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Caffeine improves performance but not duration of the countermovement jump phases

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ABSTRACT

BACKGROUND: The countermovement jump (CMJ) test is often employed to assess power generated in the lower limbs and has been related to performance in several sports modalities. The objective of this study was to assess the effects of caffeine supplementation on jump height, average power (AP), peak power (PP), maximum velocity ($V_{\max}$), force production and duration of the eccentric, isometric and concentric muscle contraction phases of a CMJ.

METHODS: Sixteen resistance-trained men (age: 22.69 ± 2.12 years; height: 1.78 ± 0.06 m; weight: 78.09 ± 10.27 kg) performed a CMJ 60 minutes after having taken an oral supplement containing $6 \text{ mg} \cdot \text{kg}^{-1}$ of caffeine or placebo (sucrose). The study design was randomized, double-blind crossover.

RESULTS: Caffeine ingestion improved jump height (+3.86%, $p=0.02$), $V_{\max}$ (+1.49%, $p=0.023$), AP (+4.83%, $p=0.006$), and PP (+3.49%, $p=0.004$).

CONCLUSIONS: Acute caffeine supplementation leads to improved CMJ height, $V_{\max}$, AP and PP without significantly affecting the duration of the different test phases. Therefore, caffeine supplementation may be employed as ergogenic aid in sports where CMJ performance has been associated with sport-specific performance enhancements.

Key words: muscle strength; coffee; sports performance; ergogenic substances.

TEXT

Introduction

Vertical jump tests are often used to assess physical fitness in both athletes and untrained individuals¹. The countermovement jump (CMJ) is one of the tasks used to measure vertical jump performance². Phosphocreatine degradation is the main energy system involved in CMJ performance³, since maximum exertion is needed for a short duration (~2 seconds). At the neuromuscular level, CMJ execution requires brief contraction times and high rates of force development⁴. Therefore, CMJ performance is determined by the contractile and neuromuscular control properties of the entire musculoskeletal system⁵, and jump height, power and force production during CMJ execution are indicators of lower limb muscular power⁶. Furthermore, CMJ performance has been associated with speed and acceleration in sprinting² and also with success in team sports like basketball and volleyball⁷, or soccer⁸.

Because of similar competitive levels between elite athletes of any given sport, a modest performance improvement can be sufficient to make a difference to performance outcome. To pursue such improvements, athletes take sport supplements like caffeine, which has been detected in sport competitions in three out of every four elite athletes⁸. In the 1970s, the ergogenicity of caffeine was believed to be related to enhanced lipolysis and enhanced muscle glycogen spare. Currently, however, the ergogenic effects of caffeine supplementation are attributed to the antagonistic effects of caffeine on adenosine receptors⁹. Caffeine binding to adenosine receptors is thought to delay fatigue through a mechanism whereby the inhibitory actions of adenosine on the release of excitatory neurotransmitters are offset, which results in enhanced neuronal excitability¹⁰, leading to improved endurance performance along with a reduction in the rate ratings of perceived exertion (RPE)⁹. In addition to its effects on the nervous system, caffeine also induces changes at the metabolic level—, increasing blood norepinephrine concentrations and glycolytic activity—, as well as at the neuromuscular level—, increasing the recruitment of motor units and muscle contractile force—¹¹.

Altogether, these effects contribute to enhanced CMJ performance after caffeine supplementation. Improved CMJ performance after caffeine intake has been observed in athletes competing in various sports such as volleyball^{12,13}, Brazilian Jiu-Jitsu¹⁴,

swimming¹⁵, badminton¹⁶, soccer^{8,17}, and basketball¹⁸, as well as recreational athletes¹⁹. Several of these studies assessed the effects of caffeine supplementation on CMJ jump height and power. However, few studies have examined the potential ergogenic effect of caffeine ingestion on jump velocity and force^{13,14,19}. Moreover, it is not yet known whether caffeine supplementation alters the duration of the different CMJ jump phases (i.e., eccentric, isometric, concentric). Given that caffeine modifies muscle contraction properties¹¹, and that jump duration has been associated with changes in muscular contractility⁷, the aim of this study was threefold: i) to examine whether caffeine ingestion affects the duration of the eccentric, isometric and concentric CMJ phases; ii) to assess its effects on jump velocity and force; and iii) to confirm evaluate its reported ergogenic effect on CMJ height and power.

