Progress in Nutrition 2021; Vol. 23, N. 2: e2021220 DOI 10.23751/pn.v23i2.9385 © Mattioli 1885

Original article

Acute Influence of Caffeinated Commercially Available Energy Drink on Performance, Perceived Exertion and Blood Lactate in Youth Female Water Polo Players

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Abstract. The purpose of this study was to investigate the effects of a commercially available energy drink (ED) on performance, rating of perceived exertion (RPE) and blood lactate in youth female water polo players. Sixteen youth Water Polo players (players in the league and national competitions) volunteered to participate in a double-blind repeated-measures cross-over counterbalanced research. The subjects ingested 6 ml/kg body weight of Red Bull (RB, n = 8) or a placebo (PL, n = 8) with the same appearance and taste. Fifteen minutes after ingestion, the subjects performed following tests: muscular strength (one repetition maximum (1RM)) and 60% of 1RM in the chest press and leg press, 50 m and 100 m swimming test, running-based anaerobic sprint test (RAST) and aerobic test. Also, before and after aerobic test and RAST, 5 ml blood from antecubital vein was taken from participants to measure plasma lactate. In addition, participants' RPE (15-point scale ranging from six (extremely light) to twenty (extremely hard)) were measured before and after the aerobic and anaerobic tests. In comparison to the PL, the ingestion of ED reduced 50 m and 100 m swim record (Δ-change=-5.34, Δ-change=-5.85, P<0.001; respectively) and increased aerobic (Δ-change=2.55, P<0.001) and anaerobic performance (peak power: Δ-change=21.68, P=0.02; average power: Δ-change=24.04, P=0.03; fatigue index: Δ-change=0.98, P=0.003). The ingestion of the ED did not increase the muscular endurance in the bench press and leg press tests (P=0.59, P=0.35; respectively). Also, no differences were found in bench press strength between the two drink conditions (P=0.30). On the contrary, significance differences were found in leg press strength (Δ-change=2.56, P=0.03) and RPE post aerobic and anaerobic test between ED and PL (Δ-change=-0.72, P=0.04; Δ-change=-0.25, P=0.02; respectively). In contrast, blood lactate levels during the post exercise were unaffected by the ED ingestion (P=0.56, P=0.12; respectively). The intake of an ED (6 ml/kg body weight) increased some performance indicators and positively affected swimming at maximal speed. It seems that RB ingestion may have a positive effect on water polo athletes' performance due to significant impact on their aerobic and anaerobic metabolism.

Key words: energy drink, water polo, muscle strength, blood lactate, rating of perceived exertion.

Introduction

Ingestion of energy drink (ED) has increased globally and has high popularity among teenagers and students. Moreover, these beverages are one of the most popular supplements among athletes, with 73% of American athletes and 42% of British elite athletes using them (1). The World Health Organization (WHO) has defined ED as the ones that can increase energy and consumer performance by their ingredients (caffeine, amino acids, plant extracts, carbohydrates, and vitamins) (2).

Each ED may contain more than 20 ingredients, including caffeine, taurine, glucuronolactone, glucose, sweeteners, vitamins B, and many others. The popular ED (Monster, Red Bull (RB), No Fear, and Rockstar) contain 80 mg of caffeine and 1 g of taurine in 250 ml cans (3). The ergogenic effects of caffeine have been studied more than other ingredients in ED. Studies have shown that caffeine can increase endurance and quantitative studies showed caffeine effects on anaerobic function (4). It has been suggested that the primary mechanism by which caffeine improves power is by increasing the use of motor units, thus causing larger output power (5). In addition to caffeine, taurine is another important ingredient in RB. The effect of taurine on athletic performance has not been thoroughly investigated; it seems that taurine exerts metabolic effects via interaction with the muscle membrane (6). A relatively high concentration of taurine is found in leukocytes (20-50 mM) and skeletal muscle (50-60 mM). Taurine has been reported to have a significant effect on anti-inflammatory processes, reduce oxidative stress and acts as a pH buffering in mitochondria (7), has a positive effect on the transmission of calcium of sarcoplasmic reticulum and cardiac muscle contraction (8). Taurine at high concentrations can increase the amount of calcium accumulation in the sarcoplasmic cells of type I and II muscle fibers, and may stimulate skeletal muscle contraction (9). Del Coso et al. (10,11) stated that consuming 3 mg/kg of caffeine available ED would increase overall running pace and sprint velocities during rugby competition. Chtourou et al. (12) concluded that drinking RB had a positive effect on physical function and RPE in male students. Furthermore, Ivy et al. (13) stated that RB improved the performance of men and women cyclists. However, contrary to them, the results of Astorino et al. (14) indicated the ineffectiveness of RB on speed performance and the RPE in women soccer players. Also, Eckerson et al. (9) showed that the ingestion of sugar-free RB did not affect upper body 1RM strength or volume load in trained men.

