Caffeinated Energy Drinks Improve High-Speed Running in Elite Field Hockey Players

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The aim of this investigation was to determine the efficacy of ingesting 3 mg·kg⁻¹ of caffeine in the form of an energy drink to improve high-intensity and sprint running activities in elite field hockey players during a simulated game. On 2 days separated by a week, 13 elite field hockey players (age and body mass = 23.2 ± 3.9 years and 76.1 ± 6.1 kg) ingested 3 mg of caffeine per kg of body mass in the form of an energy drink or the same drink without caffeine (placebo drink). After 60 min for caffeine absorption, participants played a simulated field hockey game (2 × 25 min). Individual running pace and instantaneous speed during the game were assessed using GPS devices. The total number of accelerations and decelerations was determined by accelerometry. Compared with the placebo drink, the caffeinated energy drink did not modify the total distance covered during the game (6,035 ± 451 m and 6,055 ± 499 m, respectively; \(p = .87\)), average heart rate (155 ± 13 beats per min and 158 ± 18 beats per min, respectively; \(p = .46\)), or the number of accelerations and decelerations (697 ± 285 and 618 ± 221, respectively; \(p = .15\)). However, the caffeinated energy drink reduced the distance covered at moderate-intensity running (793 ± 135 and 712 ± 116, respectively; \(p = .03\)) and increased the distance covered at high-intensity running (303 ± 67 m and 358 ± 117 m; \(p = .05\)) and sprinting (85 ± 41 m and 117 ± 55 m, respectively; \(p = .02\)). Elite field hockey players can benefit from ingesting caffeinated energy drinks because they increase the running distance covered at high-intensity running and sprinting. Increased running distance at high speed might represent a meaningful advantage for field hockey performance.

Keywords: GPS technology, team sport, ergogenic aids, exercise, caffeine, nutrition

Like other team sports, field hockey players’ movements are typically characterized by short bursts of very high-intensity activities combined with low-intensity activities for recovery and periods of inactivity (both on the pitch and during substitutions; White & MacFarlane, 2013). The mean distance covered during a field hockey game is normally between 6 and 8 km (Jennings et al., 2012b; Lythe & Kilding, 2011; White & MacFarlane, 2013), although total running distances as high as 10.7 km have been found during international competitions (Jennings et al., 2012a). Although male field hockey players spend most of a match exercising at low intensity (e.g., standing, walking, and jogging; Spencer, Bishop, & Lawrence, 2004; Spencer et al., 2005), the production of repeated actions at high or sprint intensity is crucial for success in this sport (Lythe & Kilding, 2011).

Recently, the use of caffeinated energy drinks has been found effective in significantly changing the movement patterns of several team sports. During simulated or real games, the ingestion of caffeine (3mg·kg⁻¹ of body mass) in the form of energy drinks increased the running distance covered at high intensity, sprint intensity, or both in male and female soccer players (Del Coso, Munoz-Fernandez, et al., 2012; Lara et al., 2014) and rugby players (Del Coso, Portillo, et al., 2013; Del Coso, Ramirez, et al., 2013). The ingestion of the same dose of caffeine via energy drinks has also improved jump performance in basketball players (Abian-Vicen et al., 2014), the frequency of successful actions during volleyball games (Del Coso et al., 2014; Pérez-López et al., 2015), and the distance covered at high-intensity running and the number of sprints during a tennis match in junior players (Gallo-Salazar et al., 2015). The aim of this investigation was to determine the efficacy of ingesting 3 mg·kg⁻¹ of caffeine in the form of an energy drink to improve high-intensity and sprint running activities in elite field hockey players during a simulated game.
Method

Participants

Thirteen elite male field hockey players participated in this investigation. All the participants competed professionally in the same team in the Spanish field hockey first division (Division de Honor), and they had previous hockey experience of at least 6 years. They had a $M \pm SD$ age of 23.2 ± 3.9 years, body mass of 76.1 ± 6.1 kg, height of 181 ± 7 cm, body fat of 11.3 ± 4.9%, and maximal heart rate of 193 ± 4 beats per min (bpm). All the players were considered low caffeine users (<100 mg·day$^{-1}$ of caffeine).

