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Effects of Caffeine Ingestion on Physical Performance in Elite Women Handball Players: A Randomized, Controlled Study

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Purpose: To investigate the effects of acute caffeine (CAFF) intake on physical performance in elite women handball players. ***Methods:*** A total of 15 elite women handball players participated in a randomized, double-blind study. In 2 different trials, participants ingested either a placebo (cellulose) or 3 mg of CAFF per kilogram of body mass (mg/kg/bm) before undergoing a battery of neuromuscular tests consisting of handball throws, an isometric handgrip strength test, a countermovement jump, a 30-m sprint test (SV), and a modified version of the agility *T* test. Then, participants performed a simulated handball game (2 × 20 min), and movement patterns were recorded with a local positioning system. ***Results:*** Compared with the placebo, CAFF increased ball velocity in all ball throws (P = .021–.044; Effect size [ES] = 0.39–0.49), strength in isometric handgrip strength test (350.8 [41.2] vs 361.6 [46.1] N, P = .034; ES = 0.35), and countermovement jump height (28.5 [5.5] vs 29.8 [5.5] cm; P = .006; ES = 0.22). Besides, CAFF decreased running time in the SV (4.9 [0.2] vs 4.8 [0.3] s; P = .042; ES = –0.34). In the simulated game, CAFF increased the frequency of accelerations (18.1 [1.2] vs 18.8 [1.0] number/min; P = .044; ES = 0.54), decelerations (18.0 [1.2] vs 18.7 [1.0] number/min; P = .032; ES = 0.56), and body impacts (20 [8] vs 22 [10] impacts/min; P = .032; ES = 0.30). However, postexercise surveys about self-reported feelings of performance indicate that players did not feel increased performance with CAFF. ***Conclusion:*** Preexercise ingestion of 3 mg/kg/bm of CAFF improved ball throwing velocity, jump, and sprint performance and the frequency of in-game accelerations and decelerations in women elite handball players.

Q1 ***Keyword:*** nutrition

Handball is an intermittent team sport, which is characterized by high-intensity actions, such as accelerations and decelerations, fast changes of direction, running sprints, and collisions with opponents.[1,2] At the elite level, women handball players cover ~4000 m during a match while high-intensity running constitutes ~2.5% of the total distance covered (ie, ~100 m).[3] Women handball players spend a considerable amount of energy in actions involving accelerations and decelerations as these actions are always performed in offensive and defensive in-game situations close to the goal zone.[1–3] Although handball has similarities with other team sports, such as basketball, football, and hockey, the unlimited number of substitutions allow players to occupy specific roles for attacking and defending. Interestingly, the time spent at high-intensity running and the frequency of demanding actions are typically reduced from the first to the second half, which indicates that physical performance in elite handball might be impaired toward the end of the game.[4] All this information indicates that high-intensity actions are critical for overall handball success, and because of this, the strategies to improve elite handball players' physical performance have attracted handball strength and conditioning coaches' and researchers' attention.[5,6]

Given the explosive demands that characterize handball competition, identification of nutritional aids that might contribute to the improvement of physical performance during training or matches could be an interesting strategy to be adopted by elite handball players.[7] However, despite the popularity of handball, the information about nutritional strategies to increase handball performance is scarce, in particular caffeine (CAFF). In fact, only one investigation has determined the effects of acute CAFF intake on handball performance[7] despite the fact that the postmatch urinary concentrations of elite handball players suggest a common use of this substance in competition.[8]

Caffeine (1,3,7-trimethylxanthine) is a substance rapidly absorbed by the body because it appears in the blood within 5 to 15 min, reaching peak blood concentration between 45 and 60 min after ingestion.[9] Although several mechanisms have been proposed for the increased physical performance after acute CAFF intake, there is a consensus about the antagonism of CAFF on the adenosine receptors (ie, blocking the "fatiguing" action of adenosine) as the main mechanism behind the performance-enhancing effect of this substance.[10,11] The preexercise ingestion of 3 to 9 mg of CAFF per kilogram of body mass (mg/kg/bm) has the capacity to improve performance in a wide variety of team sports,[12] and there is evidence of the ergogenicity of CAFF in basketball,[13] rugby,[14] volleyball,[15] and football[16,17] matches. Previous investigations have found that in addition to the effects of CAFF on physical performance, it was also effective to enhance the execution of team sport-specific actions such as shooting[13] and passing accuracy[18] that might end in a higher overall players' performance index.[13,15]

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As a result, CAFF has been catalogued as an ergogenic aid for ball games although the risk-benefit ratio of CAFF ingestion should be contrasted in the light of the characteristics of each sport[19,20] and accounting for the side effects it produces.[21] Particularly, CAFF intake has been associated to an increased prevalence of nervousness and insomnia after exercise,[21] which might affect those disciplines with matches played on consecutive days.

