Baltic Journal of Health and Physical Activity

Volume 14 | Issue 2 Article 3

2022

The effect of caffeine on countermovement jump performance in recreationally trained women habituated to caffeine

Dawid Gawel
Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland, dawidgawel777@gmail.com

Magdalena Kaszuba
Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland, m.kaszuba1@interia.pl

Zuzanna Komarek
Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland

Robert Krawczyk
Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland

Marta Bichowska
Faculty of Tourism and Recreation, Gdansk University of Physical Education and Sport, Poland, marta.bichowska@awf.gda.pl

See next page for additional authors

Recommended Citation

Gawel D, Kaszuba M, Komarek Z, Krawczyk R, Bichowska M, Jasinski M, Trybulski R. The effect of caffeine on countermovement jump performance in recreationally trained women habituated to caffeine. Balt J Health Phys Act. 2022;14(2):Article3. https://doi.org/10.29359/BJHPA.14.2.03

The effect of caffeine on countermovement jump performance in recreationally trained women habituated to caffeine

Abstract

Introduction. The main goal of this study was to examine the effect of acute intake of 3 mg/kg/body mass (b.m.) of caffeine (CAF) on countermovement jump (CMJ) performance in recreationally trained women habituated to CAF. Material and Methods. 17 healthy recreationally trained women habitually using CAF participated in the study. The experiment followed randomized, cross-over, double-blind design under three different conditions: control test (CONT) or consumed placebo (PLAC) or consumed 3 mg/kg/b.m. of CAF (CAF-3). Each participant performed 2 sets of 2 CMJ. The following variables were recorded: concentric peak velocity (PV), peak power (PP) and jump height (JH). Results. The two-way repeated measure ANOVA (substance × set) revealed no statistically significant interaction and main effects for all measured variables between conditions. In comparison to the CONT and PLAC, the intake of CAF-3 was not effective at increasing PV (p = 0.533), JH (p = 0.417) and PP (p = 0.871) during 2 sets of the CMJ. Conclusions. This study suggests that 3 mg/kg/b.m. of CAF did not improve CMJ height in recreationally trained women habituated to CAF. Furthermore, the level of athletic performance might be considered a factor in regard to CAF ergogenicity.

Keywords

ballistic exercise, ergogenic aid, female, sport performance

Cover Page Footnote

The authors would like to thank the participants for their commitment and effort

Authors

Dawid Gawel, Magdalena Kaszuba, Zuzanna Komarek, Robert Krawczyk, Marta Bichowska, Marcin Jasinski, and Robert Trybulski

Baltic Journal
of Health and Physical Activity
e-ISSN 2080-9999

Article

The effect of caffeine on countermovement jump performance in recreationally trained women habituated to caffeine

Dawid GAWEL[1], Magdalena KASZUBA[2], Zuzanna KOMAREK[3], Robert KRAWCZYK[4], Marta BICHOWSKA[5], Marcin JASINSKI[6], Robert TRYBULSKI[7]

1 Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland, ORCID 0000-0001-5884-9478
2 Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland
3 Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland
4 Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, ORCID 0000-0002-5163-2353
5 Faculty of Tourism and Recreation, Gdansk University of Physical Education and Sport, Poland, ORCID 0000-0001-6327-9879
6 Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland
7 Department of Medical Sciences, The Wojciech Korfanty School of Economics, Katowice, Poland; Provita Zory Medical Center, Zory, Poland, ORCID 0000-0002-4276-4813

* Correspondence: Dawid Gawel, Nutrition and Sports Performance Research Group, The Jerzy Kukuczka Academy of Physical Education in Katowice, ul. Mikolowska 72a, 40-065 Katowice, Poland. Phone no.: +48 691 930 640; e-mail: dawidgawel777@gmail.com

Abstract: Introduction. The main goal of this study was to examine the effect of acute intake of 3 mg/kg/body mass (b.m.) of caffeine (CAF) on countermovement jump (CMJ) performance in recreationally trained women habituated to CAF. Material and Methods. 17 healthy recreationally trained women habitually using CAF participated in the study. The experiment followed randomized, cross-over, double-blind design under three different conditions: control test (CONT) or consumed placebo (PLAC) or consumed 3 mg/kg/b.m. of CAF (CAF-3). Each participant performed 2 sets of 2 CMJ. The following variables were recorded: concentric peak velocity (PV), peak power (PP) and jump height (JH). Results. The two-way repeated measure ANOVA (substance × set) revealed no statistically significant interaction and main effects for all measured variables between conditions. In comparison to the CONT and PLAC, the intake of CAF-3 was not effective at increasing PV ($p = 0.533$), JH ($p = 0.417$) and PP ($p = 0.871$) during 2 sets of the CMJ. Conclusions. This study suggests that 3 mg/kg/b.m. of CAF did not improve CMJ height in recreationally trained women habituated to CAF. Furthermore, the level of athletic performance might be considered a factor in regard to CAF ergogenicity.

Keywords: ballistic exercise, ergogenic aid, female, sport performance.