Materials and methods

Participants

Sixteen healthy men with experience in resistance training (age: 22.69 ± 2.12 years; height: 1.78 ± 0.06 m; weight: 78.09 ± 10.27 kg; BMI: 24.72 ± 2.74 kg/m²) participated in this study. Inclusion criteria were: a) experience in resistance training (at least 18 months of three weekly sessions); b) a one-repetition maximum (1 RM) higher than body mass in the bench press and of 1.5 of body mass in squat exercise; c) no sports supplement taken in the previous three months; d) no smoking; e) no cardiovascular, pulmonary or neurological disease; and f) to not be considered an elite athlete. In a preliminary session, two researchers informed candidates about the procedure and the dietary requirements for participating in the study. All participants signed an informed consent form. The study protocol was approved by a local Ethics Committee (Chairperson: Dr. Francisco Javier Martín del Burgo; Protocol number: UI1-PI002; Date of approval: 12/11/2019).

Experimental design

The study design was randomized, double-blind crossover. After the initial informative session, each participant completed two sessions within the same time frame (± 0.5 hours) at the Exercise Physiology laboratory. In each session, participants ingested caffeine (CAFF) or placebo (PLAC) 60 min before the start of a standardized warm-up. After the warm-up, subjects performed a CMJ test.

Supplementation and diet control

Subjects arrived at the laboratory 75 min before the session onset, when they were given a red capsule (Guinama S.L.U, 0044634, La Pobla de Valbona, Spain) containing CAFF (6 mg·kg⁻¹) or PLAC (6 mg·kg⁻¹ of sucrose). Supplement timing was based on knowledge that caffeine reaches peak concentrations in blood 1 hour after its intake, and on its established degradation time of 13.4 minutes²⁰.

To avoid the effect of varied nutritional intake impacting our outcome measures, participants were issued dietary guidelines targeting the intake of 60% carbohydrates, 30% lipids and 10% proteins. Subjects were also instructed to avoid foods rich in caffeine (coffee, tea, chocolate, mate, energy drinks, cola drinks and chocolate drinks).

Capacity of the lower limbs to generate elastic-explosive force

Subjects performed a warm-up consisting of 5 min of pedaling at a self-selected submaximal workload on a cycle ergometer. After 1 min of passive rest, a specific warm up was started which consisted of 3 min of cycle exercise at 120 W (60 rpm) and a maximum 5 s sprint completed at the end of each minute. After 2 min of rest, subjects performed five CMJs of increasing intensity on a force platform (Quattro Jump model 9290AD; Kistler Instruments, Winterthur, Switzerland) with 45 s of rest between jumps.

Mean values from two jumps were recorded for the following variables, which have been related to the capacity of the legs to generate elastic-explosive force²¹: jump height (H), eccentric phase duration (T_{Ecc}), isometric phase duration (T_{Iso}), concentric phase duration (T_{Con}), peak power (PP), average power (AP), peak velocity (V_{max}), initial force (IF) and peak force (F_{max}).

Statistical analysis

The normality of data was first checked using the Kolmogorov-Smirnov test. To assess the effects of supplementation (PLAC and CAFF) on the different performance variables recorded during the CMJ test, paired samples t-tests were performed. For non normally distributed variables, a Wilcoxon signed-rank test was used. Effect sizes (d) were calculated using Cohen's *d*, and interpreted as: large (*d* > 0.8), moderate (*d* = 0.8 to 0.5), small (*d* = 0.5 to 0.2), and trivial (*d* < 0.2). All statistical tests were performed using

the Statistical Package for Social Sciences (version 20.0 for Mac, SPSSTM Inc, Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

