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A caffeinated energy drink improves jump performance in adolescent basketball players

Javier Abian-Vicen · Carlos Puente · Juan José Salinero · Cristina González-Millán · Francisco Areces · Gloria Muñoz · Jesús Muñoz-Guerra · Juan Del Coso

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Abstract This study aimed at investigating the effects of a commercially available energy drink on shooting precision, jump performance and endurance capacity in young basketball players. Sixteen young basketball players (first division of a junior national league; 14.9 ± 0.8 years; 73.4 ± 12.4 kg; 182.3 ± 6.5 cm) volunteered to participate in the research. They ingested either (a) an energy drink that contained 3 mg of caffeine per kg of body weight or (b) a placebo energy drink with the same appearance and taste. After 60 min for caffeine absorption, they performed free throw shooting and three-point shooting tests. After that, participants performed a maximal countermovement jump (CMJ), a repeated maximal jumps test for 15 s (RJ-15), and the Yo–Yo intermittent recovery test level 1 (Yo–Yo IR1). Urine samples were obtained before and 30 min after testing. In comparison to the placebo, the ingestion of the caffeinated energy drink did not affect precision during the free throws (Caffeine = 70.7 ± 11.8 % vs placebo = 70.3 ± 11.0 %; $P = 0.45$), the three-point shooting test (39.9 ± 11.8 vs 38.1 ± 12.8 %; $P = 0.33$) or the distance covered in the Yo–Yo IR1 (2,000 ± 706 vs 1,925 ± 702 m; $P = 0.19$). However, the energy drink significantly increased jump height during the CMJ (38.3 ± 4.4 vs 37.5 ± 4.4 cm; $P < 0.05$) mean jump height during the RJ-15 (30.2 ± 3.6 vs 28.8 ± 3.4 cm; $P < 0.05$) and the excretion of urinary caffeine (1.2 ± 0.7 vs 0.1 ± 0.1 µg/mL; $P < 0.05$). The intake of a caffeine-containing energy drink (3 mg/kg body weight) increased jump performance although it did not affect basketball shooting precision.

Keywords Ergogenic aids · Caffeine · Basketball · Jump performance · Free throw · Technique

J. Abian-Vicen (✉) · J. J. Salinero · C. González-Millán · F. Areces · J. Del Coso
Exercise Physiology Laboratory, Sport Science Institute, Camilo José Cela University, C/Castillo de Alarcon, 49. Villafranca del Castillo, 28692 Madrid, Spain
e-mail: jabian@ucjc.edu

C. Puente
Exercise Training Laboratory, University of Castilla-La Mancha, Toledo, Spain

G. Muñoz · J. Muñoz-Guerra
Spanish Anti-doping Agency, Doping Control Laboratory, Madrid, Spain

Introduction

Basketball is a team sport characterized by intermittent bouts of high-intensity activity repeated over a prolonged period of time (4 quarters of 10 or 12 min depending on whether it is international or an NBA match). Basketball requires the execution of complex sport-specific skills such as jumping (for rebounds, blocks), shooting, dribbling and sprinting (Klusemann et al. 2012) and these actions mostly rely on anaerobic pathways (Hoffman et al. 1996). Elite young basketball players spend 15–16 % of the total time of a match engaged in high-intensity actions (Abdelkrim et al. 2007) while the remaining time is spent in low-intensity activities (walking and jogging) and stoppages to recover between bouts of activity (Drinkwater et al. 2008). Moreover, the high-intensity movements of young basketball players are closely related to the development of strength, speed and agility (Castagna et al. 2008a). During a basketball game, elite young basketball players perform on average 44 ± 7 jumps and sprint activities represent 8.8 % of live time (Abdelkrim et al. 2007). In addition, a total of 105 ± 52 high-intensity runs with a mean duration of 1.7 s have been reported for elite male basketball players during competition, resulting in one high-intensity run every 21 s of live time (McInnes et al. 1995).

