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Effects of Caffeine on Tennis Serve Accuracy

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ABSTRACT

International Journal of Exercise Science 12(6): 1290-1301, 2019. This study examined the effects of caffeine on tennis serve accuracy. Division II tennis athletes (n = 10) completed two serve trials (double-blind, counterbalanced) following ingestion of 6 mg/kg of caffeine or matched placebo an hour prior to data collection. During each tennis serve trial, participants completed 48 non-fault serves divided into 3 sets with 2 serves per 8 different targets. Following each 2 serves per target format, participants completed a shuttle run sprint. Separate 2 (trial) x 8 (targets) repeated measures analysis of variances (ANOVAs) were used for distances from the target center "delta", and necessary tries for each of the 3 sets. A 2 (treatment) x 3 (set) repeated measures ANOVA was used for shuttle run times. While results were not significant, the treatment main effect approached significance (p = 0.07) in set 2 for the delta of distances when comparing caffeine (96.2 cm ± 19.8) versus placebo (107.1 cm ± 16.3). While there was no significance in sprint times, each sprint was consistently faster following caffeine consumption. Post-trial surveys revealed subjective responses approached significance with greater feelings of stomach distress (p = 0.08) and nervousness (p = 0.13) following caffeine and elevated feeling of fatigue (p = 0.19) following placebo. Therefore, with no impairment in serve accuracy coupled with some evidence of reduced fatigue, results suggest caffeine may benefit tennis athletes. Extending the understanding of the effects of caffeine on tennis serve accuracy and performance could benefit overall match performance, with the potential of improving the match outcome in extended playtime.

KEY WORDS: Ergogenic aid, precision, tennis performance

INTRODUCTION

Athletes commonly consume caffeine as an ergogenic aid to enhance sport performance (9). Caffeine has been shown to influence a variety of exercise paradigms including aerobic performance (3, 7), anaerobic performance (1-2, 5), and muscular strength (10, 14, 19, 27). Specifically, motor skills such as reaction time (6, 21), agility, and accuracy are common and important factors in many sports and the enhancement of such skills may benefit performance in high-intensity intermittent sports (26). Not only have significant ergogenic effects been reported in sprint, power, and accuracy tasks, but reduced fatigue on specific rugby-like movements has been observed following caffeine ingestion (26). Additionally, caffeine may blunt in task ratings of perceived exertion (RPE; 10) and overall sessions RPE (16). While caffeine consumption is likely to continue due to the ergogenic effect at a dosage acceptable to the International Olympic Committee (9), there remain questions regarding potential effects on intermittent sport performance tasks and skills.

Tennis is a complex sport significantly engaging both aerobic and anaerobic metabolic pathways (17). Previous research found caffeine had a significant positive impact on enhancing tennis performance during a tennis skill test for shot accuracy (8, 17). It has also shown to improve serve performance through increasing tennis serve velocity in the latter stages of a simulated match (12). Despite previous research examining effects of caffeine on tennis performance, little is known regarding effects of caffeine on tennis serve accuracy. One of the main components of a serve is the accuracy in which the server hits the diagonal service box at the location desired; however, this component can be affected by neuromuscular fatigue occurring during long tennis matches (12, 18). Fatigue has a significant negative impact on upper body muscles which may contribute to a decrease in server performance (4). Additionally, fatigue also contributes to changes in maximal angular velocities and joint kinetics which can directly impact one's serve skills (15, 20).

Although Reyner and Horne (24) found an 80mg caffeinated drink had no beneficial effect on tennis serve accuracy when participants were sleep-restricted, this is not the typical state of collegiate athletes. Also, in this study the dose of caffeine used was too small to expect benefits (80 mg), and therefore the effect of caffeine on tennis serve accuracy is not well-understood (24). It is hypothesized caffeine supplementation would increase tennis serve accuracy similar to how it increased tennis serve velocity when a moderate dosage of caffeine was consumed (12). Therefore, the purpose of this study was to determine the effects of caffeine ingestion (6 mg/kg) on the tennis serve accuracy.

