nutr J. 2007;6(35):1-7. doi: https://doi.org/10.1186/1475-2891-6-35.
3. Alford C, Cox H, Wescott, R. The effects of red bull energy drink on human performance and mood. Amino Acids. 2001;21(2):139-50. doi: https://doi.org/10.1007/s007260170021.
4. Forbes SC, Candow DG, Little JP, Magnus C, Chilibeck PD. Effect of Red Bull energy drink on repeated Wingate

cycle performance and bench-press muscle endurance. Int J Sport Nutr Exerc Metab. 2007;17(5):433-44. doi: https://doi.org/10.1123/ijsnem.17.5.433.
5. Pettitt RW, Niemeyer JD, Sexton PJ, Lipetzky A, Murray SR. Do the noncaffeine ingredients of energy drinks affect metabolic responses to heavy exercise? J Strength Cond Res. 2013;27(7):1994-9. doi: https://doi.org/10.1519/JSC.0b013e3182736e31.
6. Hernadez AJ, Nahas RM. Modificações dietéticas, reposição hídrica, suplementos alimentares e drogas: comprovação de ação ergogênica e potenciais riscos para a saúde. Rev Bras Med Esporte. 2009;15(3 Suppl):S2-12. doi: https://doi.org/10.1590/S1517-86922009000400001.
7. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and athletic performance. Med Sci Sports Exerc. 2016;48(3):543-68. doi: https://doi.org/10.1249/MSS.0000000000000852.
8. Claudino JG, Gabberr TJ, Bourgeois F, et al. CrossFit overview: systematic review and meta-analysis. Sports Med Open. 2018 ;4(1):1-11. doi: https://doi.org/10.1186/s40798-018-0124-5.
9. Thompson WR. Recursos do ACSM para o personal trainer, 3rd ed. Rio de Janeiro: Guanabara Koogan; 2011.
10. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191-4. doi: https://doi.org/10.1001/jama.2013.281053.
11. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377-81. doi: https://doi.org/10.1249/00005768-198205000-00012.
12. Foster C, Florhaug J, Franklin J, et al. A new approach to monitoring exercise training. J Strength Cond Res. 2001;15(1):109-15.
13. Sousa FAEF. Dor: o quinto sinal vital. Rev Latinoam Enferm. 2002;10(3):446-7. doi: https://doi.org/10.1590/S0104-11692002000300020.
14. Petroski EL. Equações antropométricas: subsídios para uso no estudo da composição corporal. In: Petroski EL, editor. Antropometria: técnicas e padronizações. Porto Alegre: Pallotti; 1999. p. 105-32.
15. Siri WE. Body composition from fluid spaces and density analysis of methods. In: Brozek J, Henshcel A, editors. Techniques for measuring body composition. Washington DC: National Academy of Sciences; 1961. p. 223-44.
16. World Health Organization. Obesity: preventing and managing the global epidemic. 2000. Available from: http://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/.
17. Silva VS, Vieira MFS. International Society for the Advancement of Kinanthropometry (ISAK) Global: international accreditation scheme of the competent anthropometrist. Rev Bras Cineantropom Desempenho Hum. 2020;22: e70517. https://doi.org/10.1590/1980-0037.2020v22e70517.
18. Rodrigues CEC, Rocha PECP. Musculação: teoria e prática. 23rd ed. Rio de Janeiro: Sprint; 1999.
19. CrossFit. Guia de treinamento de nível 1 CrossFit training. Washington, DC, EUA: CrossFit, Inc. 2002-2018. Available from: http://library.crossfit.com/free/pdf/CFJ_L1_TG_Portuguese.pdf.
20. Senn S. Cross-over trials in clinical research. 2nd ed. Chichester: John Wiley & Sons; 2002. https://doi.org/10.1002/0470854596.
21. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Lawrence Erlbaum Associates, Publishers; 1988.
22. Geiß KR, Jester I, Falke W, Hamm M, Waag KL. The effect of a taurine-containing drink on performance in 10 endurance-athletes. Amino Acids. 1994;7(1):45-56. doi: https://doi.org/10.1007/BF00808445.
23. Manore MM. Effect of physical activity on thiamine, riboflavin, and vitamin B-6 requirements. Am J Clin Nutr. 2000;72(2):S598-606. doi: https://doi.org/10.1093/ajcn/72.2.598S.
24. Stein JA, Ramirez M, Heinrich KM. Acute caffeine supplementation does not improve performance in trained CrossFit® athletes. Sports, 2020;23;8(4):54. doi: http://dx.doi.org/10.3390/sports8040054.
25. Fogaça LJ, Santos SL, Soares RC, et al. Effect of caffeine supplementation on exercise performance, power, markers of muscle damage, and perceived exertion in trained CrossFit men: a randomized, double-blind, placebo-controlled crossover trial. J Sports Med Phys Fitness, 2020;60(2):181-188. doi: http://dx.doi.org/10.23736/S0022-4707.19.10043-6.
26. Wesnes KA, Brooker H, Watson AW, Bal W, Okello E. Effects of the Red Bull energy drink on cognitive function and mood in healthy young volunteers. J Psychopharmacol. 2017;31(2):211-21. doi: https://doi.org/10.1177/0269881116681459.
27. Gacek, M. Selected personal conditions determining the frequency of consuming groups of products among athletes professionally training individual sports disciplines. Hum Mov. 2019;20(3):56-65. doi: https://doi.org/10.5114/hm.2019.83997.
28. Larson N, Laska MN, Story M, Neumark-Sztainer D. Sports and energy drink consumption are linked to health-

