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Caffeine improves volleyball serves precision among college male players

KEYWORDS:

Volleyball. Caffeine. Athletes.

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ABSTRACT

Objective: The aim of this study was to identify whether caffeine ingestion affects the precision of volleyball serves. **Material and Methods:** The study's design was double-blind, crossover, and counterbalanced. Nineteen college volleyball players took part of the study. They performed two adapted volleyball matches on different days, separated by a 72 hours interval. Before the matches, they consumed randomly 6 mg·kg⁻¹ of caffeine or placebo. After each volleyball match, a serving precision test with two sets of ten serves was performed. **Results:** The evaluation of each serve's mean (placebo or caffeine) as well as the sum of total points according to the serve's order and intervention were not statistically different. However, the caffeine intervention mean scores were significantly higher ($F_{1,36} = 5.98$; $p = .02$; $\eta^2 = .98$) than the placebo intervention (32.21 ± 3.95 points versus 29.31 ± 3.31 points). **Conclusion:** The study results showed that 6 mg·kg⁻¹ of caffeine dosage does not influence precision of single serves, but improves the mean scores of serving after 1 hour of volleyball practice.

A cafeína melhora a precisão no voleibol entre atletas do sexo masculino

RESUMO

Objetivo: O objetivo do estudo foi identificar se a ingestão de cafeína afeta a precisão de saque no voleibol. **Materiais e Métodos:** Tratou-se de estudo contrabalanceado cruzado com duplo-cego. Dezenove jogadores de voleibol universitário fizeram parte da amostra. Os atletas participaram de dois jogos simulados de voleibol em dias diferentes, separados por 72 horas de intervalo. Antes das partidas, eles consumiram, aleatoriamente, 6 mg·kg⁻¹ de cafeína ou placebo. Uma hora após as partidas, foi empregado teste específico de saques, com duas series de 10 serviços. **Resultados:** A avaliação de cada situação (cafeína ou placebo), bem como a soma do total de pontos dos saques não foi estatisticamente diferente entre situações. Entretanto, a media de pontos na situação com cafeína foi estatisticamente superior ($F_{1,36} = 5.98$; $p = .02$; $\eta^2 = .98$) comparada a situação placebo (32.21 ± 3.95 points versus 29.31 ± 3.31 points). **Conclusão:** Os resultados do estudo demonstraram que a ingestão de dose com 6 mg·kg⁻¹ de cafeína não influenciou a precisão de saques individualmente, mas aprimorou a media de pontuação da precisão dos saques realizadas uma hora após as partidas.

PALAVRAS-CHAVE:

Voleibol, Cafeína, Atletas

INTRODUCTION

Caffeine has been studied by many researchers, especially by its ergogenic and psychoactive effects ^(12, 24, 27, 29). Upon caffeine ingestion, there is a decrease in effort perception during exercise and delay in fatigue, thereby improving performance of anaerobic exercises ⁽¹⁰⁾. These effects can be evidenced with between 3 to 9 mg·kg of caffeine ingestion ^(27, 32) and persists even 3 hours after its acute ingestion for both caffeine consumers and non-consumers ⁽³⁾.

Besides these caffeine effects on perception effort, fatigue and physical performance, caffeine may also lead to a better precision and motor coordination ⁽¹⁸⁾. Improvement of cognitive ability during and after exercise were reported ⁽¹⁹⁾, and these effects seems to be salient for cognitive and sports performance in which concentration plays a major role ^(23, 31). In this sense, Tikuisis, Keefe, McLellan, and Kamimori ⁽³⁷⁾ have studied whether caffeine ingestion could exert effects on movement precision after sleep deprivation. Their findings have shown that caffeine acute consumption (400mg) may contribute to the preservation or even the improvement of movement precision after sleep deprivation.

Hogervorst, Riedel, Kovacs, and Jolles ⁽¹⁹⁾ carried out a study with male cyclists who underwent cognitive test batteries during and after a cycling trial. The athletes ingested in a random fashion two different bars, caffeine with carbohydrate (CAF) and carbohydrate (CHO) or placebo that consisted of 350 mL of flavored water (BEV) prior the trials. The CAF intervention exerted significant ergogenic effects on physical and mental performance after exercise compared to BEV and CHO interventions. Besides, CAF intervention also showed an improvement on mental tests during the trial.