METHODS

Participants

Ten Division II, collegiate tennis players (males n = 5, females n = 5), volunteered as participants (Table 1). Prior to data collection, the university institutional review board for protection of human subjects approved all procedures and each participant signed a written informed consent outlining study requirements. During the initial visit, a stadiometer and digital scale (BWB-800, Tanita Inc., Tokyo, Japan) were used to measure body mass (kg) and height (cm). Percent body fat was also estimated (23) using skinfold measurements (Lange, Cambridge, MD, USA) at three sites (males: chest, abdomen, thigh; females: triceps, supra iliac, thigh). A survey of average daily caffeine consumption over a five-day period was administered and used to identify habitual caffeine users for potential follow-up analyses (25). A list of foods and beverages containing caffeine was provided to participants to avoid omission of caffeine consumption.

Table 1. Descriptive characteristics for participants (n = 10).

Variable	Mean	SD
Age (years)	19.9	1.8
Height (cm)	177.2	7.2
Weight (kg)	71.7	10.6
Body Fat (%)	15.4	8.6
Average daily caffeine consumption (mg)	201.9	185.0

Note. Values are means and standard deviations.

At the end of the initial visit, participants completed a familiarization session of the tennis serve trial described below. All protocols and procedures mimicked those used in the experimental trial with the exception of treatment (caffeine vs placebo). Following the initial visit, each participant received two 500mL bottles of water in an attempt for participants to report well hydrated for subsequent trials. One bottle was to be consumed the night before the first experimental trial and the other within an hour prior to data collection. In addition to the water, participants consumed either caffeine (6mg/kg body mass) or matched placebo (maltodextrin) capsules an hour prior to data collection. All caffeine and placebo capsules were identical in appearance and distributed in sealed containers. Additionally, participants received the exact number of placebo capsules as they did caffeine capsules. Treatment (caffeine vs. placebo) was randomly assigned and administered in a double-blind and counterbalanced manner. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (22).

Protocol

Caffeine versus placebo trials: Tennis serve trials consisted of 24 non-fault serves from each side to the opposite serve box side (48 serves total) to a designated target (Figure 1). Each participant reported to the university tennis courts on two separate occasions to complete serving trials. One session followed caffeine ingestion and the other followed a matched placebo ingestion with pre-treatment blinded to both the participant and investigator. Trials were counterbalanced to control for an ordering effect and completed within 10-14 days of one another. Participants were instructed to report to the tennis courts well rested (≥ 24 hours with no heavy physical activity), well hydrated, and with instructions to not consume any alcohol or caffeinated products 24 hours prior each trial. Each participant used their personal tennis racquet. Prior to the serve trials, participants completed a 10-minute warm-up of a typical practice, which was kept consistent between trials. During each tennis serve trial, participants used new Wilson tennis balls (Wilson US Open, Wilson Sporting Goods Co, Chicago, IL, USA).