In addition to conditioning components, basketball performance depends on technical skills with the ball, especially precision during shooting (Zuzik 2011). From all the types of shooting during the course of a game, free throw shooting has been extensively studied because precision in this type of throw is key to influencing the outcome of a basketball match (Zuzik 2011). Previously, it has been determined that specific training, the technique of shooting, the player's psychological stability, motivation and environmental conditions are decisive for free throw precision (Button et al. 2003). In addition, progressive dehydration has been found to negatively affect basketball-specific skills that included shooting precision (3-point, free-throw shots) (Baker et al. 2007; Dougherty et al. 2006). However, it is unknown if nutritional supplementation, apart from proper rehydration, could modify shooting precision during basketball specific test.

A recent study has shown that three out of four elite athletes consume caffeine or caffeine-containing products before competition, based on the post-exercise urinary caffeine concentrations obtained for doping analysis (Del Coso et al. 2011). Regarding basketball players, mean urinary excretion after competition was ≈1 μg/mL, indicating that caffeine intake in this sport is moderate. The current popularity of caffeine in sports is associated with the increase in popularity of caffeine-containing energy drinks (Hoffman 2010) and with the removal of this substance from the list of prohibited substances in 2004 [World Anti-doping Web Site (Internet). Montreal (Canada): World Anti-doping Agency]. Several studies have confirmed the ergogenicity of 3–6 mg caffeine/kg bw (body weight) on physical performance in different individual and team sports (Stuart et al. 2005; Del Coso et al. 2012a), but the information about the effects of caffeine ingestion on basketball specific skills is scarce. A recent study has found that 3 mg caffeine/kg bw did not improve VO_{2max} during a maximal running test or height during a 10 vertical jumps test performed by male basketball players (Tucker et al. 2013). However, this study included a limited sample (5 participants) and the performance tests were not completely specific for basketball.

Thus, although the ability to perform repeated jumps and precision during shooting is essential for basketball players, the effects of caffeine ingestion on basketball specific drills have not been previously investigated. The aim of the present investigation was to determine the effectiveness of a commercially available caffeine-containing energy drink (3 mg caffeine/kg bw) for improving specific skills and conditional capacities of basketball players.

Methods

Subjects

Sixteen young male basketball players volunteered to participate in this study. All of them were members of a junior basketball team playing in the first division of the National Spanish League. They had a mean ± SD age of 14.9 ± 0.8 years, body mass of 73.4 ± 12.4 kg, height of 182.3 ± 6.5 cm and body fat of 17.6 ± 3.1 %. All participants had previous basketball experience of at least 6 years and had trained for 12.0 ± 0.4 h/week during the previous year. No participant had a previous history of cardiopulmonary disease or was taking medications during the study. Participants underwent a physical examination prior to enrolling in the study and they were light caffeine consumers (<60 mg/day, ≈1 cup of coffee). Each participant and his parent/guardian were informed of the experimental procedures and associated risks of the investigation and an informed consent was signed by the both of them. The study was approved by a local Research Ethics Committee in accordance with the latest version of the declaration of Helsinki.

Experimental design

A double-blind and placebo-controlled experimental design with repeated measures was used in this study. Each player performed two experimental trials under the same experimental conditions (indoor facility at 22.0 ± 0.8 °C of dry temperature; 28.8 ± 1.0 % of relative humidity). On one occasion, participants ingested a powdered caffeine-containing energy drink (Fure, ProEnergetics, Spain) dissolved in 250 mL of tap water. The amount of energy drink was set to individually provide 3 mg of caffeine per kg of body weight. On the other occasion, participants ingested the same energy drink but with no caffeine content (0 mg caffeine/kg bw, placebo). At the request of the experimenters, the placebo drink was provided by the manufacturer and had the identical appearance and taste of the caffeine-containing energy drink. The energy drink formulae included 18.7 mg taurine/kg bw, 4.7 mg sodium bicarbonate/kg bw, 1.9 mg L-carnitine/kg bw and 6.6 mg maltodextrin/kg bw, but these substances were ingested in identical proportions in the two experimental trials. The trials differed only in the amount of caffeine administered to each player (220.2 ± 37.1 mg in the energy drink trial vs 0 mg in the placebo trial). The beverages were ingested 60 min before the start of the experimental trials to allow complete caffeine absorption and they were provided in opaque plastic bottles to avoid identification. The order of the experimental trials was counterbalanced (8 players consumed caffeine and 8 players consumed placebo prior to each experimental trial) and randomized. The experimental trials were separated by 1 week to allow complete caffeine wash-out. An alphanumeric code was assigned to each trial to blind participants and investigators to the drink tested. This code was unveiled after the analysis of the variables.

