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Caffeine Improves the Motor Components of Agility in Amateur Soccer Players: Limits of Perceptual-Cognitive Enhancement

Martina Lafeková [1], Gabriela Kotyrová Štefániková [2] and Filip Skala [1,*]

[1] Department of Biological and Medical Sciences, Faculty of Physical Education and Sport, Comenius University in Bratislava, 814 69 Bratislava, Slovakia; lafekova2@uniba.sk
[2] Faculty of Health Sciences, University of Ss. Cyril and Methodius in Trnava, 917 01 Trnava, Slovakia; gabriela.kotyrova@ucm.sk
* Correspondence: filip.skala@uniba.sk; Tel.: +421-910-199-906

Abstract

Caffeine may enhance motor and cognitive performance in soccer players, yet its effects on specific agility components remain unclear. Sixteen male amateur soccer players (23.5 ± 4.0 years) completed a randomized, double-blind, placebo-controlled crossover trial. Participants ingested 300 mg of caffeine (~3.7 mg·kg^{-1}; CAF) or placebo (PLA). Thirty to 45 min after ingestion, they performed a countermovement jump (CMJ), drop jump (DJ), and three Y-shaped agility tests: planned agility, reactive agility to a light stimulus, and reactive agility to a human stimulus. Paired *t*-tests and Hedges' g effect sizes (95% CI) were used to compare conditions. Caffeine significantly improved CMJ height ($p = 0.02$, ES = 0.30), reactive strength index in the DJ ($p = 0.02$, ES = 0.35), and planned agility time ($p = 0.02$, ES = 0.62). No significant effects were observed for reactive agility to light ($p = 0.32$, ES = 0.10) or human stimulus ($p = 0.06$, ES = 0.35). These findings suggest that a moderate caffeine dose enhances motor components of agility performance but provides limited benefits for reactive agility. Coaches may consider caffeine supplementation for amateur soccer players to support their performance in motor-dominant tasks rather than reactive agility performance.

Keywords: cognition; change of direction speed; neuromuscular performance; supplementation

1. Introduction

Caffeine (1,3,7-trimethylxanthine) is a naturally occurring alkaloid that acts as a central nervous system (CNS) stimulant [1]. Its use in sports has increased significantly since its removal from the World Anti-Doping Agency (WADA) list of prohibited substances in 2004, leading to extensive scientific research into its potential as an ergogenic aid. Caffeine is rapidly absorbed after ingestion and reaches maximum plasma concentrations in approximately 45 to 60 min, with a half-life of 3 to 5 h [2]. Its ergogenic effect is increasing nerve excitability, promoting alertness, reducing the perception of exertion, and delaying fatigue [3,4]. In addition, caffeine also has peripheral effects on skeletal muscle. It promotes the release of calcium from the sarcoplasmic reticulum, increases Na^+/K^+ pump activity, and improves motor unit recruitment. These alterations lead to increased muscle contractile force [5,6].

Besides enhancing endurance performance and delaying the onset of fatigue [7,8], caffeine has the potential to acutely improve anaerobic and explosive performance. Several studies have confirmed improvements in maximum strength, jump height, or sprint performance after caffeine administration [9–11], while others have not observed any significant

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ergogenic effect [12]. These differences may be related to the performance level of the participants, their habit of consuming caffeine, genetic polymorphisms, or different testing methodologies [7,11,13]. An area that remains insufficiently explored relates to differences in the response to caffeine according to the performance level of athletes [11]. Furthermore, extensive previous research has focused on the ergogenic effects of caffeine on physical performance. Even though physical performance very likely improves after the ingestion of caffeine, the literature on its effects on sensorimotor and cognitive functions in soccer players is still limited, and the results are inconsistent [14,15].

Sensorimotor and cognitive functions in soccer are undeniably important [16]. These functions are integral components of agility performance. Young et al. [17] describe that reactive agility (i.e., the subject changes the direction of movement in reaction to the environment) includes physical, technical, and cognitive factors of performance. Caffeine may enhance the physical component of agility through its effect on explosive strength [18]. There is a direct link between explosive strength and change-of-direction (COD) speed (i.e., planned agility) in team sport players [19]. However, cognitive domains such as visual scanning, anticipation, pattern recognition, and knowledge of the situation are linked exclusively to reactive agility performance [17,20]. The majority of studies have shown improvements in reactive agility and reaction speed after caffeine intake [21–24], while decision-making and sport-specific skill improvements are limited [25–27].