Citation: Gawel D, Kaszuba M, Komarek Z, Krawczyk R, Bichowska M, Jasinski M, Trybulski R. The effect of caffeine on countermovement jump performance in recreationally trained women habituated to caffeine. Balt J Health Phys Act. 2022;14(2):Article3. https://doi.org/10.29359/BJHPA.14.2.03

Academic Editor: Agnieszka Maciejewska-Skrendo

Received: July 2021
Accepted: October 2021
Published: June 2022

Publisher's Note: BJHPA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Caffeine (CAF) is a well-established ergogenic supplement, common among athletes in many sport disciplines, and among the majority of general population [1, 2]. CAF ingestion in numerous forms [2, 3] has been shown to have an impact on exercise performance and to be beneficial in various modes of exercise, such as maximal strength, endurance and power output [4 ,5]. The ergogenic effect of CAF, particularly during anaerobic performance is most often attributed to its ability to act as adenosine A1 and A2A receptor antagonist [4, 6]. CAF and adenosine molecular structures are similar, hence CAF ingestion results in blocking adenosine and A1 and A2A receptors binding [6, 7], inducing increased arousal, motor unit firing rates, neuro-excitability and inhibited pain perception [4, 8].

The power output is known to be a significant component of athletic performance and it has been shown that CAF ingestion enhances single-bout sprinting tasks (the Wingate test), ballistic tasks (jumps and throws) or resistance exercise performance [10]. Although CAF supplementation has been shown to affect power output in both male and female subjects [8, 9, 11], it should be pointed out that the gender may be one of the factors that plays an important role in acute CAF efficiency [11–13]. Due to the differences in stages of the menstrual cycle as well as the use of oral contraceptives by females, CAF metabolization speeds and thus its ergogenic effect might be altered [13,33]. Moreover, a systematic review by Mielgo-Ayuso et al. [11] indicated a different ergogenic effect of acute CAF intake on anaerobic performance in men from that in women (greater CAF ergogenicity for males). Furthermore, in most of the studies analyzing CAF ergogenicity, the majority of subjects are male, or mixed gender populations are included, thus it is not clear whether these results translate to women or not [11–13].

Although various doses of CAF, ranging from 3 to 13 mg/kg/body mass, have been utilized in the literature [12, 14, 15], as regards the power output, most often low (3 mg/kg/body mass) to moderate (6 mg/kg/body mass) doses are used [4,9,16]. The results of several studies indicated that habitual use of CAF may reduce the ergogenic effects of such doses [12, 15, 17–19]. On the other hand, different studies (related to ballistic tasks performance) have shown that the level of daily CAF intake does not influence its ergogenicity [7, 20]. Thus, the available literature regarding the effects of habitual consumption of CAF on its ergogenicity remains inconclusive, and this issue has not been sufficiently examined, particularly in female subjects [2, 13, 20–22].

Taking into consideration that habituation to CAF may be a factor affecting its ergogenicity, and only few previous investigations included female subjects [23], the purpose of this study was to examine the effect of acute intake of 3 mg/kg/body mass of CAF on countermovement jump (CMJ) performance in recreationally trained women habituated to CAF. Given that the CAF dose of 3 mg/kg/body mass is the lowest CAF dose considered to be ergogenic [2, 12], and could be potentially used as an ergogenic aid during training by recreationally trained females, the dose of 3 mg/kg/body mass was administered. We hypothesized that acute CAF ingestion would enhance performance compared to both control and placebo conditions.

2. Materials and Methods

This study used a randomized, cross-over, double-blind design in which initially a familiarization session was conducted, followed by three different experimental sessions with a one-week rest interval between sessions to allow for complete recovery and rinsing out the substance (Figure 1). During three experimental sessions, participants performed a control test (CONT) or consumed either placebo (PLAC) or CAF at a dose of 3 mg/kg/body mass (CAF-3). One hour after consuming CAF-3 or PLAC, the subjects performed 2 series of 2 jumps with a 3-minute rest interval between each trial. Both CAF and PLAC were administered orally one hour before each exercise protocol to ensure the maximum concentration of CAF in the blood and at least 2 hours after the last meal to maintain the same absorption time of the tested substance. The CAF supplement was in the form of capsules containing an individual dose of CAF (Caffeine Kick®, Olimp Laboratories, Dębica). The manufacturer also supplied identical PLAC capsules filled with all-purpose flour. Participants abstained from strenuous physical activity the day before each test, and they were also asked to maintain their training, eating and hydration habits, including regular CAF consumption during the study period. Participants also received a list of CAF-containing products that were prohibited for consumption 12 hours prior to each trial. In addition, participants recorded their caloric intake 24 hours prior to the start of every test procedure using the "MyfitnessPal" program to ensure that the diet was similar before each trial.