A total of 22 elite hockey players initially agreed to participate in the investigation but only 13 players finished the experiment. Goalkeepers ($n = 2$) were excluded from the study sample because of the differences in their movement patterns from those of the outfield players. Two players ingested the experimental drinks but did not complete all the experimental measurements. The remaining 5 hockey players participated in the games but did not receive the experimental treatments because they did not fulfill the inclusion criteria for this investigation: (a) Potential participants had to have no previous history of cardiopulmonary diseases and (b) participants could not be taking medications or nutritional supplements during the study. One week before the onset of the investigation, participants gave their informed written consent to participate. The study was approved by a research ethics committee in accordance with the latest version of the Declaration of Helsinki.

Experimental Design

A double-blind, placebo controlled, randomized crossover study was carried out with all participants performing two experimental trials under the same experimental conditions ($19.0 \pm 1.4 \, ^\circ C$ dry temperature; $80.0 \pm 8.8%$ relative humidity). The experimental trials were separated by 7 days to allow complete caffeine wash-out and physical recovery. For the duration of the study, players followed their habitual training routines, but training and diet the day before the experimental trials were standardized and replicated with the assistance of the technical staff.

In a randomized order, players ingested an energy drink containing powdered caffeine (Fure; ProEnergetics, Madrid, Spain) dissolved in 250 ml of tap water to provide an individualized dose of 3 mg of caffeine per kilogram of body mass or the same drink with no caffeine content (0 mg·kg$^{-1}$; placebo). The drinks ingested in the experimental trials differed only in the amount of caffeine administered to each player (0 mg with the placebo drink vs. 234 ± 23 mg with the energy drink). The placebo drink was provided by the energy drink manufacturer and had the identical appearance and taste of the caffeine-containing energy drink. Both the caffeinated energy drink and the placebo drink contained a slight amount of carbohydrate (6.6 mg·kg$^{-1}$ in the form of maltodextrin) to sweeten the taste of the drinks. However, the amount of exogenous energy provided in the form of carbohydrate with the beverages was negligible (<2 kcal). In addition, the two experimental beverages contained taurine (18.7 mg·kg$^{-1}$), sodium bicarbonate (4.7 mg·kg$^{-1}$), and L-carnitine (1.9 mg·kg$^{-1}$). All these substances were ingested in identical proportions in the two experimental trials.

Experimental Protocol

Two days before the first experimental trial, participants were nude-weighed to calculate the individual energy drink dosage. The day before each experimental trial, the hockey players performed light and standardized training routines prearranged by the technical staff. Twenty-four hours before the onset of the experimental trials, players were encouraged to abstain from all dietary sources of alcohol, caffeine, and other stimulants, and this was confirmed by diet questionnaires. Three hours before the start of the tests, players had their habitual precompetition meal, which was replicated before the second experimental trial.

Players arrived at the stadium at 6:00 p.m., and the beverage assigned for the trial was individually supplied and consumed. Players dressed in a T-shirt, shorts, and hockey shoes and put on an adjustable harness that did not hinder their movements. A GPS–accelerometer–heart rate device (SPI-PRO-X; GPSports, Canberra, Australian Capital Territory, Australia) was inserted into each harness, and a heart rate band (T34; Polar, Kempele, Finland) was attached to their chest. The hockey players subsequently performed a 45-min standardized warm-up, and 60 min after ingestion of the beverages, participants were weighed in their competition clothes before taking part in a field hockey game. The technical staff of the team encouraged participants to play at their maximal intensity by indicating that players with the best performance would participate in the following official game. Each game consisted of two halves of 25 min with a 10-min halftime break. The games were played on an official hockey field (91 × 55 m, artificial grass) with 11 players per side. The match followed the rules of the International Hockey Federation, and a referee made decisions on play disputes. Participants played in their habitual position, and substitutions were not allowed to avoid different playing times among players. During the games, the GPS device and the heart rate band monitored data on distance covered, instantaneous running speed, accelerations and decelerations (e.g., body impacts), and mean heart rate at 15 Hz. Analyses of the field hockey players’ movements during the game were categorized as follows, based on a previous study by White and MacFarlane (2013). Each individual action longer than 1 s and with a velocity superior to 19 km·h$^{-1}$ was considered a high-intensity action. Similarly, each individual action longer than 1 s and with a velocity superior to 23 km·h$^{-1}$ was considered a sprint. Player-impact data were gathered from an accelerometer.
inserted within the GPS unit, and they were measured in G force units, with an accuracy of one impact. The assessment of body impacts during the match was used to calculate the amount and intensity of body accelerations and decelerations produced during the play.