risk behaviours among young adults. Public Health Nutr. 2015;18(15):2794-803. doi: https://doi.org/10.1017/S1368980015000191.
29. Poulos NS, Pasch KE. Energy drink consumption is associated with unhealthy dietary behaviours among college youth. Perspect Public Health. 2015;135(6):316-21. doi: https://doi.org/10.1177/1757913914565388.
30. Velazquez CE, Poulos NS, Latimer LA, Pasch KE. Associations between energy drink consumption and alcohol use behaviors among college students. Drug Alcohol Depend. 2012;123(1-3):167-72. doi: https://doi.org/10.1016/j.drugalcdep.2011.11.006.
31. Alhyas L, El Kashef A, AlGhaferi H. Energy drinks in the Gulf Cooperation Council states: a review. JRSM Open. 2015;7(1):2054270415593717. doi: https://doi.org/10.1177/2054270415593717.
32. Ivy JL, Kammer L, Ding Z, et al. Improved cycling time-trial performance after ingestion of a caffeine energy drink. Int J Sport Nutr Exerc Metab. 2009;19(1):61-78. doi: https://doi.org/10.1123/ijsnem.19.1.61.
33. Astorino TA, Matera AJ, Basinger J, Evans M, Schurman T, Marquez R. Effects of red bull energy drink on repeated sprint performance in women athletes. Amino Acids. 2012;42(5):1803-8. doi: https://doi.org/10.1007/s00726-011-0900-8.
34. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc. 2011;43(7):1334-59. doi: https://doi.org/10.1249/MSS.0b013e318213fefb.
35. Thompson WR. Worldwide survey of fitness trends for 2021. ACSM' Health Fitness J. 2021;25(1):10-9. doi: https://doi.org/10.1249/FIT.0000000000000631.
36. Bueno AB, Ribas MR, Bassan JC. Determinação da ingesta de micro e macro nutrientes na dieta de praticantes de CrossFit. Revista Brasileira de Nutrição Esportiva. 2016;10(59):579-86.
37. Nabuco HCG, Rodrigues VB, Ravagnani CFC. Fatores associados ao uso de suplementos alimentares entre atletas: revisão sistemática. Rev Bras Med Esporte. 2016;22(5):412-9. doi: https://doi.org/10.1590/1517-869220162205154808.
38. Tibana RA, Farias DL, Nascimento DC, Da Silva-Grigoletto ME, Prestes J. Correlation of muscle strength with weightlifting performance in Crossfit® practitioners. Rev Andal Med Deporte. 2018;11(2):84-8. doi: https://doi.org/10.1016/j.ramd.2015.11.005.
39. Williams S, Booton T, Watson M, Rowland D, Altini M. Heart rate variability is a moderating factor in the workload-injury relationship of competitive Crossfit™ athletes. J Sports Sci Med. 2017;16(4):443-9.
40. Gotshalk LA, Loebel CC, Nindl BC, et al. Hormonal responses of multiset versus single-set heavy-resistance exercise protocols. Can J Appl Physiol. 1997;22(3):244-55. doi: https://doi.org/10.1139/h97-016.
41. Ratamess NA, Falvo MJ, Mangine GT, Hoffman JR, Faigenbaum AD, Kang J. The effect of rest interval length on metabolic responses to the bench press exercise. Eur J Appl Physiol. 2007;100(1):1-17. doi: https://doi.org/10.1007/s00421-007-0394-y.
42. Day ML, McGuigan MR, Brice G, Foster C. Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res. 2004;18(2):353-8. doi: http://doi.org/10.1519/r-13113.1.
43. Lagally KM, Robertson RJ, Gallagher KI, et al. Perceived exertion, electromyography, and blood lactate during acute bouts of resistance exercise. Med Sci Sports Exerc. 2002;34(3):552-9. doi: https://doi.org/10.1097/00005768-200203000-00025.
44. Escobar K, Morales J, VanDusseldorp T. Metabolic profile of a crossfit training bout. J Human Sport Exercise. 2017;12(4):1248-55. doi: https://doi.org/10.14198/jhse.2017.124.11.
45. Oliveira AA, Oliveira AA. Suplementação e performance em praticantes de CrossFit®. Rev Brasi Nutrição Esportiva. 2017;11(66):719-23.
46. Durkalec-Michalski K, Zawieja EE, Podgórski T, et al. The effect of chronic progressive-dose sodium bicarbonate ingestion on CrossFit-like performance: A double-blind, randomized cross-over trial. PLoS ONE. 2018;13(5):e0197480. doi: https://doi.org/10.1371/journal.pone.0197480.

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