2.1. Participants

The study included 17 healthy recreationally trained women (age = 23.1 ± 1.0 years; body mass = 60.2 ± 7.6 kg; height = 166.4 ±5.3 cm; body mass index (BMI) = 21.7 ± 2.1) with at least 2 years of strength training experience (2.9 ± 0.8 years), who volunteered to participate in the study. All participants were habitual CAF consumers (3.2 ± 1.2 mg/kg/body mass; 191.6 ± 72.9 mg of CAF per day) and their reported daily ingestion of CAF was based on the Food Frequency Questionnaire (FFQ). The inclusion criteria were as follows: (a) free from neuromuscular and musculoskeletal disorders, (b) minimum 2 years of experience in strength training, (c) at least low habitual consumption of CAF, as per previously proposed thresholds for classifying individuals in sport performance research according to their habitual caffeine consumption [24]. Participants were excluded when they suffered from any pathology or injury. Additionally, participants were required not to take any medications or supplements within the 3 previous months. The study protocol was approved by the Bioethics Committee for Scientific Research at the Academy of Physical Education in Katowice, Poland (3/2019), according to the ethical standards of the latest version of the Declaration of Helsinki, 2013.

2.2. Study Protocol

Habitual Caffeine Intake Assessment

Habitual CAF intake was measured by an adapted version of FFQ proposed by Bühler et al. [25]. Portions, in household measures, were used to assess the amount of food consumed according to the frequency of consumption during a day, week and month. The list was composed of dietary products with high CAF content including different types of coffee, tea, energy drinks, cocoa products, popular beverages, medications and caffeine supplements. Previously published information and nutritional tables were used for database construction [26–28]. Based on the answers in FFQ, a qualified nutritionist estimated the habitual CAF intake.

Familiarization Session

The familiarization session which included the same procedures used in subsequent experimental sessions was the first attempt at research. Study participants arrived at the laboratory at the same time of day as for the upcoming experimental sessions (morning, between 9:00 am and 11:00 am). Upon arrival, participants cycled on an ergometer for 5 minutes at an intensity that resulted in a heart rate of around 130 beats per minute, followed by an overall lower body warm-up containing ten bodyweight forward and lateral lunges, squats and standing calf raises. Then, the participants performed a test trial consisting of 2 sets of 2 CMJ, with a 3-minute rest between sets, which is exactly the same as in the other experimental sessions.

Experimental session

Three sessions were carried out during the experimental trials with one week between each trial, and the protocols were identical. All trials were conducted between 9.00 am and 11.00 am to avoid diurnal variability. The overall warm-up for the experimental sessions was identical to that performed in the familiarization session. After the warm-up, participants performed 2 sets of 2 CMJ, with 3 minutes' rest between the sets. Each CMJ was performed on the Force-Decks FD4000 Dual Force Platforms hardware, with a sample rate of 1000 Hz. Previous research has shown high reliability and validity of this force platform (intraclass correlation coefficient [ICC] = 0.944 to 0.975) for all variables measured in this study, with jump height showing the highest coefficient of variation (CV) (3.8%) [29]. Manufacturer's software was used for the instantaneous recording of peak velocity, height, and peak power obtained during each CMJ under three different conditions: CONT (i.e. no ingestion of the substance) or consumed PLAC or CAF-3. Each CMJ was performed from a standing position with a straight torso, knees fully extended with hands-on-iliac crest and feet shoulder-width apart. Participants dropped into the counter-movement position to a self-selected depth and immediately jumped for maximum height without arm swing. The take-off was executed as a continuous movement with no observable pause between downward and upward phases. Participants were told that the landing must be with the same position than the take-off and it should be produced on the mid-section of the force platform. During the apex of the jump, participants kept their legs fully extended. No instructions were given as to the amplitude or speed of the counter-movement. The best jump of the two attempts was used for further analysis. The measurement was performed independently for each replicate and the following variables were recorded: concentric peak velocity (PV, in m/s), peak power (PP, in W), and jump height (JH, in cm). The jump height was calculated from the flight time. All participants completed the described test protocol, which was carefully repeated in subsequent experimental sessions.