Limited research has pointed out differences between physical and cognitive factors of agility. Planned and reactive agility are considered distinct skills [17]. In addition, there are also different domains influencing players' reaction to light stimuli or live human movement [28]. This difference lies mainly in the experience and anticipation skills of players [29]. Even though previous research describes significant improvements in cognitive performance of soccer players mediated by caffeine intake [30], there are still discrepancies regarding its effect on reactive agility [31,32] or soccer-specific performance [26]. One of the questions that remains unresolved concerns the response of amateur soccer players to caffeine and its influence on reactive agility. This is particularly relevant when considering responses to live human versus light-based stimuli. These responses may differ in the engagement of distinct neural pathways and mechanisms underlying perceptual-cognitive coupling [28].

Additionally, improvements in motor and cognitive function promoted by caffeine are dose-dependent. Doses of approximately 3 to 7 mg/kg (~200 to 500 mg) ingested ~1 h prior to exercise can enhance motor performance within a large interindividual variation [33]. While numerous studies have investigated caffeine intake in non-specifically trained male or female subjects, youth athletes, and elite athletic populations, the present study focused specifically on amateur soccer players. We aimed to discover differential effects of a moderate dose of caffeine (300 mg; ~3.7 mg/kg) on motor and cognitive components of agility. Comparing three agility scenarios, i.e., planned conditions, light stimulus reaction, and human stimulus reaction, this study further aims to clarify whether caffeine preferentially enhances physical or cognitive aspects of agility performance. We hypothesized that caffeine would enhance both motor-dominant tasks and perceptual-cognitive components of reactive agility, although to different degrees. We further aimed to examine the differential effects of caffeine on various reaction types within reactive agility tasks. These findings may help practitioners to administer an evidence-based dose of caffeine for performance enhancement of players and highlight the need for further research on reactive agility and its underlying cognitive domains.

2. Materials and Methods

2.1. Participants

The sixteen amateur soccer players (age: 23.5 ± 4.0 years, body mass: 80.3 ± 7.8 kg, height: 181.6 ± 6.7 cm) participated in the study. All participants were active players who regularly participated in their teams' training programs and had no current health restrictions. They were competing in lower-tier leagues, representing clubs from the third to fifth tiers of the Slovak league and the fifth to sixth tiers of the Austrian league systems. Eligibility for participation was assessed through a pre-selection online questionnaire which collected age, level of soccer experience, health status, and recent injuries. This tool was used to assess whether the players met the requirements for participation in the study. Players with recent musculoskeletal injuries, acute illnesses, cardiovascular or neurological disorders, visual impairments, or significant sleep disorders were excluded from the study. Goalkeepers were also excluded from the analysis, as their movement patterns and playing load differ significantly from those of field players. Habitual caffeine intake was assessed using a validated questionnaire adapted from Bühler et al. [33], which tracked the frequency of caffeine-containing foods and beverages. Based on these data, individual differences in habitual caffeine consumption were identified, and subjects with a habitual caffeine intake exceeding 400 mg per day were excluded from the study. Excessive caffeine intake can lead to negative effects that could affect athletic performance and distort study results [34]. Initially, 30 soccer players completed the questionnaire, of whom 24 subjects subsequently met all inclusion criteria. Due to non-participation in the second measurement session or injuries during preparation, the final analyzed sample was adjusted to sixteen participants.

All participants were thoroughly informed about the objectives and planned procedures of the study and provided written informed consent. This study was retrospectively registered at ClinicalTrials.gov (NCT07844122). At the time of study initiation, the authors did not consider a trial registration necessary. The study was subsequently registered at the request of the journal during the publication process. The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and was officially approved by the Ethics Committee of the Faculty of Physical Education and Sport, Comenius University in Bratislava (Approval No. 15/2024).

2.2. Experimental Design

The study employed a randomized, double-blind, placebo-controlled crossover design to investigate the acute effects of caffeine on explosive lower-body power and agility in amateur soccer players. Each participant underwent two testing sessions under different conditions: (I) caffeine and (II) placebo. The order of conditions was randomly determined for each participant using an independent online generator (random.org). Simple randomization was used, without stratification or blocking. This randomization was performed by an investigator not involved in testing. Supplementation was administered as caffeine capsules (Scitec Nutrition Caffeine, Scitec Nutrition, Budapest, Hungary, 100 mg per capsule) or placebo capsules filled with potato starch. Participants received 300 mg of caffeine, which represented approximately 3.74 mg·kg^{-1} of mean body mass. This dosage corresponded to an individual dose ranging from 3.16 to 4.44 mg·kg^{-1} of body mass. The capsules were visually identical, and neither the testers nor the participants were aware of the assigned condition. A week before the first measurement, all participants underwent a familiarization session during which anthropometric data were collected, and the testing procedures were practiced. Throughout the experiment, they were required to follow the same training regimen, refrain from consuming caffeinated products for at least 24 h prior to testing, and avoid intense physical activity on the previous day. Diet, fluid intake, and sleep were not standardized or monitored before testing.