Improvements related to caffeine ingestion can also be observed in some situations, such as kicking and serving a ball in soccer ⁽¹³⁾. Likewise, Foskett, Ali, and Gant ⁽¹⁶⁾ found that 6 mg·kg⁻¹ of caffeine ingestion increased kick precision in soccer players after a reliable simulation of a soccer game activity patterns. In a study with 15 male volleyball players, Del Coso et al. ⁽¹¹⁾ showed that ingestion of a caffeine content beverage improved accuracy and performance in a volleyball-specific tests battery.

These findings related to caffeine ingestion and improvement of mental, motor coordination, and precision performance can be associated with interactions between caffeine, adenosine, and dopamine in brain regions that mediates visual attention ⁽⁵⁾. Its effects on adenosine receptors also seems to be associated with the improvement of fine motor skills, accuracy, and locomotor performance ^(5, 16, 33, 40).

In order to control caffeine use among athletes, the International Olympic Committee (IOC) has established a doping limit of 12 mg·mL⁻¹ of caffeine urinary concentration ⁽²⁾, which, according to Bassini et al. ⁽²⁾, can only be achieved if oral ingestion is higher than

9 mg·kg⁻¹. This allows athletes to consume 6 mg·kg⁻¹ of caffeine, dosage associated with the positive effects on physical and cognitive performance ^(2, 14, 16, 22), compared with bigger than 9 mg·kg⁻¹ doses that may cause shivering and shaking, resulting from chronic muscular tension. In addition, high caffeine doses (9 mg·kg⁻¹ or above) may also cause insomnia, anxiety, nervousness, irritability, nausea, and gastrointestinal discomfort ^(6, 34).

Thus, based on previous studies, caffeine ingestion may improve the precision on volleyball-specific tasks, such as standing spike, maximal squat jump, maximal counter-movement jump, rebound jump, agility, and simulated volleyball match ⁽¹¹⁾. It is known that servings are one of the most important ways to score points or hinder attack actions of opponents in a volleyball match, but surprisingly, to date, no specific test for serving performance with ergogenic resources was tested yet. Also, caffeine ingestion seems to positively affect performance under fatigue conditions ⁽³⁹⁾. Therefore, the present study evaluated if caffeine ingestion may change serving precision performed by college volleyball players after a simulated match.

MATERIALS AND METHODS

DESIGN AND VARIABLES

This study is a double-blind, counterbalanced, and crossover trial aimed at assessing the effect of 6 mg·kg⁻¹ of caffeine acute ingestion, as an independent variable, on precision of volleyball serve, as a dependent variable, among male amateur players.

SUBJECTS

The sample size was calculated based on information from a previous study which evaluated kick precision ⁽¹⁶⁾. The calculation considered a difference of 2.2 points between mean values, 1.7 points of standard deviation, 80% of statistical power, and a 5% confidence level resulting from a six participants per group sample size ⁽⁴¹⁾. Due to the possibility of sample losses and to control confounding factors, we added, respectively, 10% and 15% reaching a minimum eight participants per group sample size. Nevertheless, due to an unexpected interest of amateurs players to take part of the study, 19 male participants were submitted.

All participants were healthy men which were college amateur players, between 18 to 30 years of age, and trained for 2 days a week (2 hours each day). Their average caffeine consumption was 171 mg per day (TABLE 1), equivalent to 2 to 3 cups of brewed coffee ⁽²⁶⁾. They were from two different teams. Participants that were reported as smokers ⁽¹⁵⁾ or had some adverse reaction to caffeine were excluded.

