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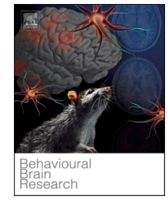

Research report

The effects of acute caffeine ingestion on decision-making and pass accuracy in young soccer players: A preliminary randomized controlled trial

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ABSTRACT

Caffeine has been shown to benefit physical aspects of different sports. In this paper, we aimed to understand the effects of caffeine on decision-making and the accuracy of soccer passes. Twelve young soccer players (16–17 years old and 20.8 ± 2.7 kg/m^2 BMI) completed the tasks once after taking 3 mg/kg body mass of caffeine (CAF) and once after consuming similar amounts of placebo (PLA). For the decision-making task, participants were asked to determine the best outcome of ten simulated pre-recorded soccer events. For the soccer pass accuracy, participants performed five short- (10 m) and five long passes (30 m), as well as the Loughborough Soccer Passing Test. Although not statistically significant, participants were 1.67 % more accurate in short- and 13.48 % more accurate in long passes when they consumed caffeine compared to the placebo (14.67 ± 2.74 vs. 14.50 ± 2.97, $p = 0.34$, $g = 0.27$ and 7.50 ± 2.84 vs. 6.83 ± 3.13, $p = 0.60$, $g = 0.14$, respectively). However, participants' decision-making was 7.14 % and LSPT scores were 3.49 % lower when they consumed caffeine compared to the placebo (29.50 ± 3.09 vs. 30.67 ± 2.93, $p = 0.28$, $g = -0.30$ and 55.38 ± 11.91 vs. 57.48 ± 12.13, $p = 0.08$, $g = -0.51$ respectively). In conclusion, while the short pass accuracy remained consistent among almost all participants before and after caffeine consumption, the performance varied in the case of long passes. Moreover, most of the participants scored lower on decision-making and LSPT after consuming caffeine. This may suggest that more complex tasks with a higher number of passes might negatively be affected by low doses of caffeine ingested one hour before playing soccer. Future studies are required to elucidate the effects of caffeine consumption on distinct cognitive and passing tasks.

1. Introduction

Association football (soccer) is an intermittent and dynamic team sport that includes low-intensity activities, such as walking, jogging, and standing, as well as high-intensity movements like maximal sprinting, turning, and tackling [4,7,31]. The performance and success of soccer players depend on several factors, including aerobic and anaerobic power, as well as cognitive and decision-making aspects [44,34,48]. Researchers and coaches often utilize objective and subjective methods to quantify player's performance, including physical fitness, soccer-specific skills, and perceptual-cognitive abilities such as anticipation, game intelligence, and decision-making [6]. To increase their chances of winning and performing better, both physically and strategically, players need to identify and implement effective strategies [15].

Caffeine is one of the most popular dietary supplements which has been shown to provide benefits during intermittent exercises, including soccer (1–6 mg/kg body mass – BM; [11,30,45]. These effects are attributed to caffeine's ability to block adenosine receptors [10], which enhances neuromuscular recruitment [47] and can improve sprint performance and countermovement jumping (3.7 mg/kg BM; [19]. Additionally, caffeine has been found to be beneficial for power-based sports, resistance training paradigms, and repeated high-intensity intermittent exercise, as well as isometric and isokinetic muscle force production and endurance (2.5–6.0 mg/kg BM – [9]; 2.0–7.0 mg/kg BM – [3].

On the other hand, the effects of caffeine on cognitive performance have received less attention. Cognitive functions include a broad range of basic mental operations, including attention, memory, and more complex executive functions involving working memory, decision-

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making, and multitasking. During a soccer match, players must process various cues such as opponents' positions, team organization, and time pressure [37]. Studies have shown that caffeine can enhance attention, accuracy, and speed, as well as self-reported measures of energy and mood [28,43]. Depending on the dosage and protocol, caffeine may also improve "lower" cognitive functions, such as reaction time, memory, and fatigue (2.5–3.7 mg/kg BM; [8,28,32]. However, the effects of caffeine on "higher" cognitive functions such as problem-solving and decision-making are often debated [25]. Decision-making in passing is particularly important in soccer, where a well-executed pass can create scoring opportunities [17]. Therefore, to gain a better understanding of the potential effects of caffeine as an ergogenic aid, our study aims to explore the impact of caffeine on decision-making and the accuracy of soccer passes.