Ribeiro et al[7] studied the effects of CAFF ingestion (6 mg/kg/bm) in 6 handball players who performed 4 × 30 s of continuous vertical jumps. These authors found that CAFF improved leg power during jumping by ~5% with no higher levels of exercise-induced muscle damage. However, the unspecific nature of this jumping test for overall handball performance and the low sample size used in this investigation preclude ascertaining whether CAFF is ergogenic for the particular characteristics of handball. Thus, the aim of this study was to determine if the ingestion of CAFF (3 mg/kg/bm) could improve physical performance in elite women handball players.

Methods

Participants

A total of 15 elite women handball players (age 22.6 [3.6] y, height 1.70 [0.08] m, body mass 69.5 [9.5] kg, handball experience 11.0 [2.7] y) from the same handball team (ie, first division of the Spanish National League) participated in this study. All participants were considered as low-CAFF consumers (50 [30] mg/d). Elite women handball players between 18 and 40 y old were eligible for inclusion. Exclusion criteria were intolerance to CAFF, suffering from any chronic pathology or an injury in the month prior to the investigation, a habitual consume of CAFF >100 mg/d, and the use of medicines or dietary supplements during the study. All the recruited participants were low-CAFF consumers, <100 mg/d of CAFF, measured with a valid semiquantitative CAFF intake questionnaire.[22] Ten participants were tested during the follicular phase of their menstrual cycle, and 5 were tested during the luteal phase according to a mobile application Q3 (Mycalendar®; Period Tracker) that identifies main events occurring during the menstruation cycle.[23] Participants gave their informed written consent to participate, and the study was approved by the Q4 University Ethics Committee (number 22/2019) in accordance with the Declaration of Helsinki.

Experimental Design

A randomized, double-blind, placebo-controlled crossover experiment was used. Each player underwent 2 identical experimental trials, separated by a week to allow recovery and substances washout. In each trial, participants ingested an unidentifiable gelatine capsule with either CAFF (3 mg/kg/bm; Bulk Powders Q5 100% purity, United Kingdom) or an inert substance (Cellulose; Q6 Guinama, Spain). The dose of CAFF was selected to replicate the treatment used in previous investigations with team-sport women athletes.[14,15,17] Capsule was ingested with 100 mL of water and 60 min before the onset of the experiment to allow substances absorption. Then, participants performed a set of physical assessments, as explained later, to determine the effects of CAFF on several aspects of handball physical performance. In both trials, the experimental procedures were performed at the same time of day to avoid the influence of circadian rhythms on performance.[24] Air temperature and humidity were monitored during both trials with a portable weather station (Meteorological Station, Küken, Spain).

Experimental Protocol

During the 24 h prior to testing, participants were encouraged to refrain from all dietary sources of CAFF and strenuous exercise. They were instructed to consume the same meals the day before each trial. On trial days, participants arrived at their habitual training facility—indoor court—at 18:00 h. Then, body composition (Tanita B-601; Tanita Corp, Tokyo, Japan) and tympanic temperature (Thermoscan 7-IRT 6520; Braun, Germany) were Q7 measured to assure similar conditions before each trial. After this, the assigned experimental capsule was ingested, and ingestion was verified by an experimenter. Participants performed a 20-min standardized warm-up, and just 60 min after capsule ingestion, they underwent a battery of physical performance tests consisting of several types of ball throws (BT; from 7 m to 9 m with and without opposition), a countermovement jump (CMJ), an isometric handgrip strength test (IHS), a modified version of the agility *T* test (MATT), and a 30-m maximal running velocity test (SV). A 5-min resting period was set among test to allow Q8 recovery. One week before the onset of the experiment, a familiarization session that included the execution of all these tests was carried out. Ten minutes after this handball-specific testing, participants played a 2 × 20-min simulated handball match.