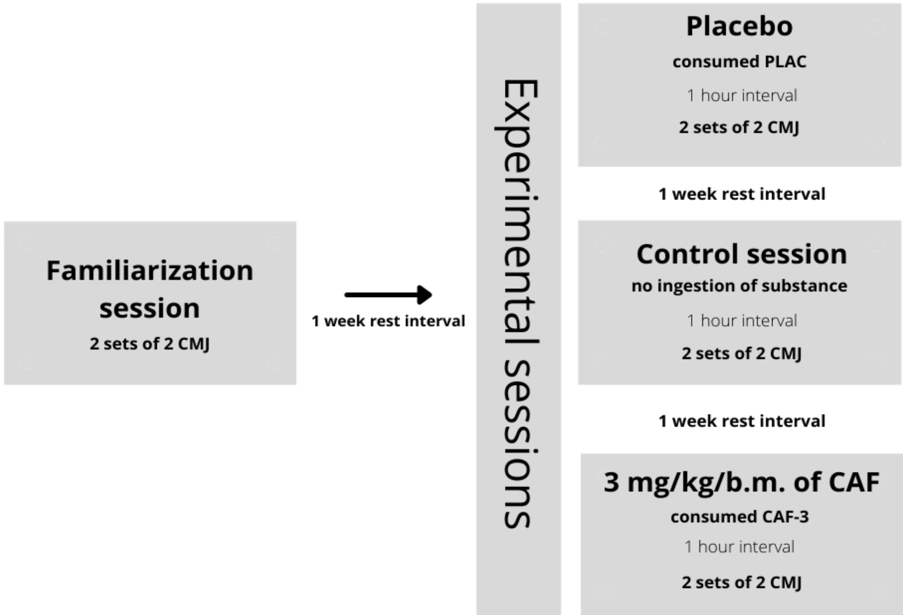

Fig. 1. Schematic representation of the study design.
CONT: control, PLAC: placebo, CAF-3: caffeine at a dose of 3 mg/kg, b.m.: body mass.

2.3. Statistical analysis

The Shapiro–Wilk test was used in order to verify the normality of the data. All data presented a normal distribution. Verification of differences between CONT, PLAC and CAF-3 was performed using ANOVA with repeated measures. Effect sizes (Cohen's d) were reported where appropriate. Parametric effect sizes (ES), were defined as large for $d > 0.8$, as moderate for d between 0.8 and 0.5, and as small for $d < 0.5$ [30]. The statistical significance was set at $p < 0.05$. All statistical analysis were performed using SPSS (version 25.0; SPSS, Inc., Chicago, IL, USA) and were expressed as means with standard deviations (± SD).

3. Results

The two-way repeated measure ANOVA (substance × set) revealed no statistically significant interaction and no main effects for all measured variables. In comparison to the CONT and PLAC, the intake of CAF-3 did not improved PV (2.43 ± 0.36 vs. 2.48 ± 0.45 vs. 2.43 ± 0.3 m/s, respectively; $p = 0.553$; Figure 2) nor JH (27.1 ± 9.0 vs. 28.7 ± 11.5 vs. 27.2 ± 7.9 cm, respectively; $p = 0.417$; Figure 3) and PP (2602 ± 511 vs. 2618 ± 520 vs. 2587 ± 401 W, respectively; $p = 0.871$; Figure 4) during 2 sets of CMJ. Additionally, small ES was found for all measured variables between the CONT, PLAC and CAF-3 groups, except for PV between CONT and CAF-3, where no effects were found (Table 1).

Table 1. Values of the effect size of peak velocity, jump height and peak power during 2 sets of CMJ with the ingestion of placebo and 3 mg/kg of caffeine or during control conditions.

Conditions		Peak Velocity [m/s]	Jump Height [cm]	Peak Power [W]
	CONT vs PLAC	0.12	0.15	0.03
ES	CONT vs CAF-3	0	0.12	0.03
	PLAC vs CAF-3	0.13	0.15	0.07

CONT: control, PLAC: placebo, CAF-3: caffeine at a dose of 3 mg/kg, ES: effect size

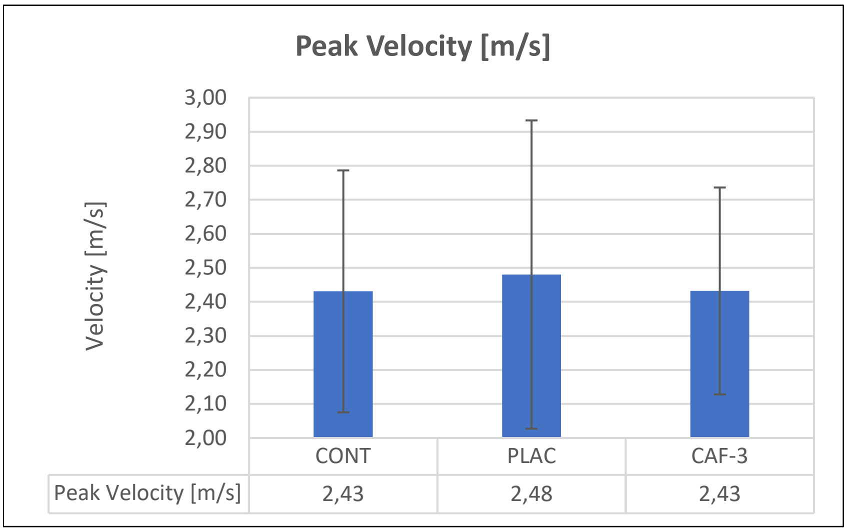

Fig. 2. Results of peak velocity during CMJ in the control, placebo and caffeine conditions. CONT: control, PLAC: placebo, CAF-3: caffeine at a dose of 3 mg/kg.
Data are presented as means ± SD.