2. Materials and methods

2.1. Design

We conducted a randomized, within-subject, double-blinded, and placebo-controlled study to evaluate the effects of caffeine on the results of three tests. Each participant completed the tests twice, once after consuming caffeine and once after consuming a placebo. The wash-out period between the sessions was one week. We employed a simple randomization technique via a Research Randomizer website. Allocation concealment was ensured using an independent third party. To eliminate the expectancy effect [41], participants and researchers were blinded about the beverage content. At the end of the experiment, none of the participants could tell which treatment they had received.

2.2. Participants

Twelve male young players (16–17 years of age, mean±SD 174.2 ± 8.4 m of height, 63.0 ± 8.1 kg BM, and 20.8 ± 2.7 kg/m^2 BMI, respectively), who had at least four years of playing soccer (playing at the Iranian Youth Tier 1 League), volunteered to participate in this preliminary study. Participants were moderate habitual caffeine users (less than 100 mg per day) according to the American Beverage Association (ABA) guidelines for moderate caffeine intake [2]. Participants were excluded if they: 1) smoked or used any psychoactive medication or illicit drugs that could interfere with test performance; 2) consumed more than 100 mg caffeine per day; 3) had a history of cardiac, hepatic, renal, pulmonary, neurological, gastrointestinal, hematological, or psychiatric illness, or any sensory or motor deficits that could be expected to affect test performance; and 4) objected to the prescribed diet (recall of diet and alcohol abstention), exercise, and resting regimens, or those who were not expected to comply with treatment.

2.3. Procedure

The study procedures were conducted in accordance with the Declaration of Helsinki and were approved by the local ethics committee (process number: IR.SUMS.REHAB.REC.1400.044). Prior to testing and on the first day, written consent was obtained from the participants and their guardians. To compare within-participant controls, participants were asked to complete a General Health Questionnaire, as well as reporting of diet, caffeine consumption [23], physical activity, and sleep. Participants were instructed to avoid consuming caffeinated products for at least two days prior to the start of the study, and to avoid strenuous activities 24 h before the tests. On the second day, participants were randomly assigned to receive either caffeine (CAF) or placebo (PLA). They then waited for an hour before participating in the tests. On the third day, similar procedure was followed, and the alternate capsule was administered to control for order effects.

2.4. Treatment

For each participant, we administered 3 mg/kg BM of either caffeine (Bulk™, Colchester, UK) or flour powder. These substances were placed in gelatin capsules that had similar shape and color. Participants received the capsules along with 200 ml of water while sitting quietly in a chair.

To measure participants' decision-making abilities, we used a computer-based task, as described by Farahani et al. [16]. Participants watched ten short video clips of a soccer player controlling a ball. After five seconds, the video was paused, and participants were presented with four options. They had three seconds to decide on the best option in terms of building a good attacking scenario. Each decision was noted and rated by three experienced coaches who ranked players' decisions from one (worst) to four (best; Fig. 1).

For measuring pass accuracy, participants dribbled for 5 m and passed the ball towards cones at 10 m (short pass) or at 30 m (long pass). The distance from the cone determined the point for the players; hitting the cone would be 4 points, missing within 1 m would be 2 points, and more than 1 m would be without any points. Each participant repeated each pass five times and the average of the five shots determined their score for short and long passes. The intraclass correlation coefficient for short pass was 0.54 (95 % CI = 0.11–0.83), and for long pass was 0.60 (95 % CI = 0.14–0.86). These coefficients indicate reasonable reliability.

We also used the Loughborough Soccer Passing Test (LSPT) to evaluate the players' pass ability [27]. Participants had to aim the ball towards four colored targets with the lowest number of mistakes and as fast as possible. At the end, the number of correct passes and the time to complete the task were noted by the experimenters.