Experimental protocol

Two days before the experimental trials, participants were nude-weighed to calculate the energy drink dosage. On this day, their body fat percentage was also calculated using a bio-impedance scale (model BC-418 Tanita Co., Tokyo, Japan). The day before each experimental trial, participants refrained from strenuous exercise and adopted a similar diet and fluid intake regimen. Participants were encouraged to refrain from all dietary sources of caffeine (coffee, cola drinks, chocolate, etc.) and alcohol for 48 h before testing. These standardizations were reported to the technical staff of the basketball team to ensure compliance.

On the day of testing, participants arrived at the basketball court 75 min before the beginning of the trial. On arrival, participants voided in a sterilized container and a representative sample was immediately frozen at −30 °C for future analysis. Then, the beverage assigned for the trial was individually supplied and consumed 60 min before the tests. Investigators paid attention to players during the drinking process to avoid the exchange of bottles between players and to ensure that all of them drank the beverage in its entirety. After that, participants performed a standardized warm-up for 15 min consisting of continuous running and specific drills with the ball (dribbling and shooting). After the warm-up, participants performed five different tests on the basketball court (see test specifications below): During and after the testing, the participants had free access to tap water. Thirty-to-sixty minutes after the last test was performed, participants voided again and a urine sample was obtained. After that, participants were required to fill out a questionnaire about their sensations of muscle power, endurance and perceived exertion (RPE) during the whole testing day. This questionnaire included a 1- to 10-point scale to assess each item, and participants were previously informed that 1 point meant minimal amount of that item and 10 points meant maximal amount of the item. Then, participants were provided with a survey to be filled out the following morning about sleep quality, nervousness, gastrointestinal problems and other discomforts. This survey included eight items on a yes/no scale and has been previously used to assess side effects derived from energy drink ingestion (Del Coso et al. 2012b).

Free throw test (FT)

For this test, we followed the standards established by the International Basketball Federation (FIBA). The player took his place behind the free throw line (5.8 m from the base line and 4.6 m from the basket) and performed 12 series of two-free throws to replicate the shooting performed after a fault during a real game situation. Participants rested for 30 s between series and players had an adequate amount of time to concentrate on shooting. The number of shots scored (total and by series) was registered by an investigator blinded to the treatment. The between-days reproducibility of this test was previously obtained in 22 young male basketball players (similar skill level to the participants in this investigation) tested on two different days of the same week. The coefficient of variation was 7 % and the intraclass correlation coefficient was 0.85.

Three-point shot test (3PS)

This test was an adapted version of the one devised by Dougherty et al. (Dougherty et al. 2006). Participants performed three attempts at three-point shots from seven different places around the three-point line (6.25 m from the base line), for a total of 21 shots. Players had to move from one position to the other and the total number of shots had to be performed in 1 min or less. The players picked the ball up from a cart to perform the test in a continuous mode. The number of three-point shots scored in the test was registered by an investigator blinded to the treatment. As in the previous test, the between-days reproducibility was previously obtained in 22 young male basketball players tested on two different days of the same week. The coefficient of variation was 12.3 % and the intraclass correlation coefficient was 0.74.

Counter movement jump test (CMJ)

Participants performed two maximal countermovement jumps on a force platform (Quattrojump, Kistler, Switzerland; sampling rate of 500 Hz) to assess jump height and leg muscle power production. For this measurement, participants began stationary in an upright position with their weight evenly distributed over both feet. Each participant placed his hands on his waist in order to remove the influence of the arms on the jump. On command, the participant flexed his knees and jumped as high as possible while maintaining his hands on the waist and landed with both feet. After 1 min rest, the countermovement jump was repeated. The jump height (from flight time), the mean power production during the concentric phase of the jump and the peak power output of the jump were obtained from ground reaction forces. A previous investigation has found that the between-days reliability of all the variables obtained during a CMJ was high and the coefficient of variation <2 % (Cormack et al. 2008).