Handball-Specific BT

Players performed 2 types of BT, always at maximal velocity one from the penalty line (7 m) and the other one from behind 9-m line. For the 7-m throw, the test followed the rules for the penalty throw in handball. For the 9-m throw, a 3-step run and a vertical jump behind the 9-m line preceded the throw to simulate an in-game throw.[2,25] Each BT was executed with and without the presence of a goalkeeper (GK). The tests were carried out in the following order: 7 m, 7 m with GK, 9 m, and 9 m with GK. A 60-s rest was set between BT. A sports radar gun (Pocket Radar Ball Coach PR1000-BC, Republic of South Korea), held by an experimenter Q9 placed 2 m behind the players, was used to record maximal ball velocity. The mean value of the 3 attempts was annotated as previously reported in other intermittent sports.[25]

IHS and CMJ

Maximal IHS was measured in the dominant hand using a calibrated handgrip dynamometer (Takei 5101, Tokyo, Japan) as Q10 previously reported.[26] The highest value out of 2 attempts was recorded and used for statistical analysis. Afterward, participants completed 2 repetitions of a maximal CMJ test with hands on the hips while jump height was measured using an infrared-beams jump system (Optojump Next, Microgate, Italy). The 2 CMJ Q11 attempts were interspersed with 45 s of passive recovery as previously described.[27] The highest jump was used for statistical analysis. Good reliability of IHS (CV = 4.1%) and CMJ Q12 (CV = 3.2%) has been previously reported.[27]

SV and MATT

In the SV test, participants ran at maximal speed for 30 m in a straight line, and the time needed to cover the distance was measured using 2 photocell gates placed 1 m above the ground Q13 (SMARTSPEED; Fusion Sport, Australia). This test was selected Q14 based on a previous investigation with elite female handballers[2] and because it might represent the distance covered during a fast break.[28] Each sprint was initiated from a standing position, 1 m behind the photocell gate. The digital timer was automatically initiated when the player crossed the first gate, and it was stopped when the players crossed the gate placed 30 m ahead at the finish line. The best performance out of 2 repetitions was recorded for subsequent analysis, and a 2-min resting period was allowed between repetitions. Afterward, the MATT was conducted using the protocol outlined by Sassi et al.[29] Two electronic time sensors (SMARTSPEED; Fusion Sport) were set 1 m above the ground and positioned 3 m apart facing each other on either side of the start or finish line. The best performance out of 2 repetitions (separated by a 2-min recovery period) was recorded for subsequent analysis. Good reliability of SV (CV = 2.6%) and MATT (CV = 1.2%) has been previously reported.[27]

Simulated Handball Match

Ten minutes after the end of the handball-specific testing, players participated in a simulated game played on an official indoor handball court and following the rules of the International Handball Federation (except for the game duration). The game consisted of 2 parts of 20 min with a break of 5 min between them. All players were equipped with an inertial measurement unit based on ultra-wideband position tracking system technology (WIMU-PROTM; RealTrack Systems, Almería, Spain; CV = 2.5%–3.5%),[30] which was introduced on a lycra vest to place the inertial measurement unit between the shoulders. A heart rate monitor (Garmin™ Heart Rate Band) was then firmly attached to their chest. The inertial measurement unit devices were calibrated and installed around the court as previously described[31] and obtained data with a frequency of 100 Hz. During these games, player's substitutions were standardized, and all variables were normalized by each participant's playing time. The distance covered was in total and categorized afterward in 5 speed zones stationary/walking (<6.0 km/h), jogging (6.0–12.0 km/h), running (12.1–18.0 km/h), high-intensity running (18.1–24.0 km/h), and sprinting (>24.1 km/h). In addition, the number of accelerations (total and zone 1 [0–1 m/s^2], zone 2 [1–2 m/s^2], zone 3 [2–3 m/s^2], and zone 4 [3–4 m/s^2]) and the total number of decelerations were recorded (total zone 1 [0 to 1 m/s^2], zone 2 [−1 to 2 m/s^2], zone 3 [−2 to 3 m/s^2], and zone 4 [−3 to 4 m/s^2]). Impact intensity was graded according to the following scale: zone 1 from 0 to ≤5 g, zone 2 from 5 to ≤8 g, and zone 3 from 8 to ≤10 g.

