ACUTE EFFECTS OF CAFFEINATED CHEWING GUM ON BASKETBALL PERFORMANCE IN ELITE FEMALE PLAYERS

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Keywords: ergogenic aid, team sports, elite athlete, exercise performance, stimulant

Abstract:

Background: To date, no study has investigated the effects of acute intake of caffeinated chewing gum in female basketball players.

Methods: Nine elite female basketball players participated in a randomized crossover placebo-controlled double-blind experiment. All athletes participated in two identical experimental trials 15 minutes after ingestion of (i) chewing gum containing 150 mg of caffeine (i.e.~2.3 ± 0.2 mg/kg of caffeine) or (ii) non-caffeinated chewing gum with an inert substance to produce a placebo. After the ingestion of the gum, the athletes performed the following tests: (i) a sprint test (0-20 m), (ii) agility T-test, (iii) isometric handgrip strength test, (iv) countermovement jump test, (v) free throw test, and (vi) three-point shot test.

Results: No significant differences were observed in any physical or skill-based tests ($p > 0.05$ for all). However, the effect size in the sprint and agility T-Test, jump height test, and free-throw test was higher in the caffeine conditions, with effect sizes of small or moderate magnitude ($ES = 0.31 – 0.64$) over the placebo.

Conclusion: From a practical perspective, the benefits of caffeinated chewing gum are minor, at least in elite athletes with a mild level of caffeine consumption.

Introduction

Caffeine is one of the most popular ergogenic aids used by athletes in all sports. Over 75% of athletes consume caffeine during participation in competitive events [1–3]. Indeed, there is strong evidence that caffeine enhances exercise tasks, including endurance [4], anaerobic [5], and resistance performance [6]. Moreover, the positive impact of caffeine has been shown in sports that require various types of energy metabolism such as team sports [7,8] or combat sports [9,10]. In the vast majority of studies, caffeine has been provided in the anhydrous form, administered in gelatin capsules or caffeinated drinks [11]. Interestingly, caffeine administered with chewing gum seems to be a valuable alternative to caffeine intake, offering new opportunities for athletes [12].

Caffeinated chewing gum may be advantageous over conventional administration methods [12]. The main advantage of caffeine intake with gum is its different pharmacokinetic profile compared to its anhydrous form, resulting in its faster absorption time. Chewing the gum allows bypassing of hepatic metabolism and can be absorbed directly into the bloodstream via the buccal mucosa, which enhances caffeine bioavailability. Hence, peak plasma caffeine concentrations occur after 5 minutes of chewing, with relative bioavailability of 90% [13,14]. From a practical point of view, the use of caffeinated chewing gum may prove beneficial, especially in team sports, where efforts are charac-
terized by unpredictable duration. Although several previous studies have analyzed the impact of caffeinated chewing gum on different sports modalities [9,15–21], only a few have assessed its effectiveness in team sports [20,22,23]. Those studies were performed on male rugby and soccer players and yielded conflicting findings, with positive effects on the results of the countermovement jump test [22,23], repeated sprint test [23], Yo-Yo [22,23] and 20 m sprint tests [23], and a neutral effect on the agility [23] and cognitive tests [20].

However, the potential benefits of administering caffeinated chewing gum have not been previously established for basketball performance. Basketball players need to have high levels of aerobic and anaerobic capacity, power, speed, strength, and agility [24], and skill-related ball tasks, such as dribbling, passing, or shooting into the hoop [25]. Those abilities might be enhanced by caffeine ingestion [8], and the use of caffeinated chewing gum might be useful due to basketball rules and specificity (e.g. unlimited substitution of players, changing total game playing time due to the clock being stopped). Since women are still underrepresented in caffeine research conducted on team sport players [8], the aim of this study was to determine the acute effects of caffeinated chewing gum on the results of a battery of physical and skill-based tests of basketball performance in female elite basketball players.