On both test days, participants received caffeine or a placebo in the laboratory. Thirty minutes after supplementation, all participants underwent a standardized warm-up consisting of dynamic aerobic and activation exercises. The warm-up included one minute of jumping jacks, followed by forward and lateral lunges, three dynamic stretching exercises, and three countermovement jumps. Before the agility tests, elements of athletic drills and one trial of the planned agility test on both sides were included to ensure optimal neuromuscular activation before the actual performance. Testing began after the standardized warm-up and was completed within a 15-min window to correspond to the typical onset of physiological effects of caffeine [35]. Firstly, explosive strength tests were performed under laboratory conditions. Specifically, the countermovement jump (CMJ) and drop jump (DJ) tests were performed. Immediately after completing these tests, the participants moved to an artificial turf field, where they underwent a series of agility tests in a fixed order: planned agility (Y-shaped planned agility test), reactive agility to a light stimulus (Y-shaped light reactive agility), and reactive agility to a live stimulus (Y-shaped live reactive agility). The order of the tests was identical in both experimental conditions, meaning that participants performed the CMJ, DJ, Y-shaped planned agility, reactive light-stimulus, and reactive live-stimulus tests in a fixed order. The tests were conducted during the same part of the season (November–December) and at the same time of day to minimize the influence of circadian variation. Individual visits were separated by a seven-day interval, which provided sufficient time for recovery and ensured consistency in the training load of participants throughout the experiment. A schematic overview of the experiment is shown in Figure 1.

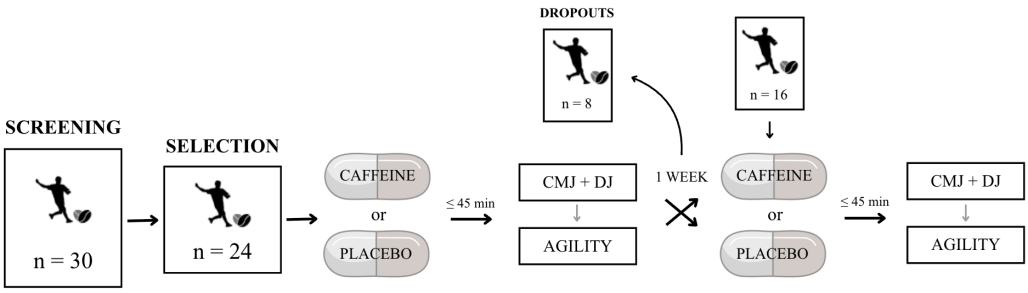


Figure 1. Schematic experimental design of the study. CMJ = countermovement jump; DJ = drop jump.

2.2.1. Vertical Jump Tests

The countermovement jump (CMJ) without an arm swing was implemented as a valid and reliable method for evaluating lower-limb explosive power. Participants initiated the movement from an upright standing position with their hands placed on their hips. They were then instructed to bend their knees to approximately 90° and jump as high as possible. This CMJ protocol is considered a standardized testing procedure to measure lower-limb explosive power in team sports [36]. Three trials were performed, with approximately 30 s of rest between attempts. The highest jump height was recorded as the outcome of the testing procedure.

The drop jump (DJ) from a height of 30 cm was employed to evaluate the reactive strength of the lower limbs. Participants initiated the test by standing on a 30 cm box with their hands positioned on their hips. They were instructed to step off the box, land with both feet simultaneously, and rapidly execute a maximal vertical jump while minimizing ground contact time (CT). Flight time (ms) and ground CT (ms) were recorded for each jump. The reactive strength index (RSI) calculated from these variables was considered as the outcome for this assessment. The RSI has been shown to be a valid and reliable indicator of explosive performance [37]. Three trials were conducted, with approximately 30 s of rest between attempts. The jump with the highest RSI was recorded as the result

of the assessment. Both jump tests were assessed using the OptoGait system (Microgate, Bolzano, Italy).

2.2.2. Planned and Reactive Agility Tests

To measure the level of agility, we employed the Y-shaped setup of tests [38,39] using a Witty GATE system with an integrated Witty SEM sensor (Microgate, Bolzano, Italy). Subjects had to start from 30 cm behind the starting gate and change the direction of movement in the area marked with cones in the middle of the whole running distance (Figure 2). There were three types of testing procedures. In the first procedure, subjects were instructed about the COD prior to the trial. A total of four trials were performed, with two direction changes to each side. This procedure measured the level of planned agility, i.e., COD speed. The second procedure included a light sensor that triggered the green arrow stimulus with a delay of 500 ms after breaking the beam of the starting gate. The side of the stimulus was randomly assigned by the system. This procedure was finished after the system assigned two CODs to each side. The third procedure included a human stimulus [28]. A tester stood 4 m from the middle cone gate. Once the subject crossed the first cone gate 2.5 m from the starting line, the tester performed one of the two possible movements in a randomized order: 1. Step forward with the right foot and change direction to the left, 2. Step forward with the left foot and change direction to the right. The subject had to evade the movement, meaning they should run to the opposite final gate. Four trials consisting of two randomized CODs to each side were performed. In case a participant made a technical error, slipped, or chose an incorrect gate, a new repetition was permitted. If the light or live reactive agility time was lower than or equal to the planned agility time, the trial was considered invalid and repeated. This helped to reduce possible bias where subjects anticipated the side of COD.