Fifteen-second maximal jumping test (RJ-15)

Maximal vertical jumping height was determined during a 15-s rebound jump series using the force platform previously described. For this test, participants began stationary in an upright position with their weight evenly distributed over both feet. Each subject placed his hands on his waist to remove the influence of the arms on the jump. On command, the participants flexed their knees and jumped as high as possible while maintaining their hands on their waist, repeating this jumping action for 15 s. Verbal feedback was given to encourage players to produce maximal performance in each repetition. The height and the mean power production during the concentric phase of each jump were obtained. Total leg muscle power production during the test was calculated from the power output obtained in each jump and the number of jumps. Between-days reliability for the variables obtained during repeated CMJ has been satisfactory in a previous study (Cormack et al. 2008).

The Yo-yo intermittent recovery test, level 1 (Yo–Yo IR1)

This test was carried out according to previously described methods (Castagna et al. 2008b; Krustrup et al. 2003). The test consisted of 20-m shuttle runs performed at increasing velocities with 10 s of active recovery between runs until exhaustion. The end of the test was considered when the participant twice failed to reach the front line in time (objective evaluation) or when he felt unable to complete another shuttle run at the dictated speed (subjective evaluation). The total distance covered during the Yo–Yo IR1 was recorded. The test was always performed on the same basketball court where players usually trained. The coefficient of variation for this test has been previously established in 4.9 % (Krustrup et al. 2003).

Urine analysis

The urine specimens obtained before and after each experimental trial were analyzed for caffeine, paraxanthine, theobromine and theophylline concentrations using an Agilent Technologies HPLC 1200 system (Santa Clara, CA, US) coupled to a triple quadrupole/ion trap mass spectrometer (MS, API 400, US). All the reagents used for these measurements were purchased from Cambridge Isotope Laboratories (Spain). For this measurement, 20 µL of the internal standard theophylline-D_6 (2 µg/mL) and 20 µL of the internal standard $^{13}C_3$ –caffeine (5 µg/mL) were added to 100 µL of urine. A volume of 900 µL of mobile phase (acetic acid 0.1 %) was added to the urine sample and 5 µL of this sample wAS then directly applied to the HPLC–MS system. To calibrate the system, aqueous solutions of caffeine, paraxanthine and theobromine (ranging from 0.1 to 7 µg/mL) and theophylline (from 0.04 to 1 µg/mL) were used before each batch of samples. The correlation coefficients for the calibration of caffeine and its main metabolites were always >0.99. The lower limit for the accurate quantization of these methylxanthines was 0.25 and 0.1 µg/mL for theophylline.

Statistical analysis

The following software programs were used: Microsoft Excel spreadsheet (Microsoft, Spain) to store the results and the SPSS v. 17.0 program (SPSS Inc., USA) to perform the statistical calculations using descriptive and inferential statistical tests and to calculate means, standard deviations and ranges. Initially, normality was tested in all variables with the Shapiro–Wilk test. After that, Student's t test for dependent samples was used to establish the differences in the variables normally distributed between the caffeine-containing energy drink trial and the placebo trial. For the non-parametric variables, differences between the energy drink trial and the placebo trial were established with the Wilcoxon signed-rank test. Jump height and leg muscle power output during the 15-s jump test were analyzed using a two-way ANOVA (beverage × repetition) with repeated measures. The criterion for statistical significance was set at $P < 0.05$. All the data are presented as mean ± standard deviation.

Results

Shooting tests

In comparison to the placebo, the ingestion of the caffeine-containing energy drink did not increase the total number of free throws scored ($P = 0.45$). In addition, the energy drink did not affect the precision of the first 12 throws ($P = 0.31$) or the last 12 throws ($P = 0.15$; Table 1). Similarly, the ingestion of the energy drink did not increase precision during the three-point shooting test ($P = 0.33$), either in the first 10 throws ($P = 0.39$) or in the last 11 throws ($P = 0.20$; Table 1).