Materials and Methods

Study athletes

Eleven healthy and experienced female basketball players volunteered to participate in the study. However, two women did not complete testing sessions due to injury or for personal reasons; thus, nine athletes were included in the final analysis (Table 1). Athletes were recruited from the same basketball team playing in the 1st division of the Polish National League. Experimental sessions were conducted during the competitive season to ensure that athletes were at their peak physical fitness. The inclusion criteria were as follows: (i) no neuromuscular and musculoskeletal disorders, (ii) not using any medications, dietary supplements, or ergogenic aids which could potentially affect the study outcomes, and (iii) good health status. Athletes were excluded if they reported (i) using nicotine-containing products and (ii) possible allergy to caffeine. All athletes trained 14 hours per week during the competitive season. Before the first experimental sessions, athletes were instructed to maintain their usual hydration levels, dietary habits, and habitual caffeine intake throughout the study period. The athletes recorded their food intake using the MyFitnessPal freeware application 24 hours before the first experimental trial. To produce a within-subject diet standardization, athletes were asked to replicate similar dietary habits before subsequent trials (Table 1). The habitual caffeine intake level was calculated using a modified version of the validated questionnaire by Bühler et al. [26] (Table 1) that lists caffeine-containing foods and dietary supplements. Habitual caffeine intake was assessed for the 28-day period before the experiment, following previous recommendations [27]. Athletes were also asked to refrain from consuming caffeine-containing products and alcohol 24 hours before each experimental trial and not to perform strenuous exercise 24 hours before testing. All athletes had experience in performing tests used in the present study during training and/or other studies. The study protocol was approved by the Bioethics Committee for Scientific Research.

Table 1. General characteristics of participants

<table>
<thead>
<tr>
<th>Variable [units]</th>
<th>Value (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>24 ± 4</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>66.8 ± 7.4</td>
</tr>
<tr>
<td>Height [cm]</td>
<td>174 ± 4</td>
</tr>
<tr>
<td>Body Fat [%]</td>
<td>17.0 ± 4.4</td>
</tr>
<tr>
<td>Basketball experience [years]</td>
<td>11 ± 3</td>
</tr>
<tr>
<td>Habitual caffeine intake [mg/kg/day]</td>
<td>2.3±2.2</td>
</tr>
<tr>
<td>Energy intake [kcal]</td>
<td>2041 ± 114</td>
</tr>
<tr>
<td>Protein [% of total energy intake]</td>
<td>22 ± 3</td>
</tr>
<tr>
<td>Fat [% of total energy intake]</td>
<td>32 ± 6</td>
</tr>
<tr>
<td>Carbohydrates [% of total energy intake]</td>
<td>47 ± 7</td>
</tr>
</tbody>
</table>

Data reported as mean ± standard deviation.
at the Academy of Physical Education in Katowice, Poland (3/2019), according to the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All athletes provided their written informed consent to participate in the study.

**Experimental design**

To analyze the effect of the use of caffeinated chewing gum on basketball performance, the athletes participated in a randomized double-blind counterbalanced placebo-controlled crossover experiment, with each athlete acting as their control (Figure 1). Each athlete took part in two identical experimental trials after 15 minutes after caffeine ingestion with (i) chewing gum containing 150 mg of caffeine (i.e., 2.3 ± 0.2 mg/kg of caffeine) or (ii) non-caffeinated chewing gum with an inert substance to produce a placebo. The trials were performed at seven-day intervals to allow full recovery and caffeine wash-out. Caffeine was administered as an absolute dose for all athletes using three pieces of commercially available caffeinated chewing gum (OneGum; OneGum France, France). The placebo gum was three pieces of non-caffeinated chewing gum with a similar taste, color, and shape (Airways, Poland). On experimental days, athletes arrived at the gym at their typical training time (10 a.m.). Upon arrival, each athlete received an opaque container with chewing gums cut into small pieces. Athletes chewed the gum for 5 minutes and then were required to expectorate it into a container. Next, athletes conducted a standardized habitual pre-workout warm-up lasting approximately 15 min. After the warm-up, they performed the following physical tests: (i) sprint test (0-20 m), (ii) agility T-test, (iii) isometric handgrip strength test, (iv) countermovement jump, (v) free throw test, and (vi) three-point shot test, previously used for basketball performance assessment [8]. Once the testing was completed, athletes were asked to report the side effects of caffeine intake during the tests. Rating of perceived exertion (RPE; using the 6–20-point Borg scale [28]) was evaluated immediately after the training session. The blinding effectiveness was examined pre- and post-exercise.