TABLE 1. Characteristics of study participants ($n = 19$)

VARIABLE	MEAN $\pm$ SD
AGE (YEARS)	24 $\pm$ 4
BODY MASS (KG)	83.63 $\pm$ 9.39
HEIGHT (CM)	185 $\pm$ 7.83
ICM (KG/M)	24.45 $\pm$ 1.91
CAFFEINE DIARY CONSUMPTION (MG)	171 $\pm$ 132

PROCEDURES

After the local ethics committee approval, participants signed written consent forms. We asked them not to exercise during the study in order to avoid the effects of caffeine tolerance, which may be developed in some subjects who consume caffeine chronically in certain diary amounts ⁽³⁾. The players were asked not to ingest chocolate, alcoholic, or caffeinated beverages such as coffee, tea, *mate* (a local caffeine-containing drink), guarana, or cola-based soft drinks 24 hours prior to the first trial (Intervention 1) until the end of the second trial (Intervention 2). There was no biological probe of abstinence, but all of them have reported no caffeine consumption and no exercise during the experiment.

The experiment was accomplished in two trials, namely Intervention 1 and Intervention 2, separated by a 72 hours interval in between. Both interventions were composed of a 20 minute warm-up (stretching, joint mobilization, and running), followed by a 6 mg·kg⁻¹ of caffeine capsule ingestion (green capsules) or starch (red capsules) with 200 mL of water, and 60 minutes of adapted volleyball match where players could only accomplish one serve at a time, independently of the result obtained on rally. The serve was passed to the opponent team keeping the volleyball pattern rotation and after the match, a serving precision test (SPT) was performed (FIGURE 1). With Intervention 2 (second day), athletes accomplished the same protocol as Intervention 1, but this time, they were asked to ingest the contrary capsules colors to those ingested in Intervention 1 (counterbalanced order).

Regarding the double-blind procedure, only a second researcher was aware about the capsule content, that is, neither the researcher who provided the capsules to the participants nor the participants knew whether they ingested caffeine or placebo, and in order to ensure a balance in the groups, the capsules ingestion was done through a block randomization.

The precision test was from the North Carolina State University Volleyball Skills Test Battery ⁽¹⁾ as shown in FIGURE 1, which exhibits a .65 intraclass reliability coefficient for university students ($n = 313$) ^(1, 25) and a 87% discriminant power with adolescents from

different levels ⁽⁴⁾. In this test, athletes were asked to carry out 10 consecutive overhand serves with 15 seconds of interval between each serve – Serving Precision Test (SPT). The participants were asked to perform their serves according to the position in the serving area that they were more familiar to perform during their daily training in both trials. They should try to hit the ball at the highlighted areas on the other side of the court in order to achieve the highest score (FIGURE 1).

FIGURE 1. Point area to the Carolina's University Volleyball Skills Test Battery

DATA COLLECTION

Demographic information and test-scoring by capsule color were recorded and checked by two supervisors who facilitated all the precision tests. Personal information was self-reported and scores on the precision test were recorded during testing by two blinded scorekeepers, standing on opposite sides, 2 meters away from the court side's sidelines that was divided into score areas. The volleyball court was divided into specific scoring areas using a white maskin tape as shown in FIGURE 2. The areas' scores were explained to participants prior the tests, but were not marked on the court for a better ecological validity. The scorekeepers compared their scores at the end of the test, and no differences were found between the scores.

The participants performed the serves one at a time within the regular area according to international volleyball rules and were told to achieve the highest score possible. The balls which have hit the net, antenna, or another area out of highlighted area were scored as 0 points, and the attempt was accounted.

STATISTICAL ANALYSIS

Data were tested using the Shapiro-Wilk test ($p = .07$) and presented as means $\pm$ sd. After checking for normality variance with Levene's test (Levene's statistic = 27, $p = .11$), the linear mixed model of repeated measures was used to compare groups (caffeine versus placebo), with a confidence-interval of 95% the p value $\leq .05$ between the means' difference and was considered significant. The percent delta for 10 serves and the combined effect size according to (Equation 1) was also calculated. The statistical procedures were carried out in SPSS, version 16.

EQUATION 1: TE: (experimental mean – placebo mean) / placebo's standard deviation.