Every field of sport has specific metabolic and physical demands, and researchers are looking for ways to increase athletes' performance. So far, no research has investigated the effect of ED on the performance of water polo athletes and its performance is in a state of uncertainty. Water polo is team water sports that require endurance, strength, power, speed, agility, technical awareness, and certain technical skills, including ball control (15). Water polo is an intense intermittent sport involving repeated and intense recurrent activities with low and moderate intensity activity periods (16). According to studies, despite intermittent activity patterns in the water polo, aerobic metabolism has a high pressure during the game and plays an important role (16,17). The median concentration of blood lactate in the elite Spanish players is between 7.1-9.5 mmol/l (during the rest breaks of the final matches), and according to study, the glycolytic need of water polo is high (17). Considering the metabolic and physical requirements of the water polo and the RB ingredients and its possible effects, it is hypothesized that the use of this beverage due to its compounds can have a positive effect on the metabolic and physical characteristics of the water polo athletes and improve their performance.

The purpose of this study was to investigate the effects of caffeinated commercially available ED on performance indicators, perceived exertion, and blood lactate in youth female water polo players. Athletes generally use ED before the sports competition, but it is unclear whether this strategy is appropriate to increase their performance, especially water polo players. Furthermore, ED can have different effects due to its different compounds, which can have different effects on the performance of athletes of various disciplines.

Materials and Methods

Participants

In this study, a total of 16 female water polo players (mean age of 15.37±0.74 years) participated voluntarily. All participants had previous water polo experience of at least 4 years, they had special skills in the field of water polo, and were players in the league and national competitions. Each participant and her parent/guardian were informed of the experimental procedures and associated risks of the investigation and an informed consent was signed by both of them. This study was approved by the Research Committee of University and conducted according to the Declaration of Helsinki. The day before each experimental trial, participants refrained from strenuous exercise and adopted a similar diet and fluid intake regimen. Also, participants were encouraged not to take drinks with caffeine (as ED, coffee, cola drinks, chocolate, etc) in the week before the test.

Exercise protocol

The study used a double-blind repeated-measures crossover counterbalanced design in which participants were randomized to supplement with RB (n = 8) or placebo (PL, n = 8) and receive the opposite treatment one week later. All participants were familiarized with the experimental design and tests before the start of the study (in order to eliminate any learning effects). Also, the subjects were presented with the equipment and the correct procedure of performing tests. Each player performed two experimental trials under the same experimental conditions (28±1°C, 87±5% relative humidity). On first session, participants randomly ingested ED (6 mL/kg body weight RB) or PL (comprised carbonated water, citric acid lemon juice, flavorings of sodium citrate, acesulfame K, sucralose, potassium sorbate and propylene glycol E1520). On the other session, participants ingested PL and ED in reversely. One can of RB drink (i.e., 250 mL) contained 80 mg of caffeine, 1 g of taurine, 27 g of carbohydrates, 0.6 g of protein, 5 mg of vitamin B6, and 487 kJ of energy. The beverages were ingested 15 minutes before the start of the experimental trials and were provided

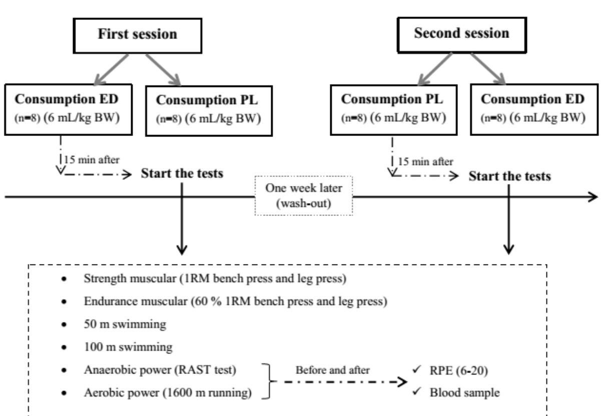

Figure 1. Experimental design. Placebo (PL), energy drink (ED), body weight (BW), rating of perceived exertion (RPE).

in opaque plastic bottles to avoid identification (equal volume, and appeared, smelled, and tasted similar) (Figure 1).

Two days before the experimental trials, height and weight (participants were nude-weighed to calculate the ED dosage) of the participants were measured, and then, the body mass index was calculated using the formula of weight divided by the square of height. Experimental trials were conducted in the following order (after the completed a standardized warm-up): muscular strength, muscular endurance, 50 meters swimming, 100 meters swimming, anaerobic power, and aerobic power. All tests were performed under the supervision of a professional trainer.

Muscular strength and endurance

One repetition maximum (1RM) of bench press and leg press was determined using the Brzycki equation (18). After 15 minutes rest, muscular endurance test with 60% 1RM in the bench press and leg press was performed. 60% of 1-RM was placed on the bar to measure muscular endurance, and the participants completed repetitions to failure**.** All subjects performed a standardized 10-min warm-up prior to performance tests.