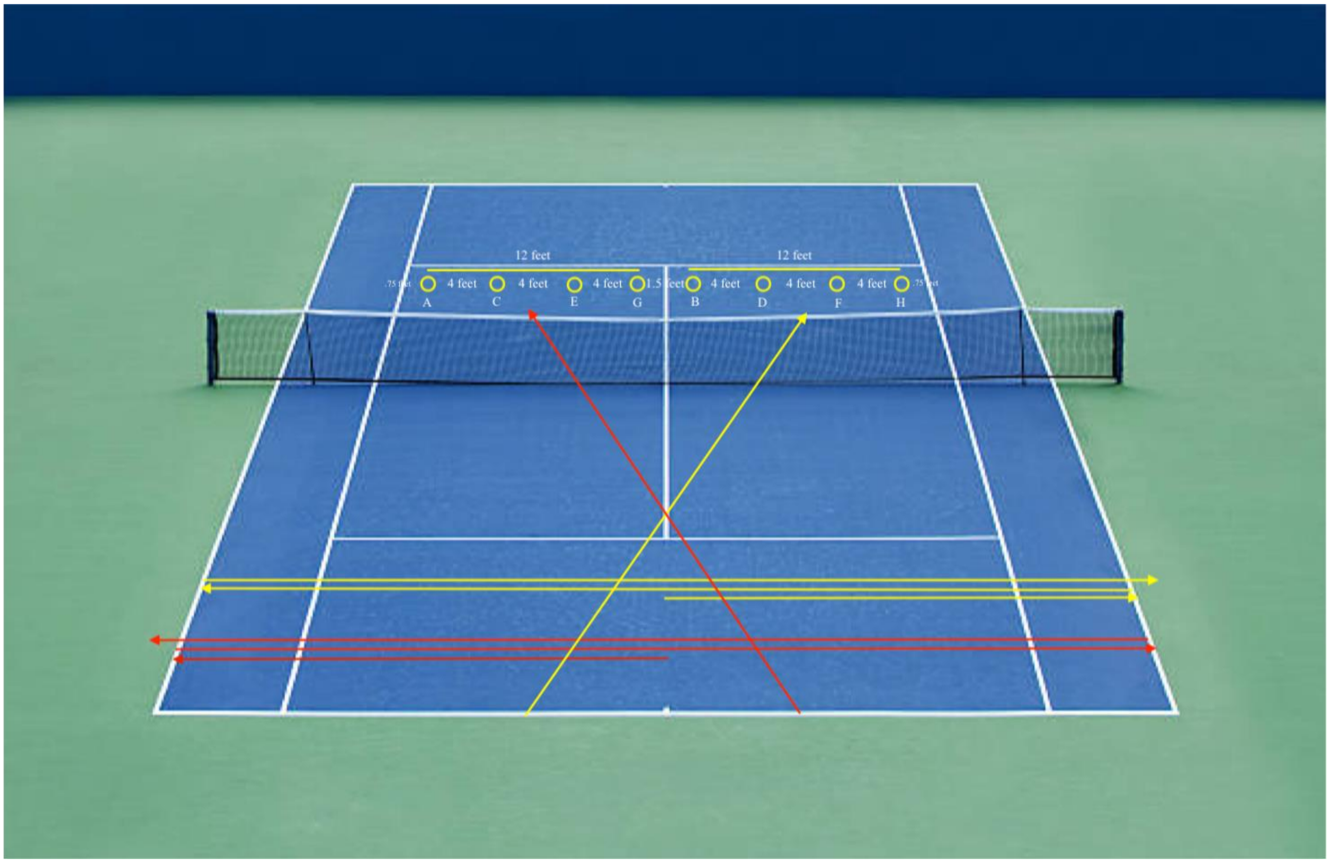

Figure 1. Target placement and measurements.

Participants completed "2 serves" on each side to a designated target; with instructions to hit the first serve as one would execute the "first serve" during a tennis match, and the second serve as one would execute a "second serve" during a match. Four designated targets were assigned in both service boxes: one target close to outside line of the service box (0.23 meters or 0.75 feet away), two targets in the middle of the service box, and one target close to the inside line ("down the T") of the court. Starting from the outside line of each service box**,** each target was 0.61 meters (2 feet) away from the service line with 1.22 meters **(**4 feet**)** between each target (Figure 1). This 2 serve format was completed at each of the 8 targets for each of the 3 sets to complete the total of 48 serves. Prior to serving, participants covered tennis balls with chalk powder to determine serve accuracy to the target. The distance from the chalk mark to the center of the target was recorded to the nearest 0.5 cm for each "non-fault" serve. In order for a serve to be considered "non-fault" it had to land in the appropriate serve box, as one would play during a singles tennis match.

Following each 2 serves, participants completed a shuttle run sprint on the court, while holding the racquet, to mimic the distance run during a tennis point on hard court. The shuttle run was 27.43 meters (90 feet) long: participants started the shuttle run facing the net in the middle of the court, sprinted to and touched the outside line ("the doubles line") of the court, changed direction and sprinted to the opposite line, and finally sprinted through the first line touched (see Figure 1). Depending on the side, participants completed the 2 serves, they were instructed to start the shuttle run sprint adjacent to mid-line on the opposite side, with completion of the serves on the "deuce side" to the left, and completion of the serves on the "advantage side" to the right. Shuttle run times were recorded to the nearest 0.01 second using timing gates (TC Timing System, Brower Timing Systems, Draper, Utah, USA). Once the shuttle run was completed, participants continued with the next serve trial on the opposite side until 48 non-fault serves were achieved. In between each set, participants had a passive recovery period of 2 minutes.