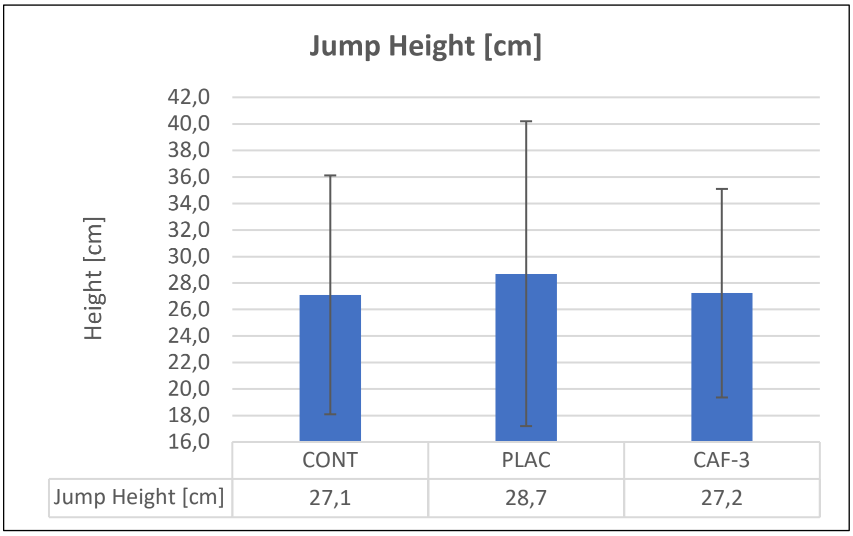

Fig. 3. Results of jump high during CMJ in the control, placebo and caffeine conditions CONT: control, PLAC: placebo, CAF-3: caffeine at a dose of 3 mg/kg.
Data are presented as means ± SD.

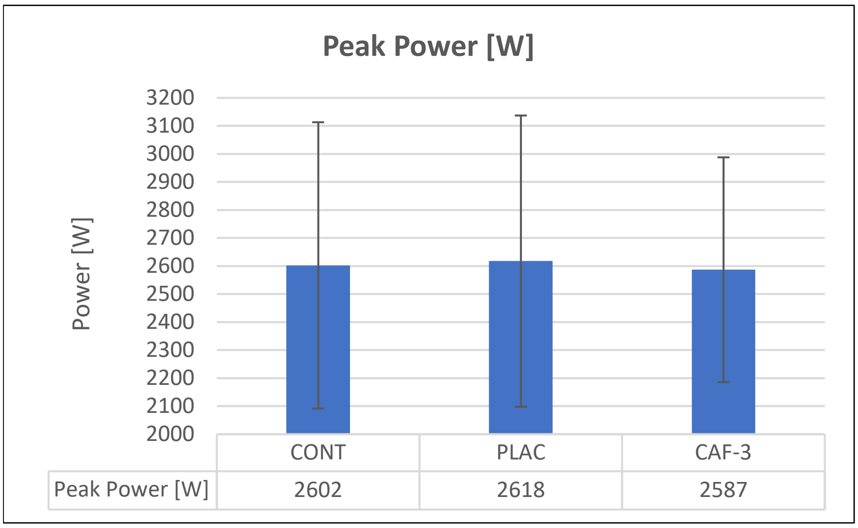

Fig. 4. Results of peak power during CMJ in the control, placebo and caffeine conditions.
CONT: control, PLAC: placebo, CAF-3: caffeine at a dose of 3 mg/kg
Data are presented as means ± SD.

4. Discussion

Given that the available literature concerning the topic of CAF ergogenicity among habituated women is scarce, particularly as regards power performance, the objective of this study was to assess the impact of acute intake of CAF-3 on CMJ performance in recreationally trained women habituated to CAF. The main finding of this study was that CAF-3 did not provide an ergogenic effect on CMJ performance compared to CONT and PLAC condition. Therefore, the low CAF dose (CAF-3) may be considered not to be ergogenic during lower body ballistic tasks among recreationally trained women habituated to CAF. Currently, there are several studies exploring CAF impact on muscle power, utilizing the CMJ test [8, 16, 31]. The CMJ test is considered to be a reliable and valid test for lower body power, and it is commonly used by scientist and sport practitioners [32, 33]. Furthermore, the meta-analysis by Grigic et al. [9] showed significant ergogenic effects of acute CAF consumption on power output, as assessed by vertical jump height. However, the results of the current study are inconsistent with most of the previous findings, which indicated an improvement of power output in lower body ballistic tasks after acute CAF intake [8, 9, 34]. Although, acute CAF intake has been shown to improve CMJ performance, previous studies mostly involved male subjects [31, 35–37] or both sexes [8, 38], thus indicating that the gender may have an impact on CAF ergogenicity during ballistic tasks, such as CMJ. To the best of the authors' knowledge, only few studies examined CAF impact on CMJ performance in women [16, 34, 39]. Stojanović et al. [39] reported that CAF dose of 3 mg/kg/body mass provided small non-significant increases in CMJ performance in professional female basketball players. By contrast, Norum et al. [34] demonstrated that CAF dose of 4 mg/kg/body mass significantly increased CMJ height in resistance-trained females during the early follicular phase. In should be pointed that the phase of the menstrual cycle is a factor that might influence strength and power performance; however, this issue has not been taken into account in other studies [34]. The aforementioned research is contrary to the present study, which included recreationally trained women, thus suggesting that the CAF impact on CMJ performance may also be related to the level of athletic performance [2, 4, 40]. It has been proposed in the literature that the ergogenic effect of CAF differs between trained and untrained individuals, and such disparity may be related to higher reliability of exercise performance (less day-to-day variation) or greater adenosine A2a receptor densities in trained compared to untrained individuals

[13, 27]. However, only limited data related to this topic is available; furthermore, the research provides conflicting findings. Thus, further investigation regarding this issue is required [13].