Q15 Q16 Q17

Questionnaire

At the end of the simulated match, players were required to fill out a questionnaire about their feelings of muscle power, endurance, and overall perceived exertion during the game, as previously reported.[21] In addition, the morning following the study the participants filled out another questionnaire based on the main side effects associated with CAFF during the hours after the game.[21]

Environmental Conditions and Tympanic Temperature

During the testing sessions, air temperature (14.2°C [2.8°C]) and relative humidity (40% [2%]) were similar on both days. No differences were reported in tympanic temperature (36.7°C [0.3°C] vs 36.9°C [0.3°C]; $P = .100$) between the different days.

Statistical Analysis

Q18

Data are presented as mean (SD). Normality of each variable was tested using the Shapiro–Wilk test. Differences between experimental conditions (CAFF vs placebo) were determined using paired *t* tests, and differences were considered as statistically relevant at $P < .05$. Effect size (ES) and 95% confidence interval (CI) were also calculated in all pairwise comparisons, whereas ES was interpreted using Cohen categorization.[32] Differences between experimental conditions in the 1- to 10-point scale used for the self-reported feelings of muscle power, endurance, and overall perceived exertion during the game were identified using the Wilcoxon signed-rank test. The McNemar test was also used to detect differences in the prevalence of side effects. Data analysis was performed using SPSS (version 22.0; SPSS Inc, Chicago, IL).

Results

Handball-Specific BT

In comparison with the placebo, ball velocity was higher with CAFF in all the BT tests in a range of improvement of 2.2% to 3.6%. Specifically, CAFF increased ball velocity in the 7-m throw ($P = .021$; ES = 0.39; 95% CI, 0.07 to 0.71), in the 7 m + GK throw ($P = .039$; ES = 0.44; 95% CI, 0.03 to 0.86), in the 9-m throw ($P = .044$; ES = 0.49; 95% CI, 0.01 to 0.96), and in the 9 m + GK throw ($P = .023$; ES = 0.45; 95% CI, 0.07 to 0.83) (Figure 1).

IHS and CMJ

The IHS in the dominant hand was 3.3% (6.9%) higher with CAFF ingestion compared with the placebo condition ($P = .034$; ES = 0.35; 95% CI, 0.03 to 0.66; Figure 2A). In addition, CMJ height was improved by 4.2% (5.2%) with CAFF compared with the placebo ($P = .006$; ES = 0.22; 95% CI, 0.08 to 0.37; Figure 2B).

SV and MATT

The time required to complete the SV was −1.6% (2.6%) lower with CAFF compared with the placebo ($P = .042$; ES = −0.34; 95% CI, −0.66 to −0.01; Figure 2C). However, no statistical differences were reported between treatments in the MATT ($P = .669$; ES = −0.08; 95% CI, −0.49 to 0.33; Figure 2D).

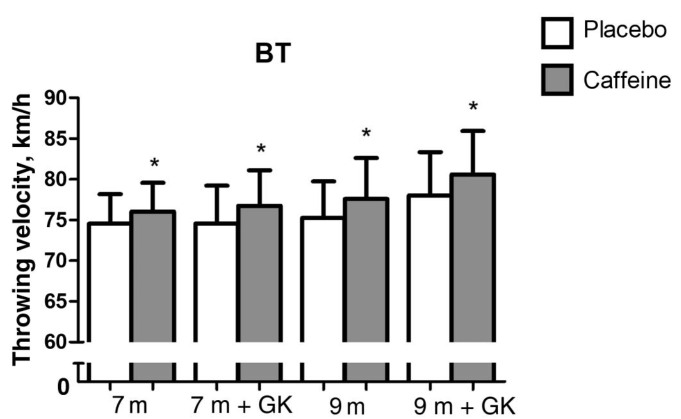

Figure 1 — Ball velocity in several throwing tests in elite female handball players with the administration of 3 mg/kg/bm of caffeine or a placebo. bm indicates body mass; BT, ball throw; GT, goalkeeper. *Significant differences compared with placebo values at $P < .05$.