After the game, players were weighed again. During each experimental trial, players drank water ad libitum only from their own individually labeled bottles, and they were instructed not to spit out or spill any fluid. Fluid intake was measured from the change in bottle weight using a scale (KD-500; Tanita, Tokyo, Japan). Sweat rate was estimated from pregame–postgame body mass change, total fluid intake, and game duration. Ten minutes after the end of the game, players were required to fill out a brief questionnaire about muscle power, endurance, and perceived exertion during the game (using a 1- to 10-point scale to assess each item), as previously used in an investigation by Salinero et al., 2014. In addition, participants were provided with a survey to be filled out the following morning about sleep quality, nervousness, gastrointestinal problems, and other discomforts (using a yes–no scale to assess each item). To evaluate the success of the blinding process during the experiment, participants were asked to guess the order of the experimental trials at the end of the second trial.

Statistical Analysis

For the variables obtained once during each experimental trial (e.g., sweat rate or dehydration), we used a paired t test to analyze the differences between the experimental beverages (caffeinated energy drink vs. placebo drink). For the variables obtained several times during each experimental trial (e.g., running distance was obtained in an investigation by Salinero et al.), we performed a two-way analysis of variance (Time × Treatment) to analyze the differences between the experimental beverages. The quantitative results are shown as M ± SD, and the results of qualitative data (e.g., side effects) are presented as percentages. Differences in side effects between the placebo drink and the energy drink were analyzed using the McNemar test. The significance level was set at p ≤ .05. The effect size (ES) was calculated when a statistical difference was found between beverages. The magnitude of the effect size was interpreted using the scale of Cohen (1998): An effect size lower than .2 was considered small, an effect size around .5 was considered medium, and an effect size more than .8 was considered large.

Results

Experimental Blinding and Total Running Distance

Only 46% (6 of 13) participants correctly guessed the order of the trials, indicating successful blinding of the participants to the intervention. During the simulated 245-min game, the total distance covered was similar in the placebo drink (6,035 ± 451 m) and the energy drink (6,055 ± 499 m; p = .87) conditions. The distances covered in the first half of the game (3,106 ± 292 m vs. 3,114 ± 243 m for the placebo drink and the energy drink, respectively; p = .87) and in the second half (2,929 ± 195 m vs. 2,941 ± 290 m; p = .90) were also similar between the two experimental beverage conditions. With respect to the distance covered in the first half, the distance covered in the second half was inferior in the placebo drink (p = .02) and the energy drink (p = .01) conditions, but the magnitude of this decline was similar between the conditions (p = .90).

Categorization of Running Distance by Velocity

Figure 1 depicts the distance covered at different speeds, ranging from walking (Zone 1) to sprinting (Zone 6). There were no statistical differences between experimental beverage conditions in the running distances covered in Zones 1, 2, and 3. However, the ingestion of the caffeinated energy drink decreased the distance in Zone 4 by 10.1% (p = .03; ES = .59), whereas it increased the running distance in Zone 5 by 18.1% (p = .05; ES = .81) and the distance covered in Zone 6 by 38.1% (p = .02; ES = .79). The number of high-intensity actions (>19 km·h⁻¹) was greater in the caffeinated energy drink condition than in the placebo condition (23.0 ± 5.6 actions vs. 27.4 ± 7.0 actions, respectively, p = .02; ES = .78). The same positive effect was found in the number of sprints (>23 km·h⁻¹) during the entire game (4.5 ± 1.9 sprints vs. 6.3 ± 2.9 sprints, p = .05; ES = .90).

Body Accelerations and Decelerations

The total number of body impacts (accelerations and decelerations), as measured by accelerometry, was similar with the ingestion of the placebo drink (697 ± 285 impacts) and with the ingestion of the caffeinated energy drink (618 ± 221 impacts, p = .15). Figure 2 depicts the number of body impacts grouped by the intensity of each acceleration or deceleration. Most of the body impacts were categorized as Zone 1 in both experimental trials. The ingestion of the energy drink decreased the number of body impacts in Zone 2 (p = .02; ES = .43) without affecting the remaining categories of body impacts.