Following the completion of each serve trial (caffeine and placebo), participants completed a questionnaire using a ten-point Likert scale (11) to assess subjective feelings of negative symptoms (restlessness, tremors, stomach distress, fatigue, elevated mood, nervousness) potentially influenced by caffeine. For every question, a response of zero reflected that the symptom was "not at all experienced" and a ten reflected that it was "extremely experienced".

Statistical Analysis

Means and standard deviations were calculated for descriptive characteristics of participants. Separate 2 (trial) x 8 (target) repeated measures ANOVAs were used for distances deltas and tries for each of the 3 sets of serves. A separate 2 (treatment) x 3 (set) repeated measures ANOVAs was used for distances deltas, shuttle run times. When necessary, t tests were used for post-hoc follow-up comparisons. Paired t tests were used for subjective responses from the post-trial questionnaire for each dependent measure. Results were considered significant at $p < 0.05$.

RESULTS

When the delta for target distances were compared between trials, no significant difference was found in set 1 for main effects for treatment ($p = 0.88$, $n_p^2 = .003$) or targets ($p = 0.36$, $n_p^2 = .111$); nor for the interaction between treatment and target ($p = 0.12$, $n_p^2 = .159$). Importantly for set 2, a main effect for treatment approached significance ($p = 0.07$, $n_p^2 = .348$); whereas, the main effect of target was not significant ($p = 0.34$, $n_p^2 = .127$). The interaction between treatment and target approached significance ($p = 0.14$, $n_p^2 = .201$). Lastly, set 3 found the main effects did not reach significance for treatment ($p = 0.11$, $n_p^2 = .259$), and target ($p = 0.06$, $n_p^2 = .185$). There was also no significant interaction for treatment and target ($p = 0.90$, $n_p^2 = .041$). Because the main effect of treatment for set 2 approached significance ($p = 0.07$), paired *t*-tests (alpha = .05 each) were used to compare target deltas between treatment methods (i.e. caffeine and placebo) for each target at each set (Table 2a, 2b, 2c). When assessing serve accuracy between sets, no significant difference was in the main effects for treatment ($p = 0.97$, $n_p^2 = .00$, $n_p^2 = .189$), set ($p = 0.19$), or the interaction between treatment and set ($p = 0.20$, $n_p^2 = .195$).

Table 2a. Average means and standard deviation distance (cm) by treatment for caffeine versus placebo.

	Treatment	AVG
Set 1	Caffeine	106.3 ± 21.2
	Placebo	107.6 ± 14.5
Set 2	Caffeine	96.2 ± 19.8*
	Placebo	107.1 ± 16.3
Set 3	Caffeine	104.6 ± 12.5**
	Placebo	92.7 ± 17.7

Note. *p = 0.07, **p = 0.11; caffeine versus placebo.

Table 2b. Means and standard deviation distance (cm) by target (A to D) for caffeine versus placebo.

	Treatment	A	B	C	D
Set 1	Caffeine	118.3 ± 34.7	117.7 ± 33.3	112.9 ± 39.8	72.3 ± 42.5
	Placebo	108.0 ± 45.0	104.4 ± 36.0	94.8 ± 24.4	98.9 ± 33.8
Set 2	Caffeine	92.1 ± 40.7*	105.4 ± 48.4	113.9 ± 41.7	80.5 ± 41.5**
	Placebo	125.6 ± 30.3	87.0 ± 46.6	98.4 ± 25.9	113.2 ± 23.8
Set 3	Caffeine	115.2 ± 33.8	99.6 ± 43.9	104.1 ± 35.5	87.2 ± 37.8
	Placebo	106.8 ± 47.5	87.8 ± 35.8	83.6 ± 39.4	82.2 ± 30.0

Note. *p = 0.03, **p = 0.11; caffeine versus placebo.

Table 2c. Means and standard deviation distance (cm) by target (E to H) for caffeine versus placebo.