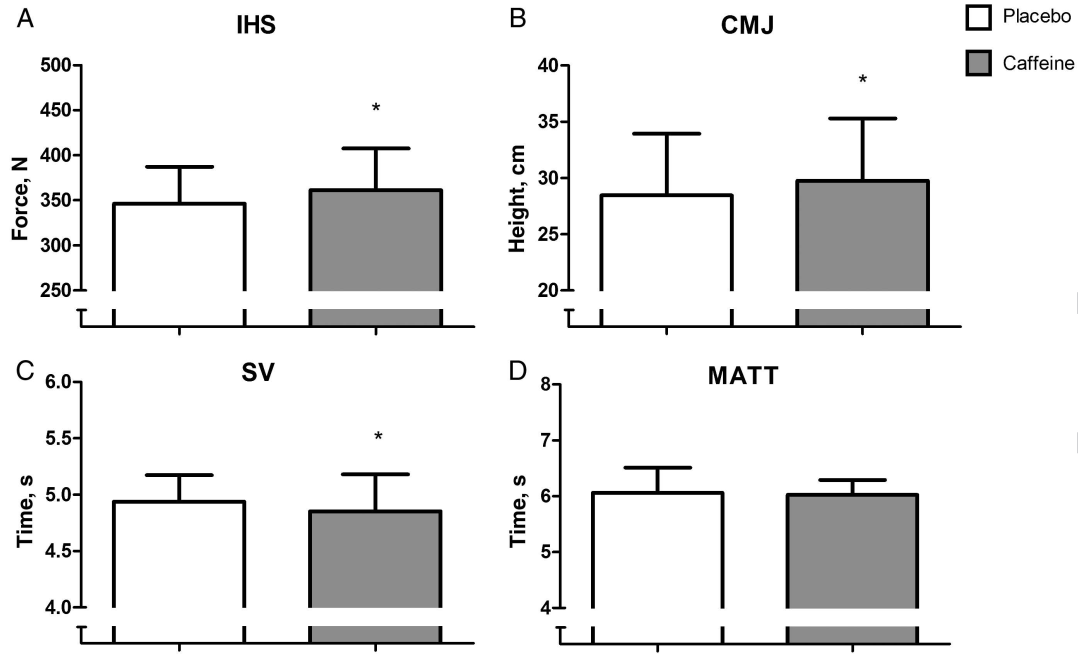

Figure 2 — The IHS, CMJ height, 30-m running time (SV), and time employed to complete a MATT in elite female handball players with the administration of 3 mg/kg/bm of caffeine or a placebo. bm indicates body mass; CMJ, countermovement jump; IHS, isometric handgrip strength; MATT, modified version of the agility T test. *Significant differences compared with placebo values at $P < .05$.

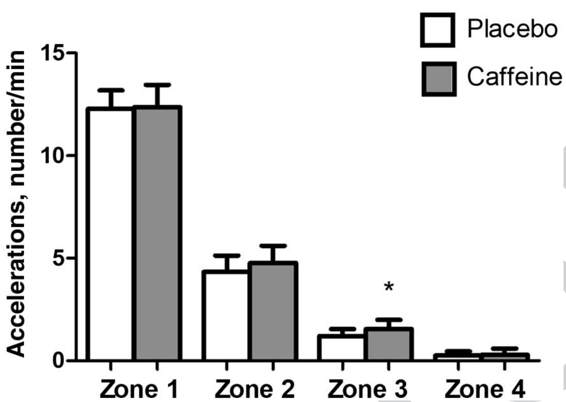

Figure 3 — Frequency of accelerations in different intensity zones (zone 1 [0–1 m/s^2], zone 2 [1–2 m/s^2], zone 3 [2–3 m/s^2], and zone 4 [3–4 m/s^2]) during a simulated handball match in elite female handball players with the administration of 3 mg/kg/bm of caffeine or a placebo. bm indicates body mass. *Significant differences compared with placebo values at $P < .05$.

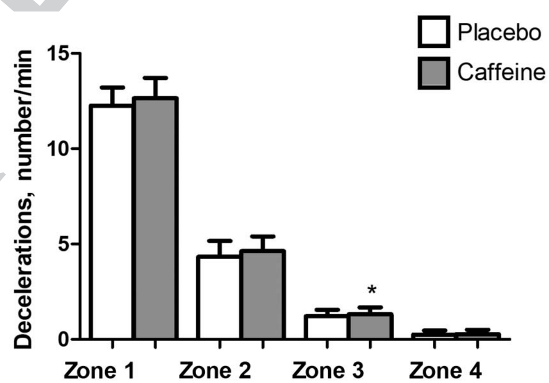

Figure 4 — Frequency of decelerations in different intensity zones (zone 1 [0 to –1 m/s^2], zone 2 [–1 to –2 m/s^2], zone 3 [–2 to –3 m/s^2], and zone 4 [–3 to –4 m/s^2]) during a simulated handball match in elite female handball players with the administration of 3 mg/kg/bm of caffeine or a placebo. bm indicates body mass. *Significant differences compared with placebo values at $P < .05$.