![Study design](image)

**Figure 1. Study design**

CMJ: Countermovement jump; RPE: rate of perceived exertion

**Sprint Test (0–20 m)**

Maximal running velocity was assessed during a 20-m sprint test and measured at 5-, 10-, and 20-m intervals using a single-beam electronic timing system (Microgate, SARL, Bolzano, Italy). Athletes started from a standing position at 0.3m before the first infrared photocell gate and had to cover the distance in a straight line as fast as possible to the second gate. Photocell gates were placed 0.75m above ground level to ensure they capture trunk movement and prevent false signals caused by limb motion. The best time of 2 trials separated by a 2-min recovery was recorded for statistical analyses.

**Agility T-Test**

Agility was measured using the T-test. Participants began the test with both feet 0.30-m behind the photocell gate (Microgate, SARL, Bolzano, Italy). Athletes started running forward for 9.14m, touched a cone with their hand, and moved 4.57m to the left using lateral shuffling to touch another cone. Next, they moved 9.14m to the right with lateral shuffling and touched the third cone. Finally, the athletes moved to the left 4.57m, still in lateral shuffling, and touched the last cone, and ran backward for 9.14m in the direction of the starting line to finish the test. The best time (s) of the two trials (separated by 2-min recovery) was recorded for further analysis.
**Countermovement jump**

Athletes performed two countermovement jumps without arm swing on a force platform (Force Decks, Vald Performance, Australia). They stood in the standing position with hands placed on the hips. Then, they bent the knees into the countermovement position to a preferred depth, followed by a maximal vertical jump. Athletes were told to land in the position of the take-off. Athletes adopted the starting position after each jump after 2 minutes of rest. The best jump of the two attempts was used for the analysis. The outcome of this test was jump height (cm).

**Maximal isometric handgrip strength**

A Jamar hand dynamometer (Bolingbrook, IL, USA) was used to analyze maximum isometric handgrip strength. The test was performed in the sitting position with the shoulder of the tested arm adducted, and the elbow flexed at 90°, whereas the forearm and wrist were set in a neutral position. The testing protocol consisted of three maximal isometric contractions for 5 seconds, with a rest period of 60 s between the attempts. In each of the two attempts, athletes were instructed to squeeze the dynamometer as hard as possible. The highest value of peak strength (kgf) of dominant and non-dominant hands was used for analysis.

**Free throw test**

For this test, the standards of the rules International Basketball Federation were applied to replicate the shooting performed after a foul during a real game situation. Each athlete took their 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 using an official ball (Molten gf7). Athletes rested for 30 s between series to achieve adequate time to concentrate on shooting. An investigator blinded to the treatment recorded the number of shots scored [29].

**Three-point shot accuracy test**

The test consisted of 10 consecutive three-point shots using an official ball (Molten gf7) from five different significant field spots (marked by cones) just beyond the three-point line, i.e., 7 m from the basket [30]. Athletes had to move from one position to the other, and the total number of shots had to be performed in 1 min or less. Athletes picked the ball up from a court to perform the test in a continuous mode. The number of three-point shots scored in the test was recorded by an investigator blinded to the treatment.

**Side effects and assessment of blinding**

Immediately after completion of the testing procedure, athletes were asked about perceived caffeine side effects by using a questionnaire with yes/no responses [31,32]. Additionally, they were asked about increased vigor/activeness and perception of performance improvement during the testing. The effectiveness of blinding was assessed post-exercise by asking the athletes the following question: “Which gum do you think you have chewed?”. This question had three possible responses: (i) “caffeinated chewing gum”, (ii) “placebo gum”, and (iii) “I do not know”.

**Statistical analysis**

All calculations were performed using Statistica 13.3 and expressed as means with standard deviations (±SD) for all participants. A Shapiro–Wilk test was performed to verify the normality of the sampling distribution. A Wilcoxon test was then applied. Hedges’ g for repeated measures was used to calculate relative effect sizes (ESs). ESs of 0.00–0.19, 0.20–0.49, 0.50–0.79, and ≥0.80 represented trivial, small, moderate, and large effects, respectively. Statistical significance was set at p<0.05.

**Results**

The Wilcoxon test indicated no significant differences in energy intake (2041±127 vs 2050±109, kcal/day; p = 0.483) and in the proportions of protein/carbohydrate/fat (22/48/31, vs 22/45/33%; p = 0.799 for protein, p = 0.326 for carbohydrate, p = 0.400 for fat) in the diet for the 24 h before placebo and caffeine conditions, respectively. A Wilcoxon test showed non-significant differences in RPE between caffeine and placebo conditions (9 ± 2 vs 8 ± 2, respectively; p = 0.500).