	Treatment	E	F	G	H
Set 1	Caffeine	92.3 ± 35.1	102.15 ± 44.6	102.0 ± 39.6	132.65 ± 64.5
	Placebo	111.25 ± 30.5	110.35 ± 42.9	123.75 ± 53.6	109.33 ± 43.4
Set 2	Caffeine	82.7 ± 26.6	104.9 ± 45.4	100.9 ± 72.0	98.7 ± 39.5*
	Placebo	85.9 ± 24.8	99.9 ± 33.9	94.7 ± 23.6	144.4 ± 53.9
Set 3	Caffeine	89.9 ± 26.9	106.0 ± 52.8	111.7 ± 50.2**	123.4 ± 34.2
	Placebo	79.3 ± 37.5	106.7 ± 32.5	78.1 ± 27.1	116.9 ± 54.7

Note. *p = 0.002, **p = 0.09; caffeine versus placebo.

When the number of serve attempts were compared for set 1 no significant difference was found for main effect of treatment (p = 0.74, n_p^2 = .013), but was found significant for target (p = 0.04, n_p^2 = .205). The interaction of treatment and target was nonsignificant (p = 0.81, n_p^2 = .055). For set 2 the main effect of treatment was not significant (p = 0.61, n_p^2 = .034), and was not significant for target (p = 0.08, n_p^2 = .197). The interaction of treatment and target was not significant (p = 0.34, n_p^2 = .127). For set 3 the main effects were non-significant for treatment (p = 0.13, n_p^2 = .233), and target (p = 0.12, n_p^2 = .162), as well as the interaction between treatment and target was also not significant (p = 0.42, n_p^2 = .095). Percentage of a successful serve on the first try are presented in Figure 2.

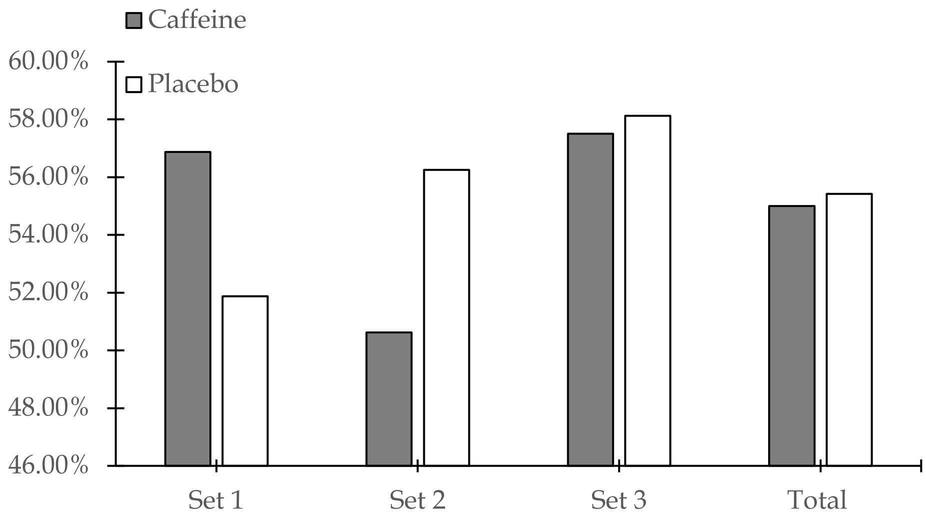

Figure 2. Percentage of successful first serves between trials (caffeine vs. placebo) during each set.

When comparing shuttle run times there was no significance (p = 0.25, n_p^2 = .257), for the main effect of treatment or for the interaction of treatment and sets (p = 0.27, n_p^2 = .051). However, there was a significant main effect found for set number (p = 0.03, n_p^2 = .057). Post hoc comparison determined the significance was approached when comparing set 1 and set 2 shuttle run times, see Table 3. In regard to subjective responses to the post-trial questionnaire, the feelings of stomach distress and nervousness approached but did not reach significance with reported higher responses reported during caffeine trial (Figure 3) while fatigue approached significance with higher responses recorded for the placebo trial (Figure 3), respectively.

Table 3. Comparison of shuttle run times between treatments.

	Caffeine		Placebo		Overall Mean	
	Mean	SD	Mean	SD	Mean	SD
Set 1	6.69	0.26	6.77	0.34	6.73	0.24
Set 2	6.95	0.21	6.99	0.39	6.97	0.24
Set 3	6.86	0.19	7.09	0.36	6.98	0.22
Overall Mean	6.84	0.19	6.96	0.33		

Note. Values are means and standard deviations.