Exercise Heart Rate and Sweat Rate

Relative to the placebo drink, the pregame ingestion of the caffeinated energy drink increased peak heart rate during the first half of the game (181 ± 9 bpm vs. 185 ± 11 bpm, p = .03; ES = .40), although this difference disappeared during the second half (190 ± 9 bpm vs. 187 ± 11 bpm, p = .44). Mean heart rate was unaffected by the ingestion of the caffeinated energy drink in the first half (154 ± 14 bpm vs. 158 ± 16 bpm, p = .34) and second half (156 ± 13 bpm vs. 158 ± 20 bpm, p = .60) when compared with the placebo drink.
with the control trial. Sweat rate (1.0 ± 0.3 L·h⁻¹ vs. 0.9 ± 0.4 L·h⁻¹; p = .30), rehydration rate (1.1 ± 0.3 L·h⁻¹ vs. 1.1 ± 0.3 L·h⁻¹; p = .84), and dehydration level attained at the end of the game (−0.1 ± 0.7 vs. −0.2 ± 0.8%; p = .50) were unaffected by the energy drink intake when compared with the control experimental trial.

**Figure 1** — Running distance covered at different speeds during a field hockey match with the ingestion of a caffeinated energy drink (3 mg of caffeine per kilogram of body weight) or the same drink without caffeine (placebo drink). Dashed lines indicate the half time. Data are presented as M ± SD for 13 elite field hockey players. Zone 1 = 0.1–5.9 km·h⁻¹; Zone 2 = 6.0–11.9 km·h⁻¹; Zone 3 = 12.0–14.9 km·h⁻¹; Zone 4 = 15.0–18.9 km·h⁻¹; Zone 5 = 19.0–22.9 km·h⁻¹; Zone 6 = higher than 23 km·h⁻¹. *Different from placebo drink (p < .05).

**Figure 2** — Accelerations and decelerations (body impacts) during a field hockey match with the ingestion of a caffeinated energy drink (3 mg of caffeine per kilogram of body weight) or the same drink without caffeine (placebo drink). Dashed lines indicate the half time. Data are presented as M ± SD for 13 elite field hockey players. Zone 1 = 1.0–1.9 g; Zone 2 = 2.0–2.9 g; Zone 3 = 3.0–3.9 g; Zone 4 = 4.0–4.9 g; Zone 5 = 5.0–5.9 g; Zone 6 = higher than 6.0 g. *Different from placebo drink (p < .05).

**Prevalence of Side Effect**

Relative to the placebo drink, the caffeinated energy drink did not modify the perceptions of muscle power (6.2 ± 2.1 point vs. 6.2 ± 2.1 point; p = .91, respectively), endurance (6.4 ± 1.7 point vs. 6.3 ± 1.9 point; p = .99),
and exertion (5.3 ± 2.1 point vs. 5.5 ± 1.1 point; \( p = .68 \)) during the game. However, the energy drink tended to increase the prevalence of insomnia after the game with no other measurable side effects (Table 1).

### Discussion

Running pace during a field hockey game is between 120 and 140 m per minute of play (Lythe & Kilding, 2011; White & MacFarlane, 2013), a value very similar to the one found in this investigation with both drinks (121 ± 9 m·min\(^{-1}\)). Running pace in field hockey decreases by 2.4%–7.5% between the first and second halves of a field hockey game (Jennings et al., 2012b; Lythe & Kilding, 2011), indicating the presence of running fatigue during the second half of the game. In the present investigation, the ingestion of the caffeinated energy drink did not modify the total running distance covered during the entire field hockey game. Furthermore, the reductions in total running distance from the first to the second half were very similar for both the energy drink and the placebo drink (5.6% vs. 5.7%, respectively).

Although most of the running activities in field hockey are performed at low intensity (Spencer et al., 2005), the reduction in the number and distance covered at more than 15 km·h\(^{-1}\) is especially relevant because high-speed running is strongly linked to overall field hockey success during a game (Spencer, Lawrence, et al., 2004). This type of running action is reduced from the first half to the second half by 1.0%–8.6% in both national and international field hockey players (Jennings et al., 2012b), indicating the deleterious effects of the physical demands of the game on ability to repeat high-speed actions. An interesting finding was that the preexercise ingestion of the caffeinated energy drink significantly increased the overall distance covered at high intensity (Zone 5) and sprinting (Zone 6; Figure 1), whereas the effect sizes for these running activities were categorized as medium to large. However, when comparing the effects of the caffeinated drink to prevent fatigue, we found that the first- to second-half reductions in distance at high-intensity running (1.6% vs. 1.1%) and at sprint intensity (3.9% vs. 3.9%) with the ingestion of the caffeinated energy drink and the placebo drink were very comparable. This information indicates that the stimulant effect of the caffeinated energy drink increased field hockey movements performed at high speed (<18 km·h\(^{-1}\)) but was not effective to reduce the magnitude of the running fatigue present during a field hockey game.