Simulated Handball Match

Compared to the placebo, CAFF increased the overall frequency of accelerations during the simulated match (18.1 [1.2] vs 18.8 [1.0] number/min; $P = .044$; ES = 0.54; 95% CI, 0.02 to 1.07). Specifically, CAFF increased the number of accelerations in zone 3 ($P = .002$; ES = 0.94; 95% CI, 0.39 to 1.48; Figure 3) with no differences in zones 1, 2, and 4 ($P = .115$–.725). CAFF also increased the overall frequency of decelerations (18.0 [1.2] vs 18.7 [1.0] number/min; $P = .032$; ES = 0.56; 95% CI, 0.06 to 1.06), reported statistical differences in zone 3 ($P = .039$; ES = 0.30; 95% CI, 0.02 to 0.59) (Figure 4), whereas no differences were obtained in zones 1, 2, and 4 ($P = .106$–.298). In addition, CAFF increased the overall frequency of body impacts (20 [8] vs 22 [10] impacts/min; $P = .032$; ES = 0.30; 95% CI, 0.03 to 0.52). This ergogenic effect was evident in zone 1 ($P = .037$; ES = 0.20; 95% CI, 0.01 to 0.38) and zone 3 ($P = .004$; ES = 1.17; 95% CI, 0.44 to 1.89) (Figure 5) with no effect in zone 2 ($P = .075$; ES = 0.36; 95% CI, –0.04 to 0.76). CAFF also increased maximal (185 [5] vs 189 [5] beats/min; $P = .018$; ES = 0.36; 95% CI, 0.08 to 0.65) and mean heart rate during the match (157 [21] vs 166 [16] beats/min; $P = .035$; ES = 0.37; 95% CI, 0.03 to 0.70). Finally, no differences were reported between conditions in the total distance covered (72 [17] vs 74 [15] m/min; $P = .519$; ES = 0.06; 95% CI,

−0.13 to 0.26), the distance covered at sprint velocity (8.57 [3.17] vs 7.97 [2.86] m/min; $P = .164$; ES = 0.20; 95% CI,−0.09 to 0.49), and the maximal running speed attained during the game (18.6 [1.72] vs 19.0 [2.07] km/h; $P = .273$; ES = 0.21; 95% CI, −0.19 to 0.62).

Prevalence of Side Effects

During the testing, the handball players reported similar self-perceived endurance (CAFF = 6.4 [2.5] vs placebo = 6.0 [1.65] point; $P = .420$), muscle power (5.87 [2.20] vs 5.73 [1.22] points; $P = .820$), and fatigue (5.20 [2.60] points vs 5.53 [2.07] points; $P = .950$). During the hours after the testing, the handball players showed a similar prevalence of side effects (insomnia, gastrointestinal problems, activeness, irritability, muscular pain, tachycardia and heart palpitations, headache, urine excretion, fatigue, and nervousness) between the 2 experimental protocols (Table 1). Only 33.3% (5 out of 15) participants correctly guessed the order of the trials, indicating successful blinding of the participants to the interventions.

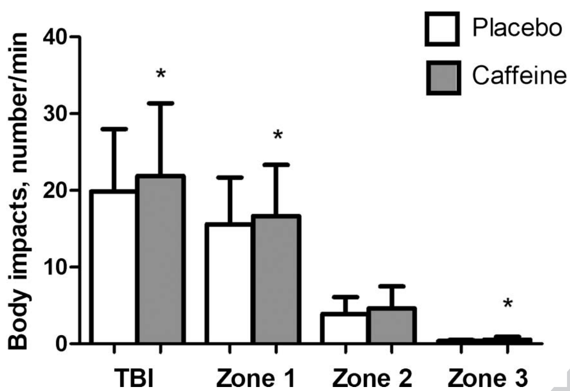

Figure 5 — Frequency of body impacts in different intensity zones (zone 1 [0 to ≤5] g; zone 2 [5 to ≤8 g]; and zone 3 [8 to ≤10 g]) during a simulated handball match in elite female handball players with the administration of 3 mg/kg/bm of caffeine or a placebo. bm indicates body mass. *Significant differences compared with placebo values at $P < .05$.