2.5. Statistics

Data normality was assessed using the Shapiro-Wilk test. A dependent t-test was run between the paired samples to determine their results among the tests under PLA and CAF consumption effect. We utilized IBM SPSS Statistics (version 28, Chicago, USA) with a statistical significance level of 0.05. To examine the differences in means, 95 % CI (raw data) and Hedges' g effect sizes were applied to the pairwise comparisons. The thresholds for effect size statistics were as follows: 0.0–0.19 (trivial); 0.20–0.49 (small); 0.50–1.19 (moderate); 1.2–1.9 (large); ≥ 2.0 (very large; [22]).

3. Results

Descriptive statistics for each test are presented in Table 1. Although not statistically significant, participants were more accurate in short and long passes when they consumed caffeine ($t(11) = 1.00$, $p = 0.34$, Hedges' g (effect size) [95 % CI]: $g = 0.27$ (small) [−0.28 to 0.80], $t(11) = 0.54$, $p = 0.60$, $g = 0.14$ (trivial) [−0.39 to 0.67], respectively). On the other hand, participants' LSPT scores and decision-making were lower when they consumed caffeine compared to placebo ($t(11) = 1.90$, $p = 0.08$, $g = -0.51$ (moderate) [−1.10 to 0.07] and $t(11) = 1.13$, $p = 0.28$, $g = -0.30$ (small) [−0.84 to 0.24], respectively).

4. Discussion

This study aimed to investigate the effects of acute caffeine ingestion on the pass accuracy and decision-making abilities of young soccer players. The results indicated that participants had 1.67 % better accuracy in short passes, and 13.48 % better accuracy in long passes when they consumed caffeine, although the differences were not statistically significant. Additionally, players' decision-making was 7.14 % and their LSPT scores were 3.49 % lower when they consumed caffeine compared to placebo. Considering the small and trivial effect sizes, while there might be a slight change in short and long passes, as well as decision-making associated with caffeine consumption, this change might not

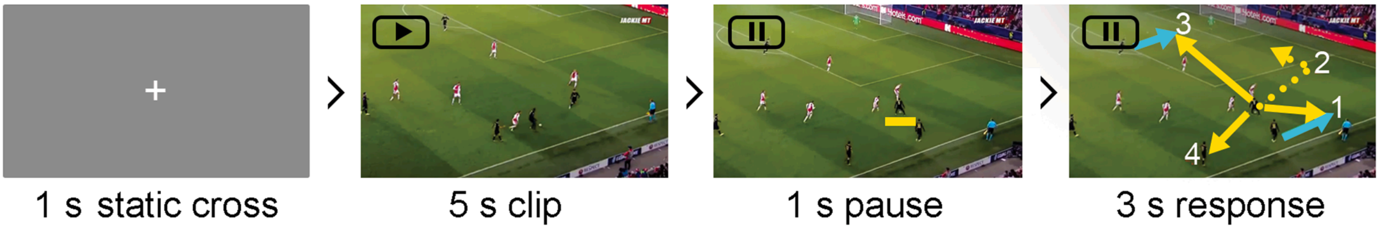

Fig. 1. The order and duration of stimuli for the decision-making task.

be noticeable or practically relevant in real-world situations. On the other hand, the moderate effect size for LSPT implies that while the scores were not statistically significantly different, the reduction after consuming caffeine could be still practically relevant and noteworthy.

4.1. Caffeine and the accuracy of pass

We showed that acute consumption of caffeine did not significantly affect soccer pass accuracy and LSPT scores. Our results align with previous research that showed low-moderate doses of caffeine (3.6–5.0 mg/kg BM) did not have a significant impact on response accuracy [19,38,14]. In contrast to our findings, previous research has reported both positive and negative effects of caffeine on accuracy. For example, lower doses of caffeine taken before and every 55 min during exercise have been found to improve the visual search accuracy but decrease the Stroop test reaction accuracy [21]. Others have shown that while ingesting 3.7 mg/kg BM of caffeine did not affect passing skills [19], larger doses of 6.0 mg/kg BM could improve passing skills [18]. These results suggest that a higher and sustained increase in blood caffeine levels may be necessary to affect certain cognitive aspects of performance [45]. Such repeated administration of caffeine seems to be beneficial and a prevalent practice in certain sports, including soccer [46]. However, coaches need to balance between the potential benefits of caffeine over longer durations, and the detrimental side effects (e.g., impact on sleep; [12]. It is also possible that more complex passing tasks, such as LSPT, which require better accuracy, speed, and control of the ball, may require higher doses of caffeine.