Results

Table 1 near here

The results of CMJ jump capacity according to treatment (PLAC vs. CAFF) are provided in Table 1. The paired t-test revealed significant differences between the conditions PLAC and CAFF in the variables: H (Fig. 1A; 32.1 ± 4.71 vs. 33.34 ± 4.44 cm; $t_{15} = -2.609$; $p = 0.02$; $d_z = 0.65$), $V_{\max}$ (Fig. 1B; 2.68 ± 0.16 vs. 2.72 ± 0.17 m/s; $t_{15} = -2.522$; $p = 0.023$; $d_z = 0.63$), PP (Fig. 1C; 51.54 ± 4.62 vs. 53.34 ± 6 N/kg; $t_{15} = -3.427$; $p = 0.004$; $d_z = 0.86$), and AP (Fig. 1D; 28.59 ± 3.45 vs. 29.97 ± 3.67 N/kg; $t_{15} = -3.235$; $p = 0.006$; $d_z = 0.81$). No significant differences were detected for the remaining variables ($p > 0.05$; see Table 1 for details).

Figure 1 near here

Discussion

The aim of this work was threefold: i) to test whether caffeine ingestion leads to changes in the duration of the eccentric, isometric and concentric phases of a CMJ; ii) to also assess the effects of caffeine supplementation on jump velocity and force; and iii) to confirm evaluate prior findings of an ergogenic effect of caffeine on CMJ height and power. We observed that caffeine supplementation significantly enhanced H, PP, AP, and $V_{\max}$. Moreover, CAFF showed a potential ergogenic effect on IF and $F_{\max}$. However, we failed to find an effect of caffeine supplementation on duration of the eccentric, isometric, and concentric CMJ phases.

The improvement observed in CMJ jump height after caffeine supplementation (+3.86%, $p=0.02$) in resistance-trained subjects confirms evidence previously observed in jump duration in elite volleyball players (+5.3%)¹³, and in jump height in competitive volleyball players (+3.4%)¹², elite Brazilian Jiu-Jitsu athletes (+3.7%)¹⁴, elite badminton players (+5.0%)¹⁶, national standard swimmers (+3.0%)¹⁵ and national level basketball players (+2.1%)¹⁸. In contrast, other investigations examining the effects of combined caffeine and carbohydrates supplementation failed to detect improvements in vertical jump height in volleyball players³ or in CMJ height in amateur football players¹⁷. A common feature of both these investigations is that, while the effects of caffeine supplementation on jump height were assessed in a vertical jump test, measurements

were made after an exercise session. Given that the CMJ requires maximal neuromuscular effort⁵, it is likely that the fatigue produced by exercise impaired optimal jump performance and this could compromise the ergogenic effect of caffeine. Moreover, Pfeifer et al.³ administered 100 mg ($\sim 1.34 \text{ mg}\cdot\text{kg}^{-1}$) of caffeine as a gel, which is provided a dose much lower than administered in our study ($6 \text{ mg}\cdot\text{kg}^{-1}$) and in studies reporting an ergogenic effect^{13,14,16}, when the administered dose was $3\text{-}6 \text{ mg}\cdot\text{kg}^{-1}$ which has been reported to increase leg muscle strength²².

The height reached in a CMJ is determined by the V_{max} recorded during the jump, such that jump height can be calculated from V_{max} which, in turn, corresponds to the velocity recorded at takeoff^{23,24}. This would explain the greater V_{max} observed in our study following CAFF supplementation compared to PLAC ($+1.49\%$, $p=0.023$) and is consistent with previous studies, which reported greater V_{max} (Jacobson, 2018) along with a longer jump duration¹³ and height¹⁴ after caffeine supplementation.

We observed that improvements in CMJ height coincided with higher levels of both AP ($+4.83\%$, $p=0.006$) and PP ($+3.49\%$, $p=0.004$), confirming previous reports of higher PP values ($+1.2\text{-}16.2\%$)^{8,12,13} following caffeine supplementation. Jacobson et al.¹⁹ noted a 2.3% improvement in PP following acute caffeine supplementation, though the difference did not attain statistical significance. However, the timing of supplementation used by Jacobson et al.¹⁹ differed from the timing used both in our study and the remaining studies that have detected increased PP after caffeine intake^{8,13,18}. Specifically, Jacobson et al.¹⁹ administered caffeine 30 min before exercise, whereas caffeine was ingested 60 min before the performance test in studies reporting an ergogenic effect of caffeine supplementation. Given that peak blood caffeine concentrations is attained 45-60 min post caffeine ingestion, it is likely that the test in the study by Jacobson et al.¹⁹ was executed before peak caffeine concentrations were reached, thereby compromising the ergogenic potential of caffeine. Our results, in combination with those available in the literature, lend support to the notion that CMJ height is associated with the power levels exerted during the jump^{23,24}.