The chances of positive, trivial, or negative effects of caffeine on SPT were assessed qualitatively as follows: < 1 %, almost certainly not; 1 – 5 %, very unlikely; 5 – 25 %, unlikely; 25 – 75 %, possible; 75 – 95 %, likely; 95 – 99 %, very likely; and > 99 %, almost certain. If the chance of having higher or lower values were both > 5 %, the true difference was considered as unclear ⁽⁹⁾.

RESULTS

The evaluation of each serve's mean (placebo or caffeine) (TABLE 2), as well as the sum of total points according to serves order and intervention (FIGURE 2, PANEL A), were not statistically different. On the other hand, a difference was observed for the sum of scores (total serves-points, FIGURE 2, PANEL B). The caffeine intervention means score was significantly higher ($F_{1,36} = 5.98$; $p = .02$; $\eta^2 = .98$) than the placebo intervention (32.21 ± 3.95 points versus 29.31 ± 3.31 points). The difference between the mean of Intervention 1's scores (3.01 ± 1.25) and the mean of Intervention 2's scores (3.14 ± 1.20) was not significant ($p = .28$) showing no influence of trial order.

FIGURE 2. Total of points according to serves order and intervention. Paine A: sum of total points related to serves order and intervention. Paine B: Values from each player, considering the condition and the mean (black line).

TABLE 2. Performance (mean $\pm$ sd) on the North Carolina's University Volleyball Skills Test Battery, according to the type of intervention.

SERVE	PLACEBO	CAFFEINE	p VALUE
Serve 1	2.78 $\pm$ 1.39	2.94 $\pm$ 1.35	.72
Serve 2	3.00 $\pm$ 1.29	3.26 $\pm$ 1.28	.53
Serve 3	3.10 $\pm$ 1.32	2.84 $\pm$ 1.46	.56
Serve 4	2.94 $\pm$ 1.31	3.31 $\pm$ 1.10	.35
Serve 5	2.63 $\pm$ 1.38	3.10 $\pm$ 1.10	.25
Serve 6	2.73 $\pm$ 1.28	3.42 $\pm$ 1.01	.07
Serve 7	3.10 $\pm$ 1.32	3.26 $\pm$ 1.28	.71
Serve 8	2.94 $\pm$ 1.02	3.05 $\pm$ 1.26	.78
Serve 9	3.00 $\pm$ 1.33	3.57 $\pm$ 0.76	.11
Serve 10	3.05 $\pm$ 1.31	3.42 $\pm$ 0.76	.29
Sum	29.31 $\pm$ 3.31	32.21 $\pm$ 3.95	.02

For the sum of 10 serves (TABLE 3), the effect size was .87 (moderate clinical magnitude, $p = .01$, with observed power = .66) and the improvement in serving precision after caffeine ingestion was 9.89%.

TABLE 3. Effect size and respective magnitude for serve among groups.

SERVE	EFFECT SIZE	MAGNITUDE
Serve 1	.11	Trivial
Serve 2	.20	Trivial
Serve 3	.20	Trivial
Serve 4	.28	Trivial
Serve 5	.34	Trivial
Serve 6	.53	Small
Serve 7	.12	Trivial
Serve 8	.10	Trivial
Serve 9	.40	Small
Serve 10	.28	Trivial
Sum	.87	Moderate

From a quantitative point of view, the mean difference between caffeine and placebo conditions was 2.89 ± 4.95 points. The chances of positive effects for caffeine supplementation to precision of single serves is 3% (very unlikely), whilst the chance of positive effects for caffeine supplementation to the sum of ten serves scores in the SPT is 97% (very likely).

DISCUSSION

The main finding of this study was that the caffeine acute consumption of $6 \text{ mg}\cdot\text{kg}^{-1}$ can positively affect the serves of college volleyball players after a 60 min. practice session. Even when using the SPT in an attempt to represent real game conditions instead of a simple target, we must highlight that the ball velocity in the serves was not measured and it can be considered a study limitation.

Despite this limitation, our findings seem to be consistent with the findings of Del Coso et al. ⁽¹¹⁾, who investigated the effects of caffeine-containing energy drink on the performance of 15 college volleyball players. The volleyball players performed volleyball-specific tests as: standing spike test, maximal squat jump, maximal counter-movement jump, 15-s rebound jump test, and agility test. Despite not measuring the serving precision, their results have shown that the increased caffeine intake had an effect on the increased ball velocity on spike and jump height. Besides, caffeine reduced the time to complete the agility test, and their volleyball actions were more successful with caffeine ingestion.