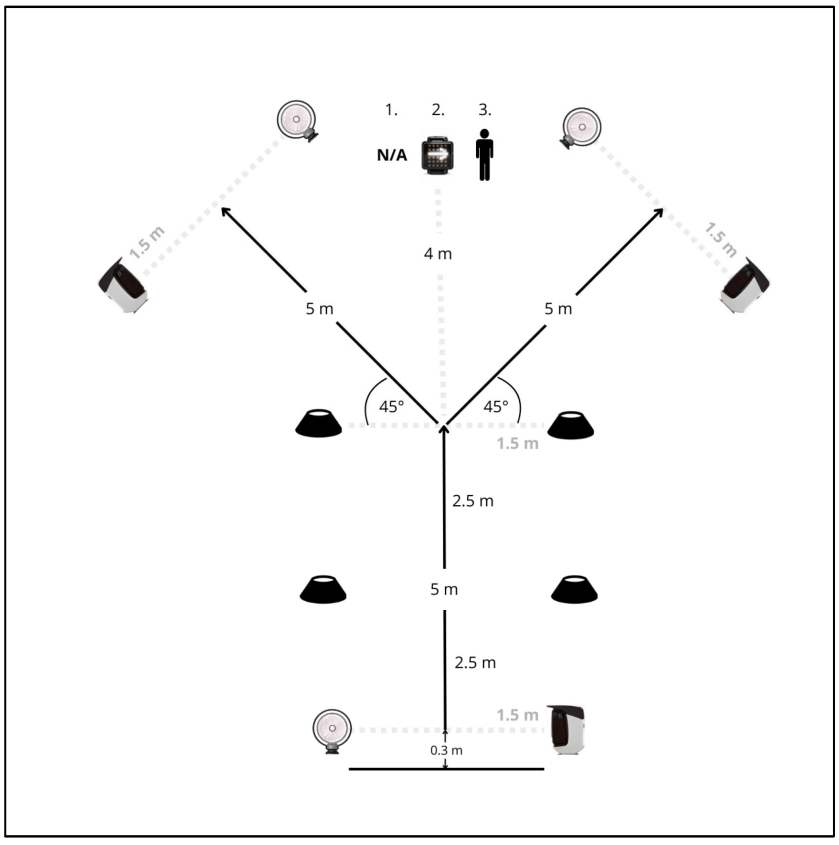


Figure 2. Setup of Y-shaped planned and reactive agility tests.

2.3. Statistical Analysis

The statistical power for the sample size was computed using G*Power (Version 3.1.9.6, Institut für Experimentelle Psychologie, Düsseldorf, Germany). The power was established a priori for an effect of 0.5 with a power of $1 - \beta = 0.80$ and $\alpha = 0.05$ ($n = 24$). Due to participant dropout for objective reasons, the final sample ($n = 16$) provided a power of $1 - \beta = 0.60$. The Shapiro-Wilk test was used to assess the normality of the data. A paired-sample *t*-test compared performance after placebo and caffeine ingestion. Differences between conditions were further expressed as standardized mean differences of effect size with a 95% confidence interval (95% CI) [40]. Thresholds for effect size (ES) statistics (Hedges' g) were defined as follows: <0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; and >2.0, very large [40,41]. Statistical analyses were conducted utilizing GraphPad Prism software version 10.3.1 (GraphPad Software, San Diego, CA, USA).

3. Results

Caffeine intake significantly improved the explosive strength of soccer players. CMJ height was higher in the CAF group compared to the PLA group (40.83 ± 4.59 vs. 39.63 ± 3.26 cm, $p = 0.02$, ES = 0.30). Reactive strength in the DJ test showed a higher RSI in the CAF group (1.72 ± 0.29 vs. 1.61 ± 0.34; $p = 0.02$, ES = 0.35). Agility performance improved in the planned agility test. The CAF group exhibited lower planned agility time compared with the PLA group (1.882 ± 0.050 vs. 1.918 ± 0.058 s, $p = 0.02$, ES = 0.62). However, reactive agility times in reactions to the light and human stimulus were not enhanced when comparing the CAF and PLA groups (1.978 ± 0.076 vs. 1.985 ± 0.052 s, $p = 0.32$; ES = 0.10; and 1.964 ± 0.098 vs. 1.994 ± 0.069 s, $p = 0.06$; ES = 0.35; respectively). A graphical description and comparison of groups are illustrated in Figure 3.