In the placebo group, no participant reported side effects, while in the caffeine group, one athlete indicated excessive sweating and another one reported their perception of performance improvement. When evaluated pre-exercise, 88% of the athletes identified the caffeine and placebo trials. When evaluated post-exercise, 88% and 66% of the athletes identified the caffeine and placebo trials, respectively.
No significant differences were observed in all performance tests ($p > 0.05$ for all, Table 2). Small effect sizes were observed for countermovement jump and free throw tests ($ES = 0.31–0.33$), while moderate effect size ($ES = 0.55–0.64$) was observed for sprint and agility T-test.

### Table 2. Results on the effects of caffeine on the exercise performance outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Placebo</th>
<th>Caffeine</th>
<th>$p$</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-m (s)</td>
<td>1.12±0.07</td>
<td>1.09±0.03</td>
<td>0.141</td>
<td>0.55</td>
</tr>
<tr>
<td>10-m (s)</td>
<td>1.92±0.10</td>
<td>1.87±0.05</td>
<td>0.138</td>
<td>0.63</td>
</tr>
<tr>
<td>20-m (s)</td>
<td>3.38±0.17</td>
<td>3.28±0.14</td>
<td>0.155</td>
<td>0.64</td>
</tr>
<tr>
<td>Agility T-Test (s)</td>
<td>6.13±0.24</td>
<td>6.10±0.34</td>
<td>0.593</td>
<td>0.11</td>
</tr>
<tr>
<td>Peak absolute strength of the dominant hand (kgf)</td>
<td>27.3±4.7</td>
<td>27.4±4.7</td>
<td>0.678</td>
<td>0.02</td>
</tr>
<tr>
<td>Peak absolute strength of the non-dominant hand (kgf)</td>
<td>25.4±5.1</td>
<td>25.5±5.3</td>
<td>0.646</td>
<td>0.01</td>
</tr>
<tr>
<td>Countermovement jump height (cm)</td>
<td>32.13±2.31</td>
<td>32.84±2.32</td>
<td>0.313</td>
<td>0.31</td>
</tr>
<tr>
<td>Sum of points from free throw test (n)</td>
<td>18±3</td>
<td>19±3</td>
<td>0.674</td>
<td>0.33</td>
</tr>
<tr>
<td>Sum of points from three-point shot test (n)</td>
<td>6±1</td>
<td>6±1</td>
<td>0.498</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Data reported as mean ± standard deviation. ES: effect size

**Discussion**

The main purpose of this study was to investigate the acute effects of caffeinated chewing gum on the results of a battery of physical tests of basketball performance in female elite basketball players. The results of the present study indicated that the ingestion of 150 mg of caffeine with chewing gum did not enhance performance in physical tests including the sprint test, agility T-test, isometric handgrip strength test, and countermovement jump test, nor in any of the skill-based tests such as free throw and three-point shot tests. However, the results of the sprint and agility test, jump height test, and free-throw test was higher in the caffeine conditions with effect sizes of small or moderate magnitude over the placebo. Collectively, the results of the present study suggest that the use of caffeinated chewing gum containing 150 mg of caffeine, corresponding to $~2.3 \pm 0.2$ mg/kg body mass, has no significant effect on performance in elite basketball players. With the positive trend observed in the performance of several physical tasks, higher caffeine doses are likely to be beneficial.