Since volleyball serving precision and caffeine ingestion has not been evaluated in other studies, we can also compare our results with the findings of Klein et al. ⁽²²⁾ who investigated the effects of caffeine on tennis stroke accuracy, which is a sport that also requires upper limbs precision and motor coordination. The study results showed that $6 \text{ mg}\cdot\text{kg}^{-1}$

of caffeine ingestion improved the number of successful shots during a tennis skill test, accomplished after 45 minutes of intermittent treadmill exercise.

Fosket et al. ⁽¹⁶⁾ assessed the potential benefits of caffeine on cognitive parameters and intermittent sprint activity. The study results showed that the same caffeine dosage used in our study ($6 \text{ mg}\cdot\text{kg}^{-1}$) improved the ball passing accuracy and control of a soccer player thereby attributing the increase in accuracy to an enhancement of fine motor skills.

Regarding to improvements of physical and motor performance related to caffeine intake, Duncan, Taylor and Lyons ⁽¹⁴⁾ studied thirteen male hockey players who performed hockey sprint dribble and ball handling tests at rest and after a bout of total body fatigue (90% maximal capacity) following caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$) or placebo ingestion. Sprint dribble times were slower postfatigue compared with rest, but were significantly faster postfatigue with caffeine compared with postfatigue with placebo ingestion. Ball handling scores were higher at rest compared with postfatigue, but scores postfatigue were higher following caffeine than placebo ingestion. Rating of perceived exertion (RPE) was lower ($p < .01$) and readiness to invest physical ($p < .01$) and mental effort ($p = .01$) were significantly higher in the caffeine condition. These findings made them conclude that ingestion may therefore be effective in offsetting decrements in skilled performance associated with fatigue.

Some authors propose that caffeine's direct antagonism of adenosine receptors on membrane of the skeletal muscle might improve motor unit recruitment and excitation-contraction coupling via greater release of Ca^{2+} ^(9, 36) from sarcoplasmic reticulum and/or improve $\text{Na}^{+}/\text{K}^{+}$ ATPase pump activity ⁽²⁴⁾. In addition, a recent work reported that high doses of caffeine (400 mg) can also produce beneficial changes in visual attention, even in habitual consumers. These results carry implications for the theorized interactions between caffeine, adenosine, and dopamine in brain regions mediating visual attention ⁽⁵⁾.

Nonetheless, we must emphasize that the dose of caffeine ingested seems to be important when caffeine related improvements were accessed. A study using lower caffeine doses (80 mg) had shown that caffeine was not able to improve the serve accuracy of tennis players when subjected to sleep restriction ⁽²⁸⁾. In addition, Share, Sanders, and Kemp ⁽³⁰⁾ accomplished a randomized, double-blind, placebo-controlled design with seven elite male shooters who were submitted to $2 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine ingestion per body mass and $4 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine per body mass or placebo prior to a round of shootings and was found that caffeine ingestion of $4 \text{ mg}\cdot\text{kg}^{-1}$ does not provide performance benefits to elite performers of clay target shooting.

Tucker, Hargreaves, Clarke, Dale, and Blackwell ⁽³⁸⁾ investigated the effects of $3 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine acute ingestion per body mass on vertical jumps performance. Five male basketball players underwent a vertical jump test (composed of 10 vertical rebound jumps) after a maximal-effort test. The caffeine dosage was administered 60 minutes prior to the exercises. The study concluded that the $3 \text{ mg}\cdot\text{kg}^{-1}$ per body mass caffeine acute ingestion had insignificant effects on players' power and endurance performance.