The observed contrasting effects of caffeine could also be attributed to other performance parameters that might have influenced accuracy. For example, Hogervorst et al. [20] reported that lower doses of caffeine, ingested 60 min prior to and every 20 min during exercise, could enhance the efficiency and speed of signal detection test by improving the attentional processes. Others have shown that a low-moderate dose of caffeine taken 60 min prior to the activity could increase task response accuracy while decreasing reaction times [14]. The improvement in reaction times could also be attributed to increased concentration which could be affected by caffeine [49,39].

Similar mixed results have been observed in other sport-specific accuracy and skill-based technical actions [42,1,19,35]. While some researchers have shown that caffeinated energy drinks do not affect shooting precision in young basketball players [1,36], others have shown that caffeine could be effective in increasing the success of volleyball game-actions [13,33]. In this regard, the potential impact of caffeine on accuracy could include improved positioning and increased opportunities for spiking, blocking, or teamwork, as well as increased number of assists and rebounds during the gameplay.

In summary, the mixed results seem to be the result of a complex interplay among several factors. These factors include the dosage of caffeine, which exhibits a differential impact on various tasks, with lower doses benefiting some physical and higher doses proving necessary for other cognitive tasks. The specific nature of the activity being undertaken is another influential factor, as more intricate tasks often demand higher caffeine dosages, or they can affect secondary performance parameters that, in turn, indirectly impact accuracy. Additionally, the frequency of caffeine intake plays a role, with sustained administration being more beneficial for certain cognitive tasks. The type of sport also comes into play, with no observable effect on shooting precision in basketball, but noteworthy improvements in volleyball. Lastly, the position of a player within the team can enhance accuracy, particularly when it involves opportunities for spiking, blocking, and collaborative teamwork.

4.2. Caffeine and decision-making abilities

Our results suggest that acute consumption of caffeine does not significantly affect decision-making abilities. Our findings are consistent with Bello et al. [5], where low doses of caffeine did not affect response accuracy for inhibitory control, which is crucial for various cognitive processes, including decision-making. Our results are in contrast with previous research where 100 mg of caffeine was shown to significantly improve cognitive functions measures [21]. Similar improvements have also been observed in simpler tasks like choice reaction time with hand and finger responses [24,26]. Sensitivity of the cognitive tests used (simple reaction time tests and number recall vs. more complex information processing tests) may explain differences in outcomes between studies [21]. It should also be noted that decision-making is a skill and may not be as sensitive as response time [16]. In general, it appears that low-moderate doses of caffeine have less consistent effects on memory and higher-order executive functions, such as judgment and decision-making [29].

4.3. Practical applications

By including individual raw data and facilitating its interpretation within an applied context, our data contribute to the growing body of literature on the relationship between caffeine consumption, performance, and cognitive responses. While no statistically significant differences were observed, it is noteworthy that most of the participants scored lower on decision-making and LSPT after consuming caffeine. This may suggest that more complex tasks with a higher number of passes might negatively be affected by low doses of caffeine ingested one hour before playing soccer. While the short pass accuracy remained consistent among almost all participants before and after caffeine consumption, the performance varied in the case of long passes. Some participants maintained comparable levels of accuracy, while others experienced either improved or reduced long pass accuracy after consuming caffeine. It appears that the effects of 3 mg/kg caffeine differ according to the individual differences between players.