Swimming

Performance in the 50 m and 100 m front crawl were measured in a maximum effort and start was given when the swimmers were in the water. These tests were performed in a 50 m pool, indoor temperature 25°C, water temperature 27°C and humidity 60%. A record of swimming was measured by a stopwatch (CASIO, HS-80TW-1) and total recovery time between 50 and 100 meters tests was 15 minutes.

Anaerobic power

After 30 minutes rest, the running based anaerobic sprint test (RAST) was performed to measure anaerobic power. This test consists six repetitions at a distance of 35 m; the maximum intensity is a quick run with 10 s rest between each repetition (recorded during the test by a timer 0.01 s) (19). Peak power

(PP) was defined as the highest calculated power, and mean power (MP) was defined as the average power over the six sprints.

Anaerobic power = body mass (kg) × distance $(m)^2$ /time $(s)^3$

Fatigue index = [highest power (W) − lowest power (W)]/ sum of 6 sprints (s)

Aerobic capacity

The participants' aerobic capacity was measured by a field test of 1600 m running (20). The run was continuous (nonstop), but subjects could run and walk if they were unable to run the entire distance. If a subject dropped out of the run for any reason, the test was stopped and considered a failure (time was recorded in the nearest 0.01 s). There was a 30 minutes rest period between RAST tests and aerobic tests.

Ratings of perceived exertion (RPE)

RPE were assessed via the standard Borg RPE scale (21). It is based on the physical sensations a person experiences during physical activity, including increased heart rate, increased respiration or breathing rate, increased sweating, and muscle fatigue. The Borg RPE scale is a numerical scale that ranges from 6 to 20; 6 (no exertion) − 20 (maximal exertion) category ratio scale was explained to the participants, and the instructions were repeated at the beginning and the end of the aerobic and anaerobic tests.

Blood Sampling

Blood samples were withdrawn (5 ml) from the antecubital vein into plain evacuated test tubes. The blood was allowed to clot at room temperature for 30 minutes and centrifuged at 3000× g for 15 minutes. The plasma was removed and frozen at 80 °C in multiple aliquots for further analyses. Enzymatic method (colorimetric, monoliquid) was used to measure plasma lactate (kit company Biorex, UK) and the results were recorded. The sensitivity was 0.165 mmol/l and coefficient of variation (CV) was 5.72-3.62 %. The blood lactate was taken after the aerobic and anaerobic tests.

Statistical analyses

All parameters met parametric assumptions on the basis of the Shapiro-Wilk's test. The Student's t-test was used to determine differences between the effects of ED and the PL in each test individually. The Δ-change induced by the drinks (i.e., the difference between PL and ED) was calculated as follow:

Δ-change drink = ED − PL

Because the number of subjects in the present study was less than 20, we used the Hedges' g formula to calculated effect size (ES). An ES of 0.20–0.49 was considered as small, 0.50–0.79 as moderate, and ≥ 0.80 as large (22,23). The analyses were performed using SPSS 20 and Excel 2016. The $P \leq 0.05$ was considered as the level of significance.

Results

Descriptive characteristics of the participants are reported in Table 1. The ED tended to increase mean swimming speed during the 50 meters, and 100 meters of swimming test with statistical significance (t=13.92, ES=-2.86; t=12.69, ES=-2.46; P<0.001; respectively, Table 2). In comparison with the PL drink, the pre-exercise ingestion of the ED increased aerobic power (t=-3.66, ES=1.10, P=0.008, Table 2).

According to Table 2, when results of anaerobic power test were examined, the values of increase in peak power (Δ-change=21.68), average power (Δ-change=24.04), fatigue index (Δ-change=0.98) during ingesting ED were shown compared to the PL (t=-2.89, ES=1.12; t=-2.53, ES=1.11; t=-4.33, ES=2.37; respectively). These differences were statistically significant (P=0.02, P=0.03, P=0.003; respectively). Compared to PL, there was no main effect of ED

Table 1. Participants' characteristics (mean ± SD).

Variable	Mean±SD
Age (years)	15.37±0.74
Weight (kg)	55.65±1.96
Height (m)	1.66±0.05
BMI (kg/m²)	20.26±1.33

SD= standard deviations, BMI= body mass index.

Table 2. Δ-change, effect size (ES), mean and standard deviations (SD) of performance indicators during the energy drink (ED) and placebo (PL) conditions.

Variable		Mean±SD		Δ-change	ES
		ED	PL		
50 m swimming (s)		30.10±1.93	35.44±1.79	-5.34*	-2.86
100 m swimming (s)		67.39±2.76	73.25±1.92	-5.85*	-2.46
Aerobic power (ml/kg/min)		46.67±2.89	44.12±1.53	2.55*	1.10
Anaerobic power	**PP (w)**	456.88±11.90	435.19±24.55	21.68*	1.12
	AP (w)	446.48±13.87	422.44±27.16	24.04*	1.11
	FI (w/s)	4.15±0.45	3.16±0.38	0.98*	2.37
Muscular Strength (kg)	**Bench press**	64.06±1.56	63.18±1.28	0.87	0.61
	Leg press	126.31±1.51	123.75±1.90	2.56*	1.49
Muscular endurance (rep)	**Bench press**	26.37±1.40	26.25±1.38	0.12	0.08
	Leg press	32.50±1.30	31.87±1.64	0.62	0.42

PP= peak power, AP= average power, FI= fatigue index, rep = repetition. *: Significant differences compared to PL at P< 0.05.

on blood lactate after the aerobic and anaerobic test (t=0.6, P=0.56, ES=-0.37; t=1.72, P=0.12, ES=-0.56; respectively, Figure 2A).