It should be taken into account that the habituation to CAF resulting in up-regulation of adenosine receptors may modify the physiological responses to acute CAF intake [41, 42]. Moreover, it has been suggested that application of doses higher than an individual's daily intake may be required to achieve an ergogenic effect of CAF [5]. However, as shown in other studies, application of higher doses of CAF in habituated subjects is not beneficial, not only in regard to resistance exercise [17, 43] but also to ballistic tasks performance [7, 41]. Nonetheless, it should be noted that all of the aforementioned studies included male subjects. Thus extrapolation of these findings to female subjects should be made with caution. In the present study female subjects were administered a CAF dose of 3 mg/kg/body mass, which almost equaled their daily intake (3.2 ± 1.2 mg/kg/body mass) and did not improve CMJ performance. However, in the study by Norum et al. [34], which produced contrary findings, subjects' daily CAF intake (5.4 ± 2.9 mg/kg/body mass) was greater than the dose ingested (4 mg/kg/body mass), and still administration of CAF significantly improved the CMJ height. Therefore, these findings suggest, similarly to male subjects, that application of CAF doses exceeding one's daily intake might not be the sole factor impacting on ergogenicity of CAF in ballistic tasks, such as CMJ in habituated subjects [7]. In support of this, one other study [16] found that even a higher CAF dose (6 mg/kg/body mass) did not improve CMJ performance in female team-sport players. However, these results may also be explained by diversified daily CAF intake among subjects (0–300 mg/day), as well as their sports level, ranging from recreational to international. Thus, further research of CAF ergogenicity among habituated women should consider such disjunctions.

Beyond the strengths of the present study, such as the participation of female subjects habituated to CAF, also its limitations should be considered. The current research did not account for the use of oral contraceptives among the subjects, as well as did not take account of the phase of the menstrual cycle. Furthermore, there were no physiological measurements which could provide an explanation of the obtained results. It is noteworthy that genetic variation between individuals may influence the magnitude of performance improvement after CAF ingestion [5, 15]; however, no genetic assessments regarding CAF metabolism were performed.

5. Conclusions

The results of the present study indicated that the acute intake of the CAF dose of 3 mg/kg/body mass did not improve CMJ performance in recreationally trained women habituated to CAF. These results suggest that the level of athletic performance might be considered a factor in regard to CAF ergogenicity. Furthermore, the administration of higher doses of CAF may not further enhance ballistic tasks performance in recreationally trained female habituated to CAF. However, the available literature regarding this topic is scarce and only few studies included populations of women habituated to CAF. Thus, further research on this issue is needed.

References

1. Heckman MA, Weil J, Gonzalez de Mejia E. Caffeine (1, 3, 7-trimethylxanthine) in foods: A comprehensive review on consumption, functionality, safety, and regulatory matters. J Food Sci. 2010;75:R77-87. DOI: 10.1111/j.1750-3841.2010.01561.x
2. Grgic J, Grgic I, Pickering C, Schoenfeld BJ, Bishop DJ, Pedisic Z. Wake up and smell the coffee: caffeine supplementation and exercise performance—an umbrella review of 21 published meta-analyses. Br J Sports Med. 2020;54:681–8. DOI: 10.1136/bjsports-2018-100278
3. Wickham KA, Spriet LL. Administration of Caffeine in Alternate Forms. Sports Med Auckl NZ. 2018;48:79–91. DOI: 10.1007/s40279-017-0848-2