CMJ test

In comparison to the placebo drink, the intake of the caffeine-containing energy drink increased CMJ height from

37.5 ± 4.4 to 38.3 ± 4.4 cm ($P < 0.05$). There were no significant differences between the caffeine-containing energy drink and the placebo drink in mean power production during the concentric phase of the jump (caffeine = 30.4 ± 2.8 W/kg vs placebo = 30.1 ± 3.5 W/kg; $P = 0.32$) or peak power output (caffeine = 53.9 ± 5.0 W/kg vs placebo = 53.8 ± 5.5 W/kg; $P = 0.45$).

RJ-15

During the 15-s jump series, the basketball players reached a higher mean jump height with the intake of the energy drink than with the placebo (caffeine = 30.2 ± 3.6 cm vs placebo = 28.8 ± 3.4 cm; $P < 0.05$). This difference was also significant when comparing the first four jumps ($P < 0.05$; Fig. 1). After the ingestion of the energy drink, the basketball players produced higher mean leg muscle power output (caffeine = 51.4 ± 5.7 W/kg vs placebo = 49.4 ± 4.6 W/kg; $P < 0.05$) and thus higher total leg muscle power production during the entire test (caffeine = 52.3 ± 13.5 kW vs placebo = 48.6 ± 9.5 kW; $P < 0.05$).

Table 1 Percentages of free throws (FT) and three-point shots (3PS) scored with the ingestion of a caffeine-containing energy drink or a placebo drink

	Placebo	Energy drink	*P*
FT, %	70.7 ± 11.8	70.3 ± 11.0	0.451
FT, % (first 12 shots)	62.5 ± 14.6	65.6 ± 18.5	0.314
FT, % (last 12 shots)	78.1 ± 14.8†	76.0 ± 17.5†	0.153
3PS, %	39.9 ± 11.8	38.1 ± 12.8	0.334
3PS, % (first 10 shots)	38.7 ± 18.2	36.9 ± 21.8	0.390
3PS, % (last 11 shots)	41.2 ± 16.2	36.9 ± 14.5	0.201

Data are mean ± SD for 16 young basketball players

† Different from preceding 12 shots ($P < 0.05$)

Yo–Yo IR-1 test

There were no significant differences in the distance covered during the Yo–Yo IR-1 test between the trial with the caffeine-containing energy drink and the placebo trial (caffeine = 2,000 ± 706 m vs placebo = 1,925 ± 702 m; $P = 0.19$).

Urine caffeine excretion and urinary variables

Pre-exercise urine samples presented low caffeine and paraxanthine concentrations and they were similar in both experimental trials (Table 1). After the caffeine-containing energy drink trial, the urine caffeine and paraxanthine concentrations significantly increased in comparison with the pre-test values (Table 2; $P < 0.05$). In contrast, urinary caffeine and paraxanthine concentrations remained unchanged or were slightly reduced after the placebo trial. Urinary theobromine concentration decreased after both experimental trials (non-significant after the energy drink trial) and theophylline remained unchanged during the testing.

Perceptual evaluation and frequency of the side-effects

In comparison to the placebo drink, the pre-exercise ingestion of the caffeine-containing energy drink increased the perception of muscle power (caffeine = 7.1 ± 1.1 vs placebo = 5.2 ± 1.2; $P < 0.05$) and endurance (caffeine = 6.6 ± 1.4 vs placebo = 5.1 ± 1.1; $P < 0.05$) while it decreased the rate of PRE (caffeine = 4.6 ± 1.8 vs placebo = 5.7 ± 2.3; $P < 0.05$) during the whole testing day. During the following hours to the test, the energy