In comparison to the PL, the ingestion of the ED did not increase the muscular endurance in the bench press and leg press exercises (t=-0.55, ES=0.08, P=0.59; t=-1, ES=0.42, P=0.35; respectively). Also, no differences were found in bench press strength between the two drink conditions (t=-1.10, ES=0.61, P=0.30). In contrast, significance differences were found in leg press strength (t=-2.58, ES=1.49, P=0.03, Table 2) and RPE post aerobic and anaerobic power between the two drink conditions (t=2.37, P=0.04, ES=-1.28; t=2.75, P=0.02, ES=-1.28; respectively, Figure 2B).

Discussion

The main objective of this study was to investigate the effect of caffeinated commercially available ED ingestion on performance, perceived exertion and blood lactate in youth female water polo players. The results showed that the ingestion of ED had a positive effect on the speed record of 50 m and 100 m swimming of water polo athletics. Moreover, the results showed the positive effect of ED ingestion on aerobic and anaerobic power and athlete's RPE. In addition, the results showed that ingestion of ED did not have effect on

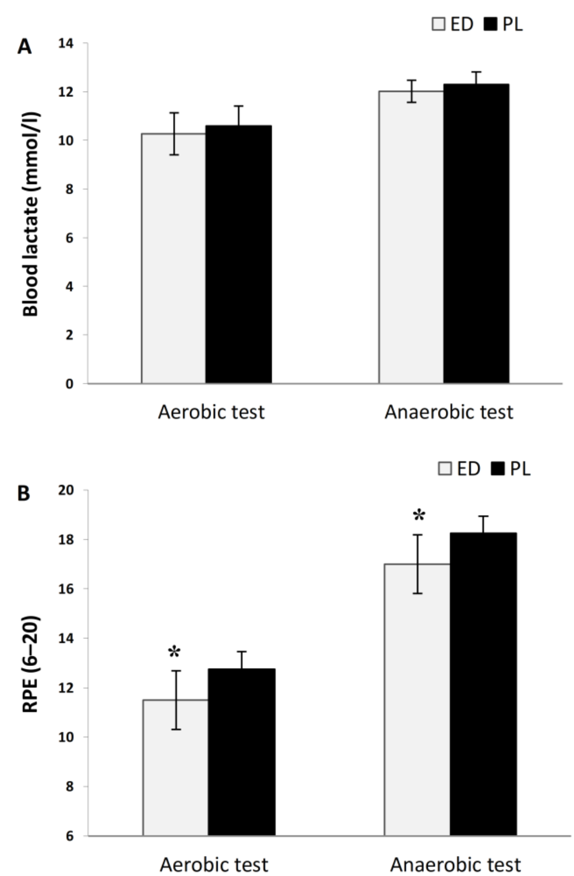

Figure 2. Evolution of blood lactate levels (A) and rating of perceived exertion (RPE) (B) (mean ± SD) from post-test (aerobic and anaerobic) during the placebo (PL) and the energy drink (ED) sessions. *: Significant differences compared to PL at P< 0.05.

strength, muscular endurance and blood lactate in female athletes of water polo.

The effect of ED ingestion on the performance of athletes in this field has not been studied so far, and this study was the first to analyze its effects as a popular drink among water polo athletes. In this study, results showed that ED ingestion had a positive effect on the record of 50 m and 100 m swimming of water polo athletes. In this regard, we can refer to the Prins et al. (24) study. Regarding the effect of ED on performance and physiological reactions of 5 km running in recreational endurance runners, the researchers concluded that the ingestion of RB before exercise could increase the efficiency of 5-km time trial performance in male and female recreational distance runners. They also argued that this beverage can be used before exercise for altering nutritional strategies (24). In contrast, Jeffries et al. (1) showed that taking caffeine and taurine with proportional doses in common ED does not improve repeat-sprint cycling performance. Most studies have shown that the average dose of caffeine (3-6 mg/kg) one hour before training increase endurance performance in various protocols such as cycling, endurance running, swimming, and boating, and can improve team-related activities such as football, field hockey, and rugby (25-27). Nevertheless, the results of this study may be affected by measurement error. In this study, 50 m and 100 m swimming tests were measured with a stopwatch (due to some limitations), and despite regarding all the standard conditions, using referees and professional trainers to measure these tests, the researchers give the probability of measurement error.