The most accepted explanation for the ergogenicity of caffeine is related to the antagonistic action of caffeine on adenosine receptors, thereby inhibiting the negative effects that adenosine induces on the central nervous system (Davis & Green, 2009; Magkos & Kavouras, 2005). Adenosine is an endogenous modulator with an inhibitory effect on central excitability, affecting the release of excitatory neurotransmitters and the firing rate of central neurons (Kalmar & Cafarelli, 2004). It is then likely that the pregame ingestion of the caffeinated energy drink blocked adenosine receptors during the game, avoiding the central fatigue naturally mediated by adenosine. A possible translation of this biological mechanism into the field hockey game can be observed in Figure 1. With the ingestion of the caffeinated energy drink, the running actions performed at moderate intensity (e.g., Zone 4) were transformed into high-speed running movements (e.g., Zone 5 and Zone 6, Figure 1), suggesting an increased ability to repeat sprints produced by the caffeine. In fact, the use of caffeinated energy drinks has been associated with increased muscle power and force during short and explosive muscle contractions in a dose–response manner (Del Coso, Salinero, et al., 2012). Nevertheless, other mechanism related to caffeine’s ergogenicity could also play a role in the improved performance of field hockey players.

### Table 1 Prevalence of Side Effects the Morning After the Field Hockey Match With the Ingestion of a Caffeinated Energy Drink (3 mg of Caffeine per kg of Body Weight) or the Same Drink Without Caffeine (Placebo drink)

<table>
<thead>
<tr>
<th>Item</th>
<th>Placebo drink</th>
<th>Energy drink</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nervousness</td>
<td>0.0</td>
<td>23.1</td>
<td>.25</td>
</tr>
<tr>
<td>Insomnia</td>
<td>15.4</td>
<td>61.5</td>
<td>.07</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>7.7</td>
<td>0.0</td>
<td>1.00</td>
</tr>
<tr>
<td>problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activeness</td>
<td>0.0</td>
<td>30.8</td>
<td>.13</td>
</tr>
<tr>
<td>Irritability</td>
<td>7.7</td>
<td>23.1</td>
<td>.50</td>
</tr>
<tr>
<td>Muscular pain</td>
<td>15.4</td>
<td>23.1</td>
<td>1.00</td>
</tr>
<tr>
<td>Headache</td>
<td>7.7</td>
<td>30.8</td>
<td>.38</td>
</tr>
</tbody>
</table>

*Note.* Data are percentages of affirmative responses obtained from 13 hockey players.
The current study also presents some limitations related to the experimental design used and the form of caffeine administration. Previous investigations indicated that field hockey players’ movements might be affected by the result of the game (Jennings et al., 2012a). To avoid this effect, the technical staff set two teams with very similar physical and technical performances and the games’ scores were even until the end of each game. Furthermore, each team was composed of players who had ingested the placebo drink and players who had ingested the energy drink. For this reason, the effects of the experimental drinks on the game’s result was not investigated. The game was played without substitutions to obtain similar playing times among players and between experimental trials. Official field hockey games allow unlimited substitutions; thus, the playing times and the physical demands in the present investigation were probably higher than during an official field hockey game. To diminish this effect, the playing time was reduced to two halves of 25 min (instead of 35 min). Also, the experimental drinks (both the energy drink and the placebo drink) contained slight amounts of carbohydrate, taurine, sodium bicarbonate, and L-carnitine. Because these components were included in the same proportions in both experimental drinks, we suggest that caffeine is the only substance responsible for the effects obtained with the caffeinated energy drink. However, more information is necessary to elucidate whether the coingestion of these substances was necessary to obtain the purported benefits of caffeine. Despite these limitations, we believe that the outcomes of this investigation are applicable to field hockey players who ingest energy drinks before competition.

In summary, the pregame ingestion of a caffeinated energy drink with an amount of 3 mg·kg⁻¹ of caffeine significantly enhanced the movement patterns of elite field hockey players. This drink reduced the amount of running actions at moderate intensity and transformed them into high-intensity and sprint actions without affecting total running distance, body impacts, or mean heart rate. However, the intake of the energy drink tended to increase the rate of insomnia after the game. Thus, the performance benefits obtained by pregame ingestion of caffeinated energy drinks should be evaluated in the light of this negative side effect.

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References