Table 1 Prevalence of Side Effects Reported in the Morning After the Ingestion of 3 mg of Caffeine Per Kilogram of Body Mass or Placebo

Items	Placebo	Caffeine	P
Insomnia, %	20.0	66.7	.065
Gastrointestinal problems, %	6.6	26.6	.250
Increased activeness, %	13.3	20.0	1.000
Irritability, %	46.6	26.6	.375
Muscular pain, %	46.6	46.6	1.000
Tachycardia and heart palpitations, %	6.6	13.3	1.000
Headache, %	20.0	40.0	.453
Increased excretion of urine, %	26.6	40.0	.687
Increased fatigue	6.6	6.0	.554
Nervousness	4.4	4.0	.326

Note: Data are percentage of affirmative responses to each of the side effects obtained from 15 elite female handball players.

Discussion

Although the ergogenicity of CAFF has been previously proven in several team sports,[14,15,17] only one study has evaluated the effects of this substance in handball.[7] Consequently, there is a need to understand how CAFF can impact physical performance of handball players to ascertain if this substance might be beneficial to increase overall handball performance. Following this lack of information, the purpose of the present study was to determine the effect of preexercise CAFF intake on handball-specific physical performance. In comparison with the placebo, CAFF increased ball velocity in throws of 7 m, 7 m with GK, 9 m, and 9 m with GK (2.2%–3.6%); enhanced IHS (3.3%); and CMJ height (4.2%) while it decreased the time needed to complete a 30-m sprint (−1.6%). Contrary to our hypothesis, CAFF did not affect the time employed to complete the MATT. To increase the application of this study, in addition to the physical testing, participants competed in a simulated match, and CAFF was effective to increase the total number of accelerations (3.9%) and decelerations (4.0%), per minute together with an increase in the total number of body impacts (12.4%). However, the total distance covered during the match and the maximal running speed attained during the match were unaffected by CAFF. All these results indicate that CAFF, in a dose of 3 mg/kg/bm, might be considered as an ergogenic aid for elite women handball players because it has the capacity of enhancing BT velocity, jump and sprint performance, and the frequency of in-game accelerations and decelerations.

In handball, a BT to goal is a common and determinant attacking skill which allows players to score. In addition to precision, a critical characteristic of this complex skill is the velocity at which the ball is thrown.[33] To assess the effect of CAFF on this skill, a set of several ball throwing tests was designed. The battery of throws included attempts at varying distances (7 vs 9 m), with/without the presence of a GK and with different approaches (none or a 3-step run). Independently of the characteristics of the throw, CAFF improved maximal ball velocity by 2.0% to 3.3%. Interestingly, the highest increase in BT velocity was found in the throws performed with an approximation to the line of 9 m (3.0%–3.3%), indicating a key effect of CAFF to increase the capacity for throwing during in-game actions. Although no previous studies have analyzed the effect of 3 mg/kg/bm of CAFF on BT in handball players, the effectiveness of this substance has also been shown in other manifestations of muscle power in the upper body such as spikes in volleyball[15] and the tennis serve.[34] Thus, the ingestion of a low dose of CAFF before a match might be effective to increase ball velocity in elite handball players.

In comparison with the placebo, IHS was improved by 3.3% in the dominant hand with the ingestion of CAFF. This effect was slightly lower to those previously reported in other intermittent sports such as volleyball or tennis (4.4%–10.8%).[15,35] Although handgrip is not a specific action of handball match play, this test is a simple method to test the effect of CAFF on force production and might be indicative of a higher capacity to produce force during game actions. In addition, handgrip strength has a strong correlation with ball velocity and might be one of the reasons for the increased ball velocity obtained with CAFF.[36] Likewise, vertical jumps, which are commonly executed to throw and to block rivals' attempts on goal[37] was improved with CAFF intake (4.2%).

According to previous literature, CAFF ingestion (3–6 mg/kg/bm) enhances jump height by 2.8% to 7.3% in different vertical jump protocols in elite women athletes of other intermittent sports such as volleyball,[15] rugby sevens,[14] or football players.[17] In addition, a recent meta-analysis carried out by Grgic et al,[38] who included 10 investigations about CAFF effect on muscle power expressed as vertical jump height, indicated that acute CAFF intake enhanced jump height with a standardized mean difference of 0.17, which is similar to the magnitude of the ergogenic effect of CAFF on CMJ Q20 height found in the current investigation. This information indicates that preexercise CAFF ingestion enhances muscle force and power that might be indicative of an improved handball physical performance.