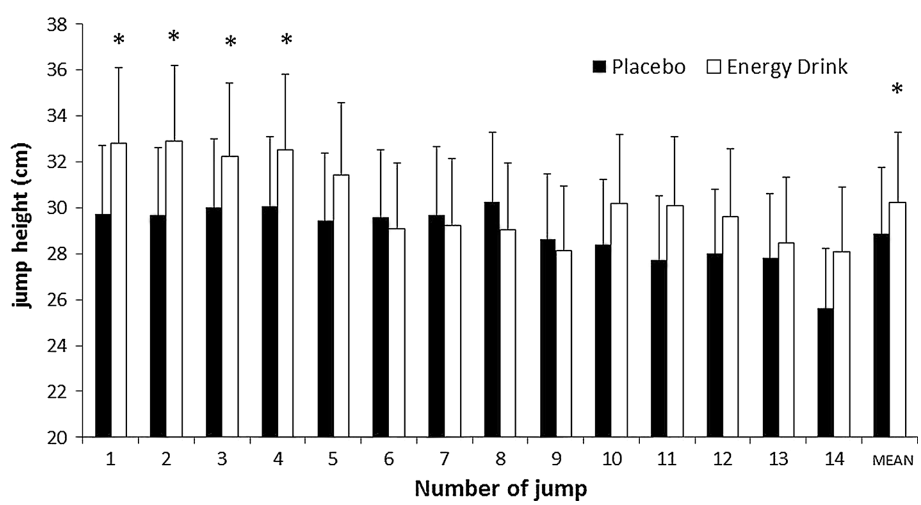

Fig. 1 Jump height for each jump and the mean of all jumps during a 15-s maximal jump series. (*$P < 0.05$ compared to placebo)

Table 2 Urine variables before and after physical testing with the ingestion of a caffeine-containing energy drink or a placebo drink

	Placebo	Energy drink
Caffeine (μg/mL)		
Pre	0.1 ± 0.1	0.1 ± 0.1
Post	0.1 ± 0.1	1.2 ± 0.7 *†
Paraxanthine (μg/mL)		
Pre	0.9 ± 1.0	0.5 ± 0.4
Post	0.4 ± 0.5†	1.7 ± 1.1 *†
Theobromine (μg/mL)		
Pre	4.5 ± 4.2	7.5 ± 9.1
Post	2.4 ± 2.3†	3.5 ± 4.3
Theophylline (μg/mL)		
Pre	0.3 ± 0.6	0.2 ± 0.3
Post	0.2 ± 0.3	0.4 ± 0.7

Data are mean ± SD for 16 young basketball players

* Different from placebo ($P < 0.05$)

† Different from Pre ($P < 0.05$)

Table 3 Prevalence of side-effects during the hours following the ingestion of a caffeine-containing energy drink or a placebo drink

	Placebo (%)	Energy drink (%)
Headache	12.5	6.3
Abdominal/gut discomfort	6.3	12.5
Muscle soreness	25	31.3
Increased vigor/activeness	0	37.5 *
Tachycardia and heart palpitations	0	0
Insomnia	0	12.5
Increased urine production	0	0
Increased anxiety	0	0

Data are percentages for 16 young basketball players

(*) Different from placebo ($P < 0.05$)

drink also increased the perceived vigor/activeness ($P < 0.05$) while the remaining side-effects were not affected (Table 3).

Discussion

The main purpose of this study was to determine the effectiveness of a commercially available energy drink (3 mg of caffeine per kg of body weight) on jump performance, endurance and shot precision in highly skilled young basketball players. For this purpose, 16 young players from a top level basketball team volunteered to ingest a caffeine-containing drink or a placebo drink before testing specific conditional capacities for basketball. In comparison to the placebo drink, when the players drank the caffeinated beverage they increased their jump height in a CMJ test (from 37.5 ± 4.4 to 38.3 ± 4.4 cm; $P < 0.05$) although leg muscle power output remain unchanged. During a 15-s jump test, mean jump height (from 28.8 ± 3.4 to 30.2 ± 3.6 cm; $P < 0.05$) and total leg muscle power output (from 48.6 ± 9.5 to 52.3 ± 13.5 kW; $P < 0.05$) were significantly increased with the energy drink. In contrast, the ingestion of the energy drink did not modify the distance covered by the players in the Yo–Yo IR1 or shooting precision during specific free throw and three-point shot tests. As a result, the pre-exercise ingestion of 3 mg of caffeine/kg bw in the form of an energy drink significantly improved jump performance but it did not have any influence on the precision of the basketball shots.