In the present study, results on aerobic power showed the positive effect of ED ingestion. Moreover, the results showed that ingestion of ED increased the maximum power, average power and has positive effects on the athlete's fatigue index. Studies showed that moderate (5-6 mg per kg body weight) to high (more than 7 mg/kg) doses of caffeine can increase anaerobic ability (4). The results of Ivy et al. (13) and Waldron et al. (28) showed that the ingestion of RB and oral taurine (varying doses 1–6 g) improves endurance performance. Del Coso et al. (29) found that the consumption of caffeine-containing drinks at a dose of 3 mg/kg 30 minutes before the start of the test increased the ability to run at a velocity of 7 × 30 m. Contrary to the results of this study, Arazi et al. (30) showed that the ingestion of Big Bear did not have a significant effect on the aerobic and anaerobic power of the adolescent professional swimmers. Besides, Del Coso et al. (11) and Astorino et al. (14) stated that the ingestion ED 60 minutes before exercise, did not affect the speed of women rugby players and soccer players. Rutherford et al. (31) showed no change in heart rate and blood VO_2 due to taurine ingestion compared to PL; the ergogenic effects of taurine occur via interaction with muscle membrane receptors or by affecting other organs such as the liver, adipose tissue, or central nervous system. Also, they suggested that the effects of taurine may be mediated through the activation of adenyl cyclase, the increased cAMP and, consequently, increased lipolysis and lipid oxidation after it; however, so far, this hypothesis has not been investigated.

Caffeine is structurally similar to adenosine and can prevent its action by binding to cell membrane receptors. Adenosine receptors are found in tissues such as the brain, heart, smooth muscle, fat cells, and skeletal muscle (32). Caffeine affects the central nervous system, inhibits phosphodiesterase, increases cAMP, and stimulates adrenaline secretion and, as a result, increases lipolysis and glycogenolysis; during these events, caffeine helps to save glycogen and increase fat oxidation, thus affecting long-term activity (32,33). It seems that the amount of caffeine in ED is the main factor for improving the performance of individuals and studies have shown that taking more than 2-3 mg per kg body weight of caffeine increases cardiovascular endurance, but has no effect for less than 2-3 mg per kg body weight (34). The phosphocreatine and ATP in the glycolytic pathway are two main products in the anaerobic system. When caffeine enters the body, it affects neuromuscular activity and neurological levels. Researchers have shown that caffeine stimulates the central nervous system and delays fatigue through acting as adenosine antagonists (4). Adenosine receptors are widely found in type 1 muscle fibers, which may explain the reduction on the likelihood of increased productivity of short-term, high intensity activities in anaerobic activities such as sprint, in which type 2 muscle fibers dominate (4).

The results of this study indicated that ED ingestion significantly increases the muscular strength of the lower body, but does not affect the upper body strength and muscular endurance of the lower and upper body of the professional female water polo players. In this regard, the results of Eckerson et al. (9) and Arazi et al. (30) indicated that the ingestion of sugar-free RB and Big Bear did not have a significant effect on the upper body strength (1RM) or volume load and muscular strength in unexercised male and adolescent swimmers participants. But, Chtourou et al. (12) and Forbes et al. (33) concluded that RB significantly increased handgrip strength and the upper body muscular endurance in male and young adult participants. Furthermore, Souza et al. (35) suggested that drinking ED improves strength and endurance, and they attributed these improvements to the taurine dose. Lim et al. (36) stated that people who did not normally take caffeine, taurine ingestion is bad for their muscle strength, while taurine ingestion in caffeine consumers improve the maximum muscle strength.

The ergogenic range of caffeine was 3-6 mg/kg (37) and taurine was 50 mg/kg (38) in previous studies. One of the reasons for this difference in results was the dose of caffeine and taurine in ED, and the effect of the other ingredients in these drinks on the performance of the participants. Caffeine increases the muscle contractility by increasing the permeability of calcium ion in muscle tissues and increasing intracellular potassium concentration with its reduction out of the cells (it helps maintain the membrane's contractility while exercising) (32,33). Research has shown that taurine is the most abundant amino acid in type II muscle fibers, even more so than glutamine, which increases the strength of athletes. This amino acid is produced in the body by the metabolism of methionine and cysteine and is involved in several physiological processes, such as cardiac contraction and antioxidant activity (8). Taurine is found at high concentrations in skeletal muscle, and it seems to play an important role in modulating the contraction of muscle. When calcium is released from the sarcoplasmic reticulum in muscle fibers and attaches to troponin, taurine releases calcium and the sensitivity of the cells to calcium increases and causing increases in contractility. Like creatine, it seems that taurine has several important functions and can act like cells in the body and increase cell size (8).