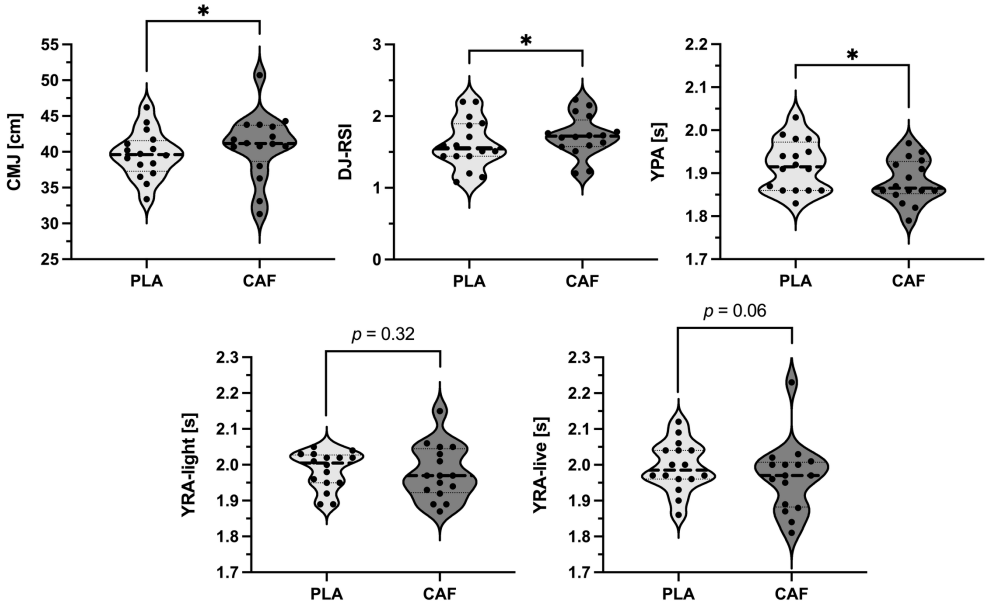


Figure 3. Comparison of explosive strength of lower limbs and agility performance between caffeine (CAF) and placebo (PLA) conditions. CMJ = countermovement jump; DJ-RSI = drop jump reactive strength index; YPA = Y-planned agility test time; YRA-light = Y-reactive agility test time (light stimulus); YRA-live = Y-reactive agility test time (human stimulus). * $p < 0.05$ between conditions.

Standardized Hedges' g value showed that caffeine ingestion produced a small, beneficial but unclear effect on CMJ performance (+1.20 ± 2.15 cm, ES (95% CI) = 0.30 (0.02, 0.58)) and RSI in the DJ test (+0.11 ± 0.20, ES = 0.35 (0.00, 0.68)). Planned agility performance improved with a moderate, beneficial but unclear effect (–0.036 ± 0.065 s, ES = 0.62 (0.02,

1.28)). Caffeine produced a trivial and unclear effect on light reactive agility performance (–0.007 ± 0.058 s, ES = 0.10 [–0.33, 0.54]) whereas human reactive agility performance exhibited a small unclear effect of caffeine (–0.030 ± 0.072 s, ES = 0.35 (−0.08, 0.78)). The effect size estimates and their 95% CIs for CAF vs. PLA conditions are illustrated in Figure 4.