One of the novelties of the present investigation was the analysis of the influence of caffeine intake on the effectiveness of shooting precision. While there are numerous studies that examined the influence of caffeine on physical capacities relevant for team sports performance (Stuart et al. 2005; Duncan et al. 2009; Del Coso et al. 2012a), no study has analyzed the influence of this substance on shooting precision even though this ability can be a key factor for football, handball or basketball players' success. Share et al. (2009) investigated the influence of 2 and 4 mg of caffeine/kg bw on elite male shooters from the double-trap discipline of shooting. They found that pre-testing caffeine ingestion did not provide any performance benefits during clay target shooting. Gant et al. found that the coingestion of caffeine (3.7 mg caffeine/kg bw) and carbohydrates did not influence the precision of soccer passing skills performed during a team sport specific test (Gant et al. 2010) although 6 mg of caffeine per kg bw tended to increase passing accuracy (Foskett et al. 2009). In contrast, other authors have suggested that caffeine may negatively affect motor skill performance due to increased nervousness, arm and hand tremors and incoordination, especially in subjects that are not accustomed to this substance (Jacobson and Edgley 1987; Franks et al. 1975). In the present investigation, the ingestion of an energy drink with 3 mg/kg of caffeine had no influence on shooting precision during free throws (performed in a static position) or during three-point throws (performed dynamically; Table 1). These results suggest that 3 mg of caffeine per kg bw did not have any positive or negative effect on shooting precision during specific basketball shooting.

The percentages of free throws scored in our study (~70 %) were higher than those found by Zuzik (2011) when testing the best junior basketball teams in Slovakia (56.9 % of free throws scored). These differences may be due to the fact that our free throws test was performed in a field situation while Zuzik obtained shooting precision data during real competitions, with the psychological burden that this entails. Interestingly, the percentage of shots scored in the last 12 free throws was higher compared to the first 12 shots and this difference was maintained in both the energy drink and the placebo trials ($P < 0.05$). Although participants were previously familiarized with the test, it is likely that players progressively adjusted their shooting technique and gained confidence. Thus, it can be concluded that the energy drink ingestion had no influence on the technique or on the progressive concentration of the players when they performed free throws.

Jumping is a very characteristic exercise action in basketball since players continuously jump during shooting, rebounds or defensive tasks. In many cases, the height reached during jumping actions influences the achievement of a defensive or offensive rebound or the success of a basketball shot (Dougherty et al. 2006). The effects of caffeine ingestion on lower body strength and power production are unclear. Beck et al. (2006) found no significant difference with the consumption of 201 mg of caffeine, as was found by Astorino et al. (2012) and Green et al. (2007) with the consumption of 6 mg caffeine/kg bw and Duncan et al. (Duncan et al. 2009) with an ingestion of 3 mg caffeine/kg bw, all of them during a test that included leg press repetitions to failure with 60 % of 1 RM. On the other hand, Hudson et al. (2008) found that 6 mg of caffeine/kg bw resulted in significantly greater total repetitions for leg extensions at 100 % of individual, predetermined, 12-repetition maximum for leg extensions. Del Coso et al. (2012a) found that a caffeinated energy drink with 3 mg caffeine/kg bw increased the mean jump height and the muscle power generated during a 15-s jump test in semi-professional soccer players and international rugby sevens players (Del Coso et al. 2013a).

The effects of caffeine on leg muscle performance may be related to the dose administered. Del Coso et al. (2008) investigated the effects of two doses of caffeine (1 and 3 mg caffeine/kg bw) in the form of an energy drink on the squat and bench press exercise. They found that 1 mg caffeine/kg bw did not affect muscle performance during the exercises, but 3 mg caffeine/kg bw increased maximal power in the half-squat and bench-press actions. In the present study, the ingestion of the caffeine-containing energy drink (3 mg caffeine/kg bw) significantly increased jumping height by 2.1 ± 4.6 % in the CMJ ($P < 0.05$) and by 4.9 ± 7.4 % in the RJ-15 test ($P < 0.05$). Although there were no significant differences in the leg muscle power produced during the CMJ, the total power generated during the 15-s jump test was higher with the energy drink than with the control drink ($P < 0.05$). In order to catalogue the improvements in the jump capacity derived from the energy drink intake (2.1–4.9 % in single and repeated jumps) as a meaningful aid for basketball performance it is necessary to these effects during either real or simulated basketball games. However, these data confirm that the ingestion of 3 mg of caffeine/kg of body weight in form of an energy drink increased physical performance.