Coaches may add these findings to their pool of performance metrices. Some of the changes could be important in certain positions or playing styles. For example, a slight decrease in pass accuracy might be crucial for a midfielder but less impactful for a goalkeeper. Ultimately, determining the practical significance of these findings in soccer performance involves a combination of quantitative analysis, expert input, and contextual understanding. It is also important to view effect sizes as part of a larger picture and consider how they fit into the broader context of the sport and its objectives. Lastly, it is worth noting that individual responses to caffeine can vary significantly. Therefore, a

Table 1
Descriptive statistics for each test.

Variables	Condition	Participants												Mean ± SD	% Change	95 % CI Difference
		1	2	3	4	5	6	7	8	9	10	11	12			
Decision-making	PLA	31	34	33	29	29	33	28	36	29	33	29	28	31.00 ± 2.70	-7.14 %	-3.43 to 1.10
	CAF	29	31	24	30	27	31	27	33	33	32	24	29	29.17 ± 3.13		
Short pass accuracy	PLA	16	18	10	10	14	14	16	18	16	12	18	12	14.50 ± 2.97	1.67 %	-0.20 to 0.53
	CAF	16	18	12	10	14	14	16	18	16	12	18	12	14.67 ± 2.74		
Long pass accuracy	PLA	4	8	0	4	6	8	8	8	10	6	8	12	6.83 ± 3.13	13.48 %	-2.06 to 3.39
	CAF	8	12	6	4	10	8	8	6	4	8	12	4	7.50 ± 2.84		
LSPT	PLA	48.76	61.10	57.74	55.09	69.57	74.33	47.01	53.48	47.45	82.26	44.04	48.94	57.48 ± 12.13	-3.49 %	-4.50 to 0.33
	CAF	42.52	65.32	55.18	47.12	64.25	71.23	49.25	50.36	50.75	79.49	44.14	45.02	55.38 ± 11.91		

CI: Confidence Interval of the Difference; CAF: Caffeine; PLA: Placebo; LSPT: Loughborough Soccer Pass Test.

prudent approach could involve trialing caffeine supplementation during training sessions or friendly fixtures to assess its effectiveness and suitability for each athlete before considering its application in more critical competitive scenarios.

4.4. Limitations and future research

We recognize the difficulty of controlling field studies where environmental and competitive conditions vary. While we controlled the dosage and timing of consumption, individual sensitivity to caffeine is harder to control. The abstention from habitual caffeine intake before the trials may have caused withdrawal effects that could change the interpretation of our findings [19]. Although none of the participant could discern the treatment they received, measuring the success of blinding exclusively, could distinguish varying levels of blinding performance in the study [40]. We also acknowledge that mimicking "game performance" can be challenging for both individual athletes and teams. To replicate real-world settings as consistently as possible, we utilized a video-based task. However, we note that such simulated protocols may not completely replicate other competitive aspects of a soccer match. Future research could use more ecological validated scenarios, such as in-game tactical and decision data, to explore the possible effects of caffeine on decision-making when more tactical strategies are present. Future research could also look at the acute effects of caffeine ingestion on players with different posts within a team. Lastly, due to time and Covid pandemic constraints, only male participants were recruited. Therefore, future studies could use more diverse participants to increase the statistical power and generalizability of the results.

5. Conclusions

The acute intake of 3 mg of caffeine per kg body mass did not change either decision-making ability or the accuracy of pass in young football players statistically significantly. However, most participants scored lower on decision-making and LSPT after consuming caffeine. While the short pass accuracy remained consistent among almost all participants before and after caffeine consumption, the performance varied in the case of long passes. Despite many benefits of caffeine on physical and cognitive performance, future studies are needed to evaluate the effects of this substance on passing accuracy and decision-making.

Author statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

Ethical process number: IR.SUMS.REHAB.REC.1400.044.

CRediT authorship contribution statement

NJ: Conceptualization, data collection and curation, project administration, and writing original draft; MS and DF: Conceptualization, supervision, review, and editing; PS: Data curation, formal analysis, supervision, writing original draft, review, and editing.

Conflict of interest

None declared.

Data availability

Data will be made available on request.

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