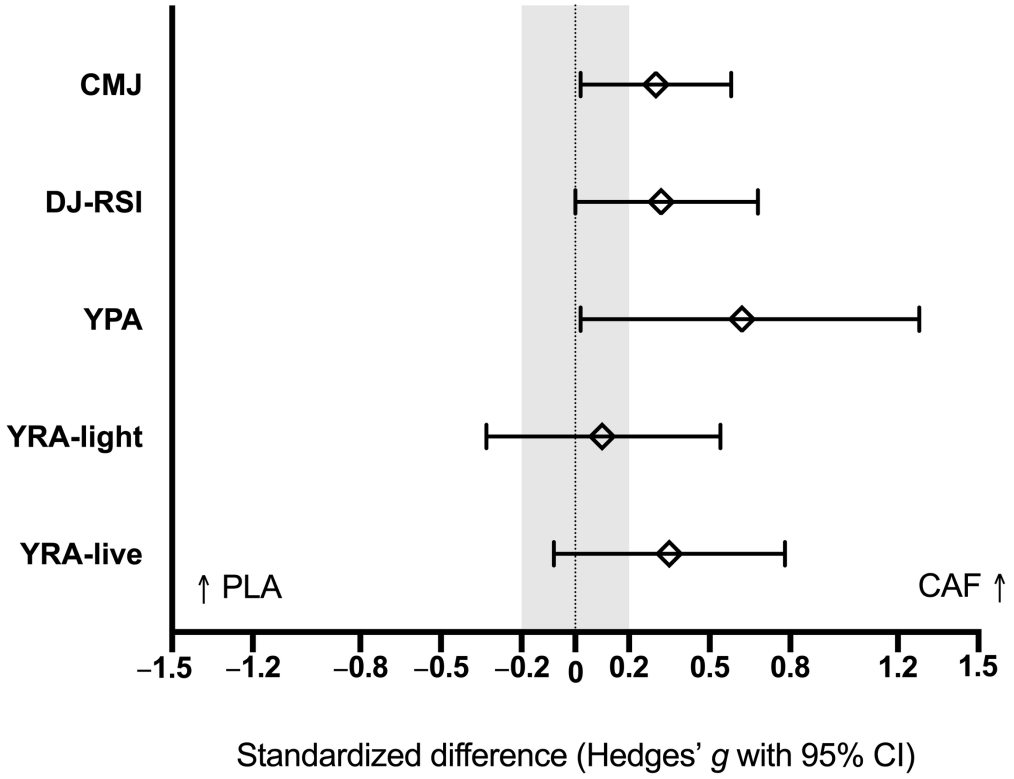


Figure 4. Standardized Hedges' g differences in effects of caffeine and placebo ingestion on lower limb explosive strength and agility performance. CMJ = countermovement jump; DJ-RSI = drop jump reactive strength index; YPA = Y-planned agility test time; YRA-light = Y-reactive agility test time (light stimulus); YRA-live = Y-reactive agility test time (human stimulus); CAF = in favor of caffeine; PLA = in favor of placebo. The gray area represents the region of trivial effect sizes.

4. Discussion

Caffeine ingestion provides an ergogenic effect, predominantly on neuromuscular performance of amateur soccer players. In the specific dynamic conditions, caffeine improved planned change-of-direction performance but did not significantly improve total reactive agility time in response to either a light or human stimulus. Our results show that caffeine ingestion tends to improve explosive strength and planned agility in soccer players. However, the effect size confidence intervals overlapped trivial values, suggesting that the effects were unclear. Agility tasks that require sensorimotor engagement exhibited greater variability and uncertainty. These findings suggest that caffeine may be less effective for complex, decision-driven agility tasks than for pre-planned or explosive actions.

4.1. Effects of Caffeine on Motor Performance

Numerous systematic reviews and meta-analyses have demonstrated that 3 to 6 mg/kg of caffeine consumed 30 to 60 min prior to exercise can increase vertical jump height and acceleration speed in soccer players [42,43]. Less is known about these effects when induced by a moderate dosage of caffeine in amateur players. Previous research on this topic has mainly focused on elite populations or cohorts of athletes responding to higher doses of caffeine [43,44]. In our study, a uniform dosage of 300 mg (averaging 3.74 mg/kg) improved

both CMJ (3%) and DJ (6.9%) performance. The practical effects ranged from trivial to moderate based on the 95% CIs, with an approximately 1.2 cm improvement in CMJ height and a 0.11 improvement in DJ-RSI. This is in accordance with the 3 mg/kg dose used by Del Coso et al. [45], who observed a mean 3.2% increment in jump height in semi-professional players. However, those authors administered caffeine via a sugar-free energy drink instead of other pure forms. A very similar increment and its effect size occurred in a group of resistance-trained men after chewing a caffeinated gum 10 min prior to testing (ES = 0.21; 3.7%) [46]. Caffeine improves voluntary activation of the quadriceps muscles responsible for vertical jumping [47]. This activation, coupled with improvements in intramuscular and intermuscular synchronization during muscle contraction, indicates higher motor unit recruitment during the explosive movement [18].