The amount of caffeine metabolism varies among people due to the variability of the CYP1A2 hepatic enzyme that causes different responses to caffeine (39). Also, the sensitivity of caffeine consumers to the performance-enhancing effects of caffeine is related to habitual intake (40). Besides, peak caffeine in plasma is 0.25 to 1 hour (average 0.5 hours) (41) and taurine is 1-2.5 hours (1.5 hours average) after it is consumed (42). Caffeine is completely absorbed in the stomach and intestine after 45 minutes and has a half-life of 3-4 hours. Therefore, the maximum effect of caffeinated beverages should be taken 45 minutes before activity (14). In this study, ED was ingested 15 minutes before the test, and it is possible that caffeine and taurine were not at its peak ergogenic potency and therefore no significant effect was observed (14). Regarding increase in the lower body strength, researchers are likely to think that more muscle mass in the lower body or the type of muscle fibers in athletes may have had an impact on the effect of ED consumption, which has had a significant effect. Besides, Lack of significant the upper body strength and muscular endurance of the lower and upper body can be due to the lack of mental preparation and measurement errors.

Another part of the results of the present study was that the ingestion of ED had a significant effect on RPE after the aerobic and anaerobic tests. Several mechanisms may be responsible for reducing RPE. Caffeine enhances the activation of the central sympathetic nervous system through adenosine receptor antagonism (43); therefore, caffeine blocks endogenous adenosine inhibiting properties (especially in the A1 and A2A receptor), which increases dopamine-related behaviors, norepinephrine and glutamate release. Generally, caffeine is a dopamine agonist that increases dopamine secretion (44) and possibly reduces RPE. Chtourou et al. (12) and Guttierres et al. (45) stated that the consumption of RB and caffeine tends to reduce RPE. A research also found that caffeine reduces RPE in protocols that use constant exercise intensity (46). In contrast, Astorino et al. (14) and Santos et al. (47) reported that the ingestion of RB and caffeine before exercise did not affect RPE. The amount of caffeine used in the Santos research was 5 mg/kg caffeine, 1 hour before exercise and the amount of caffeine used in the Astorino study was 3.1 mg/kg. Likely, the reason for this contradiction was the amount of caffeine being present in beverages, other ingredients, time of ingesting and the type of tests that before and after it, RPE was measured.

Concerning the effect of ED ingestion on blood lactate, the results indicated that the ingestion of ED reduces blood lactate levels after aerobic and anaerobic tests, but the observed changes are not significant. In this line, the results of Arazi et al. (30) showed that the ingestion of Big Bear had no significant effect on the level of blood lactate in adolescent girls. Balshaw et al. (6) showed that the ingestion of 1,000 mg of taurine does not affect blood lactate concentrations of trained endurance athletes during maximal middle-distance running. Also, Rutherford et al. (31) did not see a change in blood lactate levels as a result of taurine ingestion compared to PL. The findings of Jeffries et al. (1) showed that taking caffeine and taurine with proportional doses in common ED increases blood lactate concentrations during sprinting. They stated that the increased blood lactate concentration during the study of caffeine and taurine ingestion indicated an increase in glycolytic response. In contrast, da Silva et al. (48) in a study that investigated the effect of taurine supplement on oxidative stress following eccentric exercises in young men, found that the use of 50 mg/kg body weight of taurine reduced serum LDH activity. Caffeine seems to be able to remove lactic acid faster than muscle cells by increasing adrenaline secretion, increasing blood flow and heart rate (49). In addition, taurine is involved in antioxidant activity and fat oxidation (taurine as mitochondrial matrix buffer for stabilizing the mitochondrial oxidation) (7,8,31). It seems that these mechanisms can affect the level of blood lactate and the dose of caffeine and taurine and their time of use have a potential role in the effects of caffeine and taurine contained in ED. Furthermore, the type of test and protocol used, blood sampling time, the amount of fitness level and type of sport field participant can affect the results.

One limitation of the current study included lack of evaluation of dietary intake and the amount of caffeine consumed in the diet. Another limitation of the present study was that subjects were all female. Future studies are required to examine detail of daily diet and the amount of caffeine consumed. Also, using male or mixed-gender samples is warranted.

Conclusions

In general, the results of this study indicated the positive effect of caffeinated commercially available ED ingestion on the record of swimming speed, aerobic and anaerobic power, and the RPE of the youth female water polo players. It seems that its utilization may have a positive effect on water polo athletes' performance due to the significant impact on their aerobic and anaerobic metabolism. In order to conclude more precisely, there is a need for further research in other gender and age categories.

Author Contributions: HA designed the study. SR carried out the experiment. HA and EE conducted analyses, and wrote the manuscript. SR and EE assisted in acquisition, analysis and interpretation of data. HA and KS reviewed and edited the article. HA and KS made substantial contribution including conception and a critical revision of the article. All authors read and approved the final content of the manuscript.

Funding: This study was made possible by a Grant-in-Aid for MEXT-Supported Program for the Strategic Research Foundation at Private Universities 2015-2019 from the Ministry of Education, Culture, Sports, Science and Technology of Japan (S1511017).

Acknowledgments: The authors hereby declare their gratitude to all athletes who participated as participants in this study.