Several previous studies have analyzed the effectiveness of acute caffeine intake in team sports [8]. Eight studies in basketball have assessed the impact of caffeine on several basketball-related performance tasks [29,33–39]. In most of these studies, caffeine intake led to improvements in vertical jumps [29,34,35,37,40], shooting [34,39], agility [37,40], and sprint tests [37,40]. However, no previous studies have analyzed the impact of chewing gum as a caffeine administration method, mostly using low caffeine doses. Thus, the possible explanation for no significant differences observed in the present study might be the lower dose compared to previous studies ($~2.4$ mg/kg of caffeine vs at least 3 mg/kg of caffeine). Although at least 3 mg/kg of caffeine is usually suggested as a minimal dose to enhance performance [11,41], some studies suggest a positive impact of low (i.e., <3 mg/kg of caffeine) doses in some sports scenarios [42]. However, it is worth noting that using chewing gum as a caffeine source with higher caffeine doses has some limitations. Firstly, the commercially available products allow only ingestion in absolute caffeine doses, including 50 mg to 100 mg pieces of gum. Secondly, chewing more than three or four pieces of gum at the same time may be problematic for technical reasons, and it seems possible that part of the caffeine remains in the gum after recommended 5 min of chewing. Thus, ingestion of some doses might be impossible for athletes with higher body weights. Interestingly, in some previous studies, the positive effects of caffeine in increasing physical performance were not observed when caffeinated chewing gums were used [9,20,21]. Nevertheless, further studies, including protocols comparing different caffeine doses and sources, are still needed to confirm these findings.

It has to be highlighted that the participants of the present study were elite athletes [43]. Since the ergogenic effects of caffeine can also be associated with sports skill level, the high-performance group of participants included in the present study might be the explanation for no performance improvement. It could be argued that in highly trained individuals, there is less ‘potential for improvement’ following caffeine intake as they are close to reaching
peak exercise performance capabilities [44,45]. Some previous studies conducted on elite basketball players have confirmed that caffeine’s ergogenic modalities could be influenced by training status [33,34,36]. Indeed, when high-performance athletes were included in those studies, no efficacy of caffeine was reflected in the results of the vertical jump [33], agility [34], free throws [34], and dribbling speed [36] tests. However, it is still possible that the effects of caffeine on various tasks might differ between sports skill levels.

Furthermore, habitual levels of daily caffeine ingestion by athletes might influence the ergogenic effect of caffeine [46]. Several previous studies have observed a reduced ergogenic effect of caffeine administration in participants habituated to caffeine [31,32,47–50]. Regular caffeine intake may influence the physiological response to its acute administration by forming new adenosine receptors [51,52]. Therefore, they may bind to adenosine and diminish the role of caffeine in blocking adenosine receptors [51]. It has to be taken into consideration that athletes involved in the present study were classified as mild caffeine users because they consumed an average of 2.4 mg/kg of caffeine per day [27]. Further, the single acute caffeine dose was similar to the daily intake. Pickering and Kiely [46] suggested that reducing caffeine’s ergogenic effects might be offset by using a dose higher than the daily caffeine intake. Thus, the possible diminished effect after caffeine ingestion observed in the present study might be explained by habituation. Additionally, a systematic review analyzing differences between sexes in caffeine research has shown the increased ergogenic effect of caffeine in men than in women [53]. The reason explaining those results is the increase in neuromuscular activity that facilitates neural transmission is observed in men, without such evidence in women [54].

**Study limitations**

In addition to its strengths, the present study has several limitations that should be addressed: (i) the number of athletes who completed the examinations in the present study was limited; (ii) the study did not assess any biochemical analysis; (iii) the study sample was composed of habitual caffeine users; thus the interpretation of the current results should be made with caution; (iv) the study was conducted on elite female players; thus, it is unknown if similar effects can be observed in males or athletes with different training backgrounds. Finally, basketball performance was assessed using standardized tests. Further studies need to analyze the potential performance benefits of chewing caffeinated gum during the simulated game to create a real-life competitive environment.

**Conclusions**

The results of the present study indicate that the ingestion of 150 mg of caffeine (i.e. ~2.3 mg/kg of caffeine) with chewing gum had no performance benefits on the results of a battery of physical tests of basketball performance (i.e. sprint test, agility T-test, isometric handgrip strength test, and countermovement jump test), nor in any of the skill-based test (i.e. free throw and three-point shot test) in elite female basketball players. However, values of the sprint test, agility T-test, jump height test, and free-throw test were higher in the caffeine conditions with effect sizes of small or moderate magnitude over the placebo. From a practical perspective, the benefits of caffeinated chewing gum seem to be minor, at least in athletes with mild caffeine intake levels.

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**Institutional Review Board Statement:** The study protocol was approved by the Bioethics Committee for Scientific Research, at the Academy of Physical Education in Katowice, Poland, (3/2019) according to the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All athletes gave their informed consent prior to their inclusion in the study.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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References:


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