Even though the effect sizes in vertical jump and RSI were rather small (ES = 0.30 and 0.35; respectively), the transfer of improved neuromuscular functions caused by acute caffeine intake [48] can be visible in other aspects of performance. We found that planned agility time decreased by 1.9% due to caffeine ingestion (ES = 0.62). Again, the 95% CIs indicated a wide range of effects, suggesting higher interindividual variability in planned agility performance after caffeine ingestion. However, the data showed that the effect was generally positive. In practice, the 36 ms difference might seem small but statistically significant. A similar effect was reported in a basketball-specific planned agility test (ES = 0.61), when national-level players took 5 mg/kg of caffeine in the morning at 10 a.m. [49]. In soccer players, a dosage of 3 mg/kg slightly decreased the arrowhead agility test time. However, the decrements of 0.08 to 0.12 s were not considered significant [50]. The dosage of caffeine might be one of the possible explanations for the differential effect sizes found by these authors. In pre-planned conditions, changes of direction are dependent on both explosive and reactive strength, combined with the rapid changes in velocity of whole body or body segments [51]. An explanation for smaller effects of caffeine on jump height and RSI is well illustrated by Merino Fernández et al. [52]. In their study, Jiu-Jitsu athletes improved in CMJ height by 4.4% (flight-time method ES = 0.25). However, by analyzing different phases of the CMJ it was found that flight time:contraction time ratio and RSI-modified improved by 8.9% and 11.5%, respectively. Thus, the benefits of caffeine for athletes may not be attributed to a large increase in power production but rather to faster production of force. Practitioners might be aware of possible minor improvements in explosive strength and planned agility performance but should be cautious about the possible downsides of caffeine ingestion, such as gastrointestinal discomfort or nervousness.

Another way in which caffeine can support athletes is by preventing performance decline under fatigued conditions. Dosages such as 3 mg/kg are sufficient to target fatigue and maintain the level of neuromuscular performance following exhaustive intermittent exercise [50]. There is also a potential for improvement in planned agility performance under fatigued conditions. An intake of 6 mg/kg of caffeine reduced Illinois agility time by 2.8% with a large effect size (ES = 1.20) in amateur soccer players [53]. Similarly, youth amateur players can maintain their neuromuscular performance in training using 4 mg/kg of caffeine [54]. The effects of caffeine on COD speed (i.e., planned agility) may be variable, but this substance has notable potential to enhance or maintain performance in anaerobic tasks during exhaustive games or training. Our findings indicate trivial to small effects of 3.74 mg/kg of caffeine on the physical factor of agility performance in amateur soccer players. A meta-analysis indicates that the minimal ergogenic effect of acute caffeine intake occurs at approximately 1 to 2 mg/kg. This level is equivalent to a dose of caffeine in one to two cups of coffee [55]. However, higher doses, such as ≥6 mg/kg, appear to be more effective in boosting planned agility performance in amateur team sport players [56].

4.2. Effects of Caffeine on Perceptual-Cognitive Performance

Caffeine strengthens sensorimotor aspects of athletic performance predominantly by stimulating the CNS as an adenosine antagonist. Our data showed non-significant alterations in reactive agility performance in the caffeine condition. Domains such as alertness and reaction speed tend to improve with caffeine, while athletes experience reduced perceived fatigue [57]. Our results indicate a limited transfer of these domains to reactive agility performance.

Several studies have reported positive effects of caffeine on reactive agility performance. For example, 6 mg/kg of caffeine produced faster reactive agility performance in elite male youth soccer players. However, the subjects in the mentioned study were 14-year-old soccer players [24]. According to Duvnjak-Zaknich et al. [21], caffeine ingestion improves reactive agility when participants are either fresh or fatigued. Using a live stimulus protocol with video presentation on the screen, total time in the Y-shaped reactive agility test decreased by 3.9%. In our study, we found a 1.5% decrease in live reactive agility time induced by caffeine. However, this decrement was not significant ($p = 0.06$, ES = 0.35). Interestingly, the same study [21] found decreased decision time by 9.3%, whereas motor execution time decreased by only 2.7%. This analysis shows that 6 mg/kg of caffeine successfully improves sensory processing and decision-making in reactive tasks. Although agility performance when reacting to a live opponent tended to improve with a uniform dosage of caffeine, averaging 3.74 mg/kg, the 95% CI pointed to an unclear result (−0.08 to 0.78).

Differences between our results and previous findings may be caused by a lower dosage of caffeine used in our experiment. The importance of higher caffeine dosages for enhancing decision-making in the live reactive agility task is supported by Egesoy & Öksüzoğlu [22]. These authors found that youth soccer players (16.5 ± 0.5 years) significantly decreased their decision time (–0.06 s) in the live reactive agility task. However, the fraction of the test in which motor performance was separated (i.e., sprint time) was not significantly lower compared to the placebo condition. These studies indicate that sensory processing and decision-making in Y-shaped reactive tests are possibly enhanced by caffeine. However, we only found slightly decreased live reactive agility time (–0.03 s, $p = 0.06$) and no alternation in the light reactive agility time. This indicates that a moderate dose of caffeine may influence visual scanning and pattern recognition without a significant impact on the speed of sensory processing in amateur players. At the same time, we cannot clearly distinguish between these domains because we did not assess them directly. Instead, we compared agility times in response to light and live stimuli, which may differ in their engagement of perceptual-cognitive functions. However, another study found that 4 mg/kg of caffeine is effective in improving visual perception in a dynamic scenario [58]. To confirm the theory that caffeine has a greater effect on the live compared to light reaction in athletes, further research in this field is needed.