Conflicts of Interest: The authors state that there is no contradiction in their interests.

References

1. Jeffries O, Hill J, Patterson SD, Waldron M. Energy drink doses of caffeine and taurine have a null or negative effect on sprint performance. J. Strength Cond. Res. 2017; 1.
2. WHO/Europe. Energy drinks cause concern for health of young people. Available at: http://www.euro.who.int/en/health-topics/ disease.
3. Laquale KM. Red Bull: The other energy drink and its effect on performance. Athlet. Ther. Today. 2007; 12: 43-45.
4. Astorino TA, Roberson DW. Efficacy of acute caffeine ingestion for short-term high-intensity exercise performance: a systematic review. J. Strength Cond. Res. 2010; 24: 257-265.
5. Warren GL, Park ND, Maresca RD, McKibans KI, Millard-Stafford ML. Effect of caffeine ingestion on muscular strength and endurance: a meta-analysis. Med. Sci. Sports Exerc. 2010; 42: 1375-1387.

6. Balshaw TG, Bampouras TM, Barry TJ, Sparks SA. The effect of acute taurine ingestion on 3-km running performance in trained middle-distance runners. Amino acids. 2013; 44: 555-561.
7. Hansen SH, Andersen ML, Birkedal H, Cornett C, Wibrand F. The important role of taurine in oxidative metabolism. Adv. Exp. Med. Biol. 2006; 583:129–35.
8. Spriet LL, Whitfield J. Taurine and skeletal muscle function. Curr. Opin. Clin. Nutr Metab. Care. 2015; 18: 96-101.
9. Eckerson JM, Bull AJ, Baechle TR, Fischer CA, O'brien DC, Moore GA, Pulverenti TS. Acute ingestion of sugar-free red bull energy drink has no effect on upper body strength and muscular endurance in resistance trained men. J. Strength Cond. Res. 2013; 27: 2248-2254.
10. Del Coso J, Ramírez JA, Muñoz G, Portillo J, Gonzalez-Millán C, Muñoz V, Muñoz-Guerra J. Caffeine-containing energy drink improves physical performance of elite rugby players during a simulated match. Appl. Physiol. Nutr. Metab. 2012; 38: 368-374.
11. Del Coso J, Portillo J, Muñoz G, Abián-Vicén J, Gonzalez-Millán C, Muñoz-Guerra J. Caffeine-containing energy drink improves sprint performance during an international rugby sevens competition. Amino acids. 2013; 44: 1511-1519.
12. Chtourou H, Trabelsi K, Ammar A, Shephard RJ, Bragazzi NL. Acute Effects of an "Energy Drink" on Short-Term Maximal Performance, Reaction Times, Psychological and Physiological Parameters: Insights from a Randomized Double-Blind, Placebo-Controlled, Counterbalanced Crossover Trial. Nutrients. 2019; 11: 992.
13. Ivy JL, Kammer L, Ding Z, Wang B, Bernard JR, Liao YH, Hwang J. Improved cycling time-trial performance after ingestion of a caffeine energy drink. Int. J. Sport Nutr. Exerc. Met. 2009; 19: 61-78.
14. 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: 1803-1808.
15. Cox GR, Mujika I, Van den Hoogenband CR. Nutritional recommendations for water polo. Int. J. Sport Nutr. Exerc. Met. 2014; 24: 382-391.
16. Tan F, Polglaze T, Dawson B. Activity profiles and physical demands of elite women's water polo match play. J. Sports Sci. 2009; 27: 1095-1104.
17. Rodríguez FA. Physiological Testing of Swimmers and Water Polo Players in Spain. Med. Sport Sci. 1994; 39: 172-177.
18. Brzycki M. Strength testing-Predicting a one-rep max from a reps-to-fatigue. J. Phys. Health Edu. Recreat. 1993; 64: 88-90.
19. Zagatto AM, Beck WR, Gobatto CA. Validity of the Running Anaerobic Sprint Test for assessing anaerobic power and predicting short-distance performances. J. Strength Cond. Res. 2009; 23: 1820–1827.
20. American Alliance for Health, Physical Education and Recreation. Health Related Physical Fitness Test Manual. Washington, DC. 1980.
21. Borg GA. Perceived exertion: a note on" history" and methods. Med. Sci. Sport. Exerc. 1973; 5: 90-3.
22. Ellis PD. The essential guide to effect sizes: Statistical power, meta-analysis, and the interpretation of research results. Cambridge University Press. 2010.
23. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale: Routledge. 1988.
24. Prins PJ, Goss FL, Nagle EF, Beals K, Robertson RJ, Lovalekar MT, Welton GL. Energy Drinks Improve Five-Kilometer Running Performance in Recreational Endurance Runners. J. Strength Cond. Res. 2016; 30: 2979-2990.
25. Burke LM. Caffeine and sports performance. Appl. Physiol. Nutr. Metab. 2008; 33: 1319-1334.
26. Ganio MS, Klau JF, Casa DJ, Armstrong LE, Maresh CM. Effect of caffeine on sport-specific endurance performance: a systematic review. J. Strength Cond. Res. 2009; 23: 315-324.
27. Goldstein ER, Ziegenfuss T, Kalman D, Kreider R, Campbell B, Wilborn C, Wildman R. International society of sports nutrition position stand: caffeine and performance. J. Int. Soc. Sports Nutr. 2010; 7: 5.
28. Waldron M, Patterson SD, Tallent J, Jeffries O. The effects of an oral taurine dose and supplementation period on endurance exercise performance in humans: a meta-analysis. Sports. Med. 2018; 48: 1247-1253.
29. Del Coso J, Muñoz-Fernández VE, Muñoz G, Fernández-Elías VE, Ortega JF, Hamouti N, Muñoz-Guerra J. Effects of a caffeine-containing energy drink on simulated soccer performance. PloS one. 2012; 7: e31380.
30. Arazi H, Najafdari A, Eghbali E. Effect of Big Bear energy drink on performance indicators, blood lactate levels and rating of perceived exertion in elite adolescent female swimmers. Prog. Nutr. 2016; 18: 403-410.
31. Rutherford JA, Spriet LL, Stellingwerff T. The effect of acute taurine ingestion on endurance performance and metabolism in well-trained cyclists. Int. J. Sport Nutr. Exerc. Met. 2010; 20: 322-329.
32. Graham TE. Caffeine and exercise. Sports Med. 2001; 31: 785-807.
33. 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. Met. 2007; 17: 433-444.
34. Dragoo KR, Silvers WM, Johnson KE, Gonzalez EA. Effects of a caffeine-containing transdermal energy patch on aerobic and anaerobic exercise performance. Int. J. Exerc. Sci. 2011; 4: 7.
35. Souza DB, Del Coso J, Casonatto J, Polito MD. Acute effects of caffeine-containing energy drinks on physical performance: a systematic review and meta-analysis. Eur. J. Nutr. 2017; 56: 13-27.
36. Lim ZX, Singh A, Leow ZZX, Arthur PG, Fournier PA. The Effect of Acute Taurine Ingestion on Human Maximal Voluntary Muscle Contraction. Med. Sci. Sports Exerc. 2018; 50: 344–352.