4. Davis JK, Green JM. Caffeine and anaerobic performance: ergogenic value and mechanisms of action. Sports Med Auckl NZ. 2009;39:813–32. DOI: 10.2165/11317770-000000000-00000
5. Pickering C, Kiely J. What Should We Do About Habitual Caffeine Use in Athletes? Sports Med Auckl NZ. 2019;49:833–42. DOI: 10.1007/s40279-018-0980-7
6. McLellan TM, Caldwell JA, Lieberman HR. A review of caffeine's effects on cognitive, physical and occupational performance. Neurosci Biobehav Rev. DOI: 2016;71:294–312. 10.1016/j.neubiorev.2016.09.001
7. Grgic J, Mikulic P. Acute effects of caffeine supplementation on resistance exercise, jumping, and Wingate performance: no influence of habitual caffeine intake. Eur J Sport Sci. 2020:1–11. DOI: 10.1080/17461391.2020.1817155
8. Bloms LP, Fitzgerald JS, Short MW, Whitehead JR. The Effects of Caffeine on Vertical Jump Height and Execution in Collegiate Athletes. J Strength Cond Res. 2016;30:1855–61. DOI: 10.1519/JSC.0000000000001280
9. Grgic J, Trexler E, Lazinica B, Pedisic Z. Effects of caffeine intake on muscle strength and power: A systematic review and meta-analysis. J Int Soc Sports Nutr. 2018;15. DOI: 10.1186/s12970-018-0216-0
10. Guest NS, VanDusseldorp TA, Nelson MT, et al. International society of sports nutrition position stand: caffeine and exercise performance. J Int Soc Sports Nutr. 2021;18:1. DOI: 10.1186/s12970-020-00383-4
11. Mielgo-Ayuso J, Marques-Jiménez D, Refoyo I, Del Coso J, León-Guereño P, Calleja-González J. Effect of Caffeine Supplementation on Sports Performance Based on Differences Between Sexes: A Systematic Review. Nutrients. 2019;11:E2313. DOI: 10.3390/nu11102313
12. Filip-Stachnik A, Wilk M, Krzysztofik M, et al. The effects of different doses of caffeine on maximal strength and strength-endurance in women habituated to caffeine. J Int Soc Sport Nutr. 2021;18:25. DOI: 10.1186/s12970-021-00421-9
13. Pickering C, Grgic J. Caffeine and Exercise: What Next? Sports Med Auckl NZ. 2019;49:1007–30. DOI: 10.1007/s40279-019-01101-0
14. Pallarés JG, Fernández-Elías VE, Ortega JF, Muñoz G, Muñoz-Guerra J, Mora-Rodríguez R. Neuromuscular responses to incremental caffeine doses: performance and side effects. Med Sci Sport Exerc. 2013;45:2184–92. DOI: 10.1249/MSS.0b013e31829a6672
15. Wilk M, Filip A, Krzysztofik M, Maszczyk A, Zajac A. The acute effect of various doses of caffeine on power output and velocity during the bench press exercise among athletes habitually using caffeine. Nutrients. 2019;11:1465. DOI: 10.3390/nu11071465
16. Ali A, O'Donnell J, Foskett A, Rutherfurd-Markwick K. The influence of caffeine ingestion on strength and power performance in female team-sport players. J Int Soc Sports Nutr. 2016;13:46. DOI: 10.1186/s12970-016-0157-4
17. Wilk M, Krzysztofik M, Filip A, Zajac A, Del Coso J. The effects of high doses of caffeine on maximal strength and muscular endurance in athletes habituated to caffeine. Nutrients. 2019;11:E1912. DOI: 10.3390/nu11081912
18. Beaumont R, Cordery P, Funnell M, Mears S, James L, Watson P. Chronic ingestion of a low dose of caffeine induces tolerance to the performance benefits of caffeine. J Sports Sci. 2017;35:1920–7. DOI: 10.1080/02640414.2016.1241421
19. Evans M, Tierney P, Gray N, Hawe G, Macken M, Egan B. Acute ingestion of caffeinated chewing gum improves repeated sprint performance of team sport athletes with low habitual caffeine consumption. Int J Sport Nutr Exerc Metab. 2018;28:221–7. DOI: 10.1123/ijsnem.2017-0217
20. Sabol F, Grgic J, Mikulic P. The effects of 3 different doses of caffeine on jumping and throwing performance: A randomized, double-blind, crossover study. int j sports physiol perform. 2019:1170–7. DOI: 10.1123/ijspp.2018-0884
21. Gonçalves L de S, Painelli V de S, Yamaguchi G, et al. Dispelling the myth that habitual caffeine consumption influences the performance response to acute caffeine supplementation. J Appl Physiol Bethesda Md. 1985 2017;123:213–20. DOI: 10.1152/japplphysiol.00260.2017
22. Filip-Stachnik A, Krzysztofik M, Kaszuba M, et al. Effects of acute caffeine intake on power output and movement velocity during a multiple-set bench press exercise among mild caffeine users. J Hum Kinet. 2021;78:219–28. DOI: 10.2478/hukin-2021-0044
23. Filip-Stachnik A, Krzysztofik M, Kaszuba M, et al. Placebo effect of caffeine on maximal strength and strength endurance in healthy recreationally trained women habituated to caffeine. Nutrients. 2020;12:3813. DOI: 10.3390/nu12123813
24. Filip A, Wilk M, Krzysztofik M, Del Coso J. Inconsistency in the ergogenic effect of caffeine in athletes who regularly consume caffeine: Is it due to the disparity in the criteria that defines habitual caffeine intake? Nutrients. 2020;12:1087. DOI: 10.3390/nu12041087