The Yo–Yo IR1 has been previously used to assess the aerobic capacity of team sports players. Professional soccer players at the beginning of the competitive season covered 1,760 ± 59 m (Krustrup et al. 2003) while they can perform more than 2,000 m during the competitive season (Castagna et al. 2006; Krustrup et al. 2003). In contrast, the distance covered in this test is much lower for female top-level (840–1,049 m) and recreational (1,010–1,048 m) team sport athletes (Thomas et al. 2006). Several previous studies have used the Yo–Yo IR1 to measure the endurance capacity of basketball players (Castagna et al. 2008a, b; Krustrup et al. 2003). Young basketball players covered between 1,200 and 1,700 m during this test (Castagna et al. 2008b; Vernillo et al. 2012), a distance very similar to the one covered in the present investigation with the placebo (1,925 ± 702 m). In addition, basketball players increased the running distance in the Yo–Yo IR1 by 3.7 % after the ingestion of the caffeine-containing energy drink, although this increase was not statistically significant ($P = 0.19$). The ingestion of 3–6 mg of caffeine per kg of body weight has been repeatedly shown as ergogenic in several endurance activities (MacIntosh and Wright 1995; Wiles et al. 1992) and has also increased running distance during a similar Yo–Yo test (Mohr et al. 2011). There is a need for more information to elucidate if caffeine-containing energy drinks increase the endurance capacity of basketball players.

The Medical Commission of the International Olympic Committee included caffeine in the prohibited substances list in 1984 to minimize the use of high caffeine doses in sports. It was considered doping when an athlete presented a post-competition urine caffeine concentration of over 12 µg/mL. On January 1 2004, the World Anti-doping Agency decided to remove this substance from the prohibited list, due to the generalized use of caffeine in sports. The most modern version of the World Anti-Doping Code [World Anti-doping Web Site (Internet) Montreal (Canada): World Anti-doping Agency] indicates that a substance shall be prohibited before or during sports competition when it meets any two of the following three criteria: (1) it has the potential to enhance sport performance; (2) it represents an actual or potential health risk to the athlete; (3) it violates the spirit of sport.

The design of this study was set to determine whether basketball players met the first and second criteria, since the confirmation of the third condition is difficult to prove scientifically. From the results of this study, we can conclude that caffeine increased jumping performance in basketball players, but it did not affect shooting precision, as has been discussed previously. To determine whether caffeine represents a risk to the athlete, we assessed side effects derived from the energy drink ingestion and we compared them with the placebo (Table 3). The pre-exercise ingestion of the energy drink increased the feeling of power and endurance during the testing and reduced the PRE. In addition, the energy drink increased vigor/activeness (Table 3) and tended to increase the frequency of gut/abdominal discomfort after the game, as has been previously found in active (Del Coso et al. 2012b) and rugby players (Del Coso et al. 2013a). This information reveals that the intake of 3 mg/kg of caffeine in the form of energy drinks increased the perceived performance during basketball-specific tests and it had minor side-effects during the following hours to the competition. Thus, we conclude that, in the basketball setting, caffeine meets only one of these two criteria. To determine whether the physical advantage obtained with caffeine represents a violation of the spirit of sport corresponds to anti-doping authorities.

In the present investigation, the post-exercise urinary caffeine concentration was 1.2 ± 0.7 µg/mL after the ingestion of the caffeine-containing energy drink. This value is close to the ones found in a male soccer players (Del Coso et al. 2012a) and male rugby players (Del Coso et al. 2013b) after the ingestion of a similar amount of energy drink. All these studies found ergogenic properties during team sports simulated performance after the ingestion of 3 mg caffeine/kg bw while the urinary caffeine concentration was much lower than 12 µg/mL. It seems that the previous urinary threshold for caffeine doping was not sensitive enough to restrain the use of caffeine as a doping substance.

In summary, the ingestion of 3 mg of caffeine per kg of body weight by using a commercially available energy drink increased the height obtained during single or repeated jumping tests in young basketball players although it had no effects on the precision of free throws, three-point shots or the Yo–Yo IR1 test. The energy drink intake produced marginal side-effects during the following hours to the testing which suggests that these beverages did not represent a potential health risk to the young basketball players, at least with the dosage used in this investigation.

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Conflict of interest All the authors declare that they have no conflict of interest derived from the outcomes of this study.

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