37. Graham TE, Spriet LL. Metabolic, catecholamine, and exercise performance responses to various doses of caffeine. J. Appl. Physiol. 1995; 78: 867-874.
38. Tarnopolsky M, Cupido C. Caffeine potentiates low frequency skeletal muscle force in habitual and nonhabitual caffeine consumers. J. Appl. Physiol. 2000; 89: 1719-1724.
39. Owens DS. Lifestyle Modification: Diet, Exercise, Sports, and Other Issues. In Hypertrophic cardiomyopathy. Springer, Cham. 2019.
40. Woolf K, Bidwell WK, Carlson AG. The effect of caffeine as an ergogenic aid in anaerobic exercise. Int. J. Sport Nutr. Exerc. Met. 2008; 18: 412-429.
41. Arnaud MJ, Welsch C. Theophylline and caffeine metabolism in man. In Theophylline and other Methylxanthines/ Theophyllin und andere Methylxanthine. Vieweg+ Teubner Verlag, Wiesbaden. 1982.
42. Ghandforoush-Sattari M, Mashayekhi S, Krishna CV, Thompson JP, Routledge PA. Pharmacokinetics of oral taurine in healthy volunteers. J. Amino Acids. 2010; 346237: 2010.
43. Davis JK, Green JM. Caffeine and anaerobic performance. Sports. Med. 2009; 39: 813-832.
44. Brunyé TT, Mahoney CR, Lieberman HR, Taylor HA. Caffeine modulates attention network function. Brain. Cognition. 2010; 72: 181-188.
45. Guttierres APM, Alfenas RDC, Gatti K, Lima JRP, Silva ÂA, Natali AJ, Marins JCB. Metabolic effects of a caffeinated sports drink consumed during a soccer match. Motriz: J. Phys. Ed. 2013; 19: 688-695.
46. Doherty M, Smith PM. Effects of caffeine ingestion on rating of perceived exertion during and after exercise: a meta analysis. Scand J. Med. Sci. Sports. 2005; 15: 69-78.
47. Santos V, Santos V, Felippe L, Almeida JrJ, Bertuzzi R, Kiss M, Lima-Silva A. Caffeine reduces reaction time and improves performance in simulated-contest of taekwondo. Nutrients. 2014; 6: 637-649.
48. da Silva LA, Tromm CB, Bom KF, Mariano I Pozzi B, da Rosa GL, Cassiano W. Effects of taurine supplementation following eccentric exercise in young adults. Appl. Physiol. Nutr Metab. 2013; 39: 101-104.
49. Weltman A. The blood lactate response to exercise. Human kinetics. 1995.

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