During handball matches, the number and velocity of the sprints performed are critical for success.[2] To fulfill the aim of this investigation, we selected a 30-m maximal running test and an adapted version of the *T* test (MATT) to verify the effect of CAFF on speed and agility. The results indicate that CAFF reduced sprint time by 1.6%, while the effect of this stimulant was not statistically significant to reduce the time necessary to complete the MATT (−0.5%). Other studies that used similar CAFF doses in team sports players have found that CAFF is effective to increase running speed in single and repeated sprint actions.[12] In addition, it seems that CAFF ergogenicity in maximal running sport-specific testing might be transferred to improve movement patterns at sprint velocity during a simulated match.[14] In the current investigation, the higher sprint velocity during the 30-m sprint test was not accompanied by a higher running distance at sprint velocity during the match between placebo and CAFF ingestion (7.97 vs 8.57 m/min, respectively). It is likely that the court dimensions and the presence of adversaries limited the transference of the ergogenic effect of CAFF from the SV to the sprints performed during the match. Thus, while it seems proven that CAFF might be effective to increase running speed and agility in team sport-specific testing,[12] more information is required to verify whether this effect is transferred to in-game sprint actions during a handball match.

To our knowledge, this is the first study to analyze the effects of CAFF intake (3 mg/kg/bm) on handball in-game performance using ultra-wideband tracking system technology devices. CAFF increased the number of accelerations and decelerations per minute by 3.9% and 4.0%, respectively, with a concomitant positive effect on body impacts. This effect could be related to a better maintenance of physical performance during the game as the frequency of these high-intensity actions decreases across the match.[4] However, no differences were observed in total distance covered, the distance covered in different speed zones or the maximal speed reached Q21 during the match. Since the number of high-intensity actions, such as accelerations, decelerations, and body impacts are crucial in handball performance,[2] because they represent fast changes of direction, running sprints, and collisions with opponents, our results seem to support the ergogenic effect of CAFF on handball in-game performance, as previously found in other team sports.[13–15] Although the measurement of body accelerations/decelerations and impacts is unspecific to differentiate among different handball actions, the higher frequency of these actions with the ingestion of CAFF suggests that this substance might be able to augments the number of changes of directions and the quantity of blocks (produced or received) and sprints.

Finally, the results of postmatch surveys about self-reported feelings did not indicate any difference between CAFF or placebo ingestion. Nevertheless, a tendency for increased prevalence of insomnia was evident with CAFF over the placebo, as previously found.[21] Thus, attention should be paid to the use of this substance when 2 games are played on consecutive days or when training routines are carried out in the afternoon.

The current investigation has several limitations. First, the simulated game was shorter than an official handball game, and further investigations should determine the effect of CAFF in real competitive scenarios. Second, the dietary patterns before the first experimental trial, including avoidance of dietary sources of CAFF, were recorded and replicated in the second experimental sessions while the obtaining of urine samples might have helped to certify that all players had complied with the removal of CAFF from their diets. Finally, the findings of this study should only be Q23 translated to elite female handball players unhabituated to CAFF who are willing to use 3 mg/kg of CAFF to increase the performance, as tolerance, dose, and sex might significantly affect the positive effect of CAFF.[39,40]

Practical Applications

The results of this investigation showed that 3 mg/kg/bm of CAFF might be catalogued as a useful strategy for improving physical performance in elite women handball players and for enhancing handball performance during a simulated match. However, despite these positive outcomes, CAFF should be recommended on an individual basis, after careful evaluation of potential drawbacks and after experimenting its effects during training. CAFF should not be recommended to those who do not positively respond to acute CAFF intake, those who report side effects such insomnia, or those who are not willing to use stimulants to increase sports performance.

Conclusion

The ingestion of 3 mg/kg/bm of CAFF improved jump height, sprint speed, handgrip force, BT velocity, as well as accelerations, decelerations, and body impacts during a simulated handball game in elite women handball players.

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Queries

Q1. Keywords "handball," "caffeine," "physical performance," and "women" were deleted, as repeats of words in article and journal title are not allowed in keywords section, per journal style. Provide additional keywords so that the total number of keywords equals at least 3, ideally 4–5.

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