Although some studies have shown limited effects of caffeine on cognitive aspects of performance in soccer players, Jafari et al. [26] describe a negative impact of a 3 mg/kg caffeine dose on decision-making skills in young soccer players. They found that performance in more complex computerized tasks was not affected by caffeine. Additionally, caffeine possibly diminished performance in a soccer-specific passing test that required decision-making and accuracy of passing (−3.5%; $p = 0.08$). A higher dose of 5 mg/kg produced mixed results when tactical performance in games was evaluated [25]. While caffeine reduces simple and choice reaction times, its effects on advanced cognitive functions, including decision-making and tactical judgment, are inconsistent and may be detrimental under high cognitive load [25,31]. Certain studies indicate diminished decision-making accuracy in soccer-related activities following caffeine ingestion [26,27]. These effects are possibly related to impulsivity and cognitive control of athletes. Higher caffeine intake has

the potential to make players anxious and overly impulsive in their decision-making [59]. Therefore, team sport players need to be careful when using higher doses of caffeine to improve decision-making processes. Lastly, the analysis of the literature identified studies utilizing different forms of caffeine intake, such as caffeinated beverages, chewing gum, or the method of mouth rinsing. For example, caffeine mouth rinsing seems to improve selected aspects of soccer-specific performance [60], although further research is needed on this topic. It remains unknown whether this method would influence planned and reactive agility differently compared with conventional caffeine intake.

4.3. Limitations and Further Directions for Research

Our study is limited by lower statistical power due to a small sample size. However, previous studies have shown small to medium effect sizes based on similar sample sizes [21,24,26]. In addition, generalization of the results is restricted due to relative differences in caffeine intake. We used a fixed absolute dose of caffeine (300 mg). However, this approach likely mimics the use of amateur players who prefer supplementation via pills. To our knowledge, this is the first crossover trial using a dose of 3 to 4 mg/kg of caffeine to evaluate explosive strength, COD speed, and different forms of reactive agility performance simultaneously. Additionally, we did not objectively measure the effectiveness of blinding the caffeine effects. Nevertheless, many participants incorrectly identified the treatment they received, suggesting that they could not consistently distinguish between caffeine and placebo conditions while testing. Lastly, this study applied paired-samples *t*-tests without adjustment for multiple comparisons, which may have increased the risk of Type I error. Therefore, these findings should be interpreted with caution. Further research could replicate and enhance our methodology to examine the effects of caffeine on motor and cognitive aspects of agility under fatigued conditions.

Caffeine was administered in a crossover, randomized, double-blind design, excluding habitual high caffeine consumers. In addition, subjects had no previous history of caffeine intake for performance enhancement. Therefore, possible bias in our findings was minimized. However, we admit that the 24 h caffeine abstinence may have introduced minor withdrawal effects and contributed to interindividual variability in responsiveness to caffeine.

On the other hand, performance could not be measured at a single time point, but rather within a 15-min window due to the administration of multiple tests. We consider this approach as ecologically valid for soccer players, as it reflects the need for sustained performance during training and matches rather than in "one-shot" scenarios. Further studies might examine the responses of amateur-level soccer players, both male and female, to different types of exhaustive exercise or cognitively demanding tasks and investigate the effects of caffeine on decision-making ability. These studies should consider athletes' competitive level or habitual caffeine exposure in addition to caffeine dosage, as potential factors contributing to their responsiveness to caffeine.

5. Conclusions

Caffeine provides a greater ergogenic effect on the motor component of agility than on its perceptual and cognitive aspects in amateur soccer players. The effects are demonstrated by increased countermovement jump height, reactive strength index in drop jump, and reduced planned agility time under caffeine conditions compared to placebo. Minor alterations in performance occurred in the reactive task responding to a human stimulus. However, caffeine was ineffective in improving performance in the reactive task involving a light stimulus. Amateur soccer players may practically use ~3.7 mg·kg^{-1} of caffeine ingested 30 to 45 min before exercise to enhance their explosive power and change-of-direction speed.

Perceptual-cognitive improvements are likely to be limited. Since effect size estimates indicated some uncertainty in the magnitude of the observed effects, our findings should be interpreted with caution. Future studies should increase the sample size and investigate the effects of higher doses of caffeine on reactive agility performance and examine these effects in decision-making tasks.

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Abbreviations

The following abbreviations are used in this manuscript:

CNS	Central nervous system
WADA	World Anti-Doping Agency
COD	Change of direction
CAF	Caffeine (condition)
PLA	Placebo (condition)
CMJ	Countermovement jump
DJ	Drop jump
RSI	Reactive strength index
CT	Contact time
ES	Effect size
YPA	Y-shaped planned agility
YRA	Y-shaped reactive agility

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