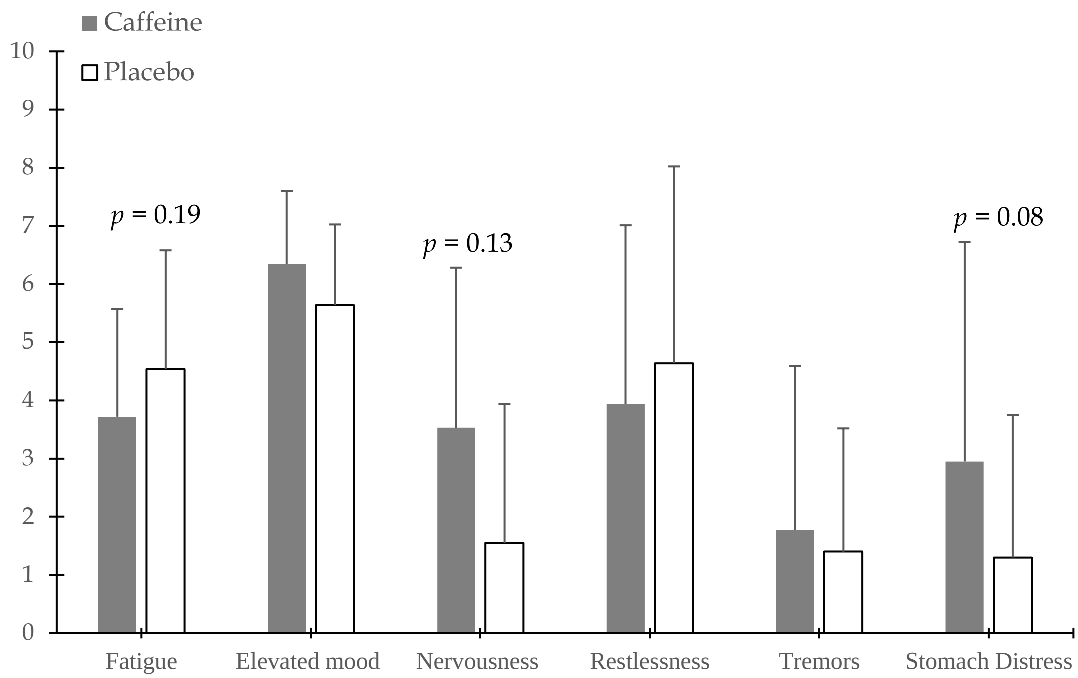

Figure 3. Means and standards deviation for measurements in the post-trial questionnaire. A response of zero indicated no feeling of the described symptom and 10 indicates extreme feeling of symptom.

DISCUSSION

Determining the effects of caffeine ingestion on serve accuracy and fatigue would aid an athletes' decision regarding consumption prior to competition. Previously, caffeine ingestion had a significant impact on females' overall play through winning more matches (8), and shots (i.e. groundstrokes, volleys, etc.) made during a simulated tennis match (17). Additionally, Hornery et al. (12) reported serve velocity was significantly greater ($p = 0.008$) when comparing caffeine (165 ± 15km/h) to a placebo (159 ± 15km/h) session in the latter stages of a simulated tennis match. While caffeine may benefit some variables in tennis match performance, the effects of caffeine on tennis serve accuracy are not well-understood. Therefore, this study examined effects of caffeine on serve accuracy, as previous studies have focused on other aspects of tennis match performance (8, 12, 17).