25. Bühler E, Lachenmeier D, Schlegel K, Winkler G. Development of a tool to assess the caffeine intake among teenagers and young adults. Ernahrungsumschau. 2014;61:58–63. DOI: 10.4455/eu.2014.011
26. Burke L. Caffeine and sport performance. Appl Physiol Nutr Metab Physiol/Appliquée Nutr Métabolisme. 2009;33:1319–34. DOI: 10.1139/H08-130
27. Frankowski M, Kowalski A, Ociepa A, Siepak J, Niedzielski P. Kofeina w kawach i ekstraktach kofeinowych i odkofeinowanych dostępnych na polskim rynku [Caffeine levels in various caffeine-rich and decaffeinated coffee grades and coffee extracts marketed in Poland]. Bromat Chem Toksykol. 2008;1:21–27. Polish.
28. SELF Nutrition Data. [Available at https://nutritiondata.self.com] [Accessed on 1 June 2021].
29. Heishman AD, Daub BD, Miller RM, Freitas EDS, Frantz BA, Bemben MG. Countermovement jump reliability performed with and without an arm swing in NCAA Division 1 Intercollegiate Basketball Players. J Strength Cond Res. 2018;50:669. DOI: 10.1519/JSC.0000000000002812
30. Cohen J. Statistical power analysis for the behavioral sciences. Academic Press; 2013.
31. Zbinden-Foncea H, Rada I, Gomez J, et al. Effects of caffeine on countermovement-jump performance variables in elite male volleyball players. Int J Sports Physiol Perform. 2018;13:145–50. DOI: 10.1123/ijspp.2016-0705
32. Markovic G. Does plyometric training improve vertical jump height? A meta-analytical review. Br J Sports Med. 2007;41:349–55. DOI: 10.1136/bjsm.2007.035113
33. McLellan CP, Lovell DI, Gass GC. The role of rate of force development on vertical jump performance. J Strength Cond Res. 2011;25:379–85. DOI: 10.1519/JSC.0b013e3181be305c
34. Norum M, Risvang L, Bjornsen T, et al. Caffeine increases strength and power performance in resistance-trained females during early follicular phase. Scand J Med Sci Sport. 2020;30. DOI: 10.1111/sms.13776
35. Foskett A, Ali A, Gant N. Caffeine enhances cognitive function and skill performance during simulated soccer activity. Int J Sport Nutr Exerc Metab. 2009;19:410–23. DOI: 10.1123/ijsnem.19.4.410
36. Apostolidis A, Mougios V, Smilios I, Rodosthenous J, Hadjicharalambous M. Caffeine supplementation: Ergogenic in both high and low caffeine responders. Int J Sports Physiol Perform. 2019;14:650–7. DOI: 10.1123/ijspp.2018-0238
37. Venier S, Grgic J, Mikulic P. Caffeinated gel ingestion enhances jump performance, muscle strength, and power in trained men. Nutrients. 2019;11:E937. DOI: 10.3390/nu11040937
38. Muñoz A, López-Samanes Á, Aguilar-Navarro M, et al. Effects of CYP1A2 and ADORA2A genotypes on the ergogenic response to caffeine in professional handball players. Genes. 2020;11:933. DOI: 10.3390/genes11080933
39. Stojanović E, Stojiljković N, Scanlan AT, et al. Acute caffeine supplementation promotes small to moderate improvements in performance tests indicative of in-game success in professional female basketball players. Appl Physiol Nutr Metab. 2019;44:849–56. DOI: 10.1139/apnm-2018-0671
40. Tallis J, Duncan MJ, James RS. What can isolated skeletal muscle experiments tell us about the effects of caffeine on exercise performance? Br J Pharmacol. 2015;172:3703–13. DOI: 10.1111/bph.13187
41. Wilk M, Filip A, Krzysztofik M, Gepfert M, Zajac A, Del Coso J. Acute caffeine intake enhances mean power output and bar velocity during the bench press throw in athletes habituated to caffeine. Nutrients. 2020;12:406. DOI: 10.3390/nu12020406
42. Halz M, Kaszuba M, Gawel D, Jarosz J, Matykiewicz P, Bichowska M. Influence of caffeine supplementation on bench press performance – review. Trends Sport Sci. 2021;28:69-82. DOI: 10.23829/TSS.2021.28.2-1
43. Wilk M, Filip A, Krzysztofik M, Maszczyk A, Zajac A. The acute effect of various doses of caffeine on power output and velocity during the bench press exercise among athletes habitually using caffeine. Nutrients. 2019;11:1465. DOI: 10.3390/nu11071465

Author Contributions: Study Design, DG, MK; Data Collection, DG, MK, ZK, MJ; Statistical Analysis, DG, MK, ZK, RK, MB, RT; Data Interpretation, DG, MK, ZK, RK, MB, MJ, RT; Manuscript Preparation, DG, MK, ZK, RK, MB, MJ, RT; Literature Search, DG, MK, ZK; Funding Acquisition, DG, RK, MB, RT. All authors have read and agreed to the published version of the manuscript.

Acknowledgements: The authors would like to thank the participants for their commitment and effort.

Funding: The study was supported and funded by the statutory research of the Jerzy Kukuczka Academy of Physical Education in Katowice, Poland.

Institutional Review Board Statement: The study protocol was approved by the Bioethics Committee for Scientific Research at the Academy of Physical Education in Katowice, Poland (3/2019), according to the ethical standards of the latest version of the Declaration of Helsinki, 2013.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.