Although some studies with lower than 6 mg·kg⁻¹ caffeine dosages do not show physical and motor improvement, the wide range of caffeine ingestion effects on physical and motor performance demonstrated in doses around 6 mg·kg⁻¹ may be the major cause of its great consumption among athletes. Coso, Muñoz, and Muñoz-Guerra⁽⁸⁾ evaluated caffeine use by athletes after its removal from the World Anti-Doping Agency list, measuring caffeine concentration in 20686 urine samples. The urine samples utilized were obtained after official national and international competitions, and the results showed that most urine samples (67.3%) had urinary caffeine concentrations below 5 µg·mL⁻¹. Only 0.6% of urine samples exceeded the former threshold for caffeine doping (12 µg·mL⁻¹). Older competitors (> 30 y) had higher levels of caffeine in their urine than younger competitors (< 20 y; $p < .05$). Furthermore, they conclude that three out of four athletes had consumed caffeine before or during sports competitions. Nevertheless, only a small proportion of these competitors (0.6%) had a urine caffeine concentration higher than 12 µg·mL⁻¹.

The findings of Coso et al.⁽⁸⁾ show caffeine consumption prevalence among athletes, but do not provide data about how it has been used. Nevertheless, many studies have been done with different procedures related to caffeine abstinence prior its acute ingestion. In the studies by Tallis et al.⁽³⁵⁾, the evaluated effects of caffeine on mood, perceptual-motor coupling, and muscular strength in healthy older population had 48 hs of caffeine abstinence.

Hodgson, Randell, and Jeukendrup⁽¹⁷⁾ and Irwin et al.⁽²¹⁾ studied these effects on caffeine moderate consumer cyclists performance, establishing a different abstinence period in their studies of 24 hs and 96 hs, respectively. Also, in order to evaluate the effects of caffeine acute ingestion, Bell and McLellan⁽³⁾ studied the cycling performance until exhaustion in (15 male and 6 female) physically active subjects, who underwent 12 hs of caffeine abstinence.

According to our findings, there was no difference on performance between ingesting 6 mg·kg⁻¹ of caffeine after a 24 or 72 hours period of caffeine abstinence, since the difference between the average score of Intervention 1 (accomplished after 24 hs of caffeine abstinence) and Intervention 2 (accomplished after 72 hs of caffeine abstinence) was not significant. In other words, the trials' order did not affect the results even with differences in abstinence periods. Also, regarding to caffeine abstinence, Irwin et al.⁽²¹⁾ concluded that the effects of caffeine acute ingestion on physical performance are irrespective of whether a withdrawal period is imposed on caffeine moderate consumers. Finally, more studies about how caffeine abstinence, withdrawal, and caffeine regular consumption can affect the response to caffeine acute ingestion are warranted.

CONCLUSION

The 6 mg·kg⁻¹ caffeine acute ingestion did not improve the precision of single serves 60 minutes after volleyball practice. However, this caffeine dose contributed to improve the total sum of points from 10 volleyball serves after a 1-hour volleyball practice.

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Efeitos do foco de atenção na aprendizagem do chute em crianças: Foco de atenção na aprendizagem do chute

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RESUMO

Há evidências de que o aumento da distância entre o foco de atenção e os movimentos corporais possam potencializar a aquisição de habilidades motoras. O objetivo do presente estudo foi verificar os efeitos de diferentes tipos de foco de atenção na aprendizagem do chute, em uma tarefa do futsal, em crianças. Participaram 29 crianças, com idade média de 6.12 ± 0.4 anos, distribuídas aleatoriamente em quatro grupos (foco de atenção externo próximo, foco de atenção externo distante alvo, foco externo distante goleiro e grupo sem indução de foco). Os participantes realizaram uma tentativa de pré-teste, seguida por 20 tentativas, na fase de aquisição. Dez minutos após a fase de prática realizaram cinco tentativas na fase de retenção e cinco tentativas na fase de transferência. Os resultados mostraram grande precisão na habilidade de chute no futsal para o grupo que foi induzido ao foco externo distante no alvo, em comparação ao foco externo próximo e ao controle, nas fases de retenção ($p = .003$) e transferência ($p = .011$). Conclui-se que instruções induzindo foco externo distante de atenção foram capazes de aumentar os níveis de aprendizagem de habilidades esportivas do grupo de crianças avaliadas.

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