Current results indicated caffeine ingestion prior to tennis serves did not significantly influence serve accuracy. While the current study's overall results are similar to previous research (12, 24) in that caffeine did not affect accuracy, it should be noted serve accuracy approached significance for set 2 ($p = 0.07$; Table 2a,b,c). These findings are similar to Klein et al. (17) who observed ~2.1% improved performance following 6 mg/kg of caffeine ingestion on a tennis skill test involving a variety of shots used throughout a match. When considering the trend toward a positive impact of caffeine on set 2 (Table 2), the "equivocal" results among studies could potentially be explained by target location, dosage amounts, timing of ingestion, or also by the variability in skill level between division II athletes. Specifically in the current study, caffeine had a significant positive impact on targets A and H which are the targets with the widest location which could help to "open the court" to start the point, and approached significance for target D, a location typically deemed an easier shot as it is near the lowest point of the net (Figure 1; Table 2b; Table 2c). To optimize ecological validity, the current study utilized the entire service box, more accurately mimicking the play area during a tennis match, versus isolating only the far corners (12) or the inner corners (24) of the service box. In addition to Reyner and Horne (24) using the inside corners of the service box, accuracy was determined by the number of hits deemed accurate landing within the marked location. In contrast, the current study measured accuracy in terms of distance from impact of the serve to the center of target, allowing greater precision in assessing accuracy. Additionally, 6 mg/kg of caffeine was consumed an hour prior to serve trials in the present study in contrast to only 3 mg/kg 30 minutes (12) or an absolute value of 80 mg 30 minutes prior to data collection (24). These findings could possibly explain caffeine has a positive effect on accuracy; however, the dosage must be high enough. Graham (9) suggests a minimum dosage of 6 mg/kg, and consumed within a specific time period to elicit an ergogenic response. However, while caffeine only approached a significant positive outcome in terms of serve accuracy for set 2 it should be noted while there was a reduction in serve accuracy for set 3 (Table 2a) it is plausible there is an interaction between level of fatigue and accuracy that was not directly measured in the current study. With moderate fatigue, expected in set 2, it appears caffeine has the potential to improve accuracy; whereas, with greater (vs. set 2) fatigue expected in set 3, the fatigue may have overwhelmed the potential positive impact of caffeine on serve accuracy. Thus, athletes should not fear caffeine consumption due to negative effects on performance, nor the diuretic effect (29) as both have been found absent.

In comparison to Reyner and Horne (24), the current study assessed the serve trials by having participants complete 48 serves, 24 serves as they would complete a "first" serve during a tennis match and 24 like they would complete a "second" serve to simulate an actual tennis match. The number of attempts needed to complete the tasks were recorded and compared between trials, with results similar to Reyner and Horne (24). While results in both studies are similar in that caffeine did not improve the number of successful hits it is somewhat difficult to make a comparison because Reyner and Horne (24) also had participants sleep restricted which could have compounded the challenge of serving accurately. However, when comparing the percentage of successful shots, the caffeine trial of set 1 was slightly higher (Figure 2), a finding similar to Klein et al. (17) whose methodology consisted of a tennis skill test which accessed stroke accuracy following an intermittent treadmill exercise intended to mimic the intensity of game play.

Even though there was no significant difference in shuttle run times between treatments, sprint performance caffeine trials (~56%) were consistently faster in comparison to the placebo trails (Table 3). Although previous studies found caffeine had a positive impact on sprint performance of a tennis sprint test (8) it is possible caffeine mitigated fatigue, although not significantly based on aggregate data analysis. In the current study, caffeine could have an impact on the athletes' level of fatigue not only from improved serve accuracy in set 2, and sprint time trials being consistently faster in the caffeine trials over 3 sets, but also in the post-trial questionnaire in comparison to the placebo. Participants' responses approached significance when reporting subjective results of nervousness, fatigue, and stomach distress indicating caffeine affected individuals' symptoms following consumption. With only 50% of participants correctly identifying the substance consumed and similar scores in assessing symptoms between trials, contradicting Hudson et al. (11) and Killen et al. (16) it is possible the current study had a low number of responders reducing the possibility of detecting a difference. However, further research would be needed to identify caffeine responders in which research should consider conducting follow up evaluations to assess the consistency and magnitude of any caffeine effects. Future studies should evaluate serve velocity in comparison to accuracy further evaluating tennis performance following caffeine ingestion.

In summary, tennis is prolonged sport in which accuracy significantly influences match outcome. Results from the current study suggest that while caffeine has no effect early on or in the latter stages in tennis serve performance, caffeine has the potential to improve accuracy when athletes are slightly fatigued (Table 2). While an overall enhancement in performance was not found as in previous research (17), caffeine did not have a negative impact in performance of a sport in which accuracy has a significant impact on the outcome of the match. Therefore, based on current results, coaches can potentially provide caffeine consumption suggestions which will not result in negative performance outcomes. More research is needed to provide a definitive answer regarding the effects of caffeine on tennis performance in particular with the diverse responses to caffeine observed among individuals.

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