As for the force recorded during the concentric phase of the CMJ, Zbiden-Foncea et al.¹³ observed greater strength (F_{max}) after caffeine consumption, while we noted no significant differences between PLAC and CAFF; although we did detect a trend towards significance both for F_{max} ($p=0.053$) and IF ($p=0.06$). Our findings are therefore in line with the hypothesis that peak force may not be the best measure of vertical jump

performance²⁵ unlike other variables such as $V_{\max}$, AP and PP, which improved concurrently with jump height following caffeine supplementation.

Jump duration has been associated with muscular contractility⁷, which may be modified through caffeine supplementation¹¹. Our findings, nevertheless, suggest that caffeine does not affect the duration of the different jump phases (T_{ecc} , T_{iso} and T_{con}), despite our observed improvements in jump height, $V_{\max}$, AP and PP following caffeine supplementation. These disparate results may be explained by the low correlation reported for CMJ duration and height²⁴, and there is evidence to suggest that T_{ecc} and T_{con} are poor indicators of the height reached in a CMJ²³. Similarly, when Thorlund²⁶ compared CMJ performance before and after a handball match, it was observed that fatigue led to a decrease in both jump height (5.2%) and $V_{\max}$, with no changes produced in T_{ecc} and T_{con} ²⁶. Finally, in an investigation conducted by García-Pinillos et al.²⁷, increased jump capacity was observed in some runners following a racing session (post-activation potentiation, PAP), without differences in jump duration. Therefore, based on our findings and those reported in the aforementioned studies, it seems reasonable to suggest that the duration of the different jump phases may not be good indicators of the potential ergogenic effect of caffeine on the execution of a CMJ.

However, if we consider that for a given T_{con} value, $V_{\max}$ was greater during the concentric CMJ phase after the intake of caffeine, we may infer that CMJ movement during the concentric phase was greater following caffeine supplementation. Other authors have observed that, as opposed to the duration of the different jump phases, the knee flexion angle influences CMJ performance, increasing jump height as the consequence of an increased movement range²⁸. Hence, it could be that caffeine supplementation increases the velocity of movement via improved intramuscular coordination along with increased neuromuscular recruitment¹⁰ leading to a greater range of knee flexion and $V_{\max}$ in the CMJ in response to caffeine intake. As a future line of research, we propose examining the effect of acute caffeine supplementation on the degree of knee flexion during the CMJ.

Caffeine acts antagonistically on adenosine receptors and offsets the negative effects of adenosine on neural drive, neuromuscular recruitment is increased¹⁰. Caffeine has been attributed a positive effect on intra- and inter-muscular coordination during muscle contractions²⁹. Hence, part of the caffeine effect can be explained by increased motor unit recruitment³⁰ and an increase in neuromuscular efficiency³¹, thus resulting in

greater power output. Therefore, improved CMJ performance in the current study following caffeine ingestion is likely a result of enhanced neuromuscular function.

Conclusions

Acute supplementation with $6 \text{ mg} \cdot \text{kg}^{-1}$ of caffeine improved CMJ performance 60 min post ingestion. Our data indicate that improved jump height after caffeine intake was paralleled by improvements also in V_{max} , AP and PP with no effects on the duration of the different muscle contraction phases of the jump (eccentric, isometric, concentric). In contrast, we observed no improvements in force following caffeine supplementation, supporting the notion of Kirby et al.²⁵ that the force generated in a CMJ is not the best predictor of jump height.

Practical applications

- Caffeine supplementation may be used as ergogenic aid in sports where the ability to accelerate and sprint is crucial for performance.
- Caffeine supplementation may improve performance in team-sports involving jump actions (i.e., soccer, basketball, volleyball).
- Due to its ergogenic effects on jump height but not on the different jump duration phases, caffeine supplementation may be used in sport modalities where athletes seek to achieve a maximum vertical displacement of the center of mass through jumping with no timing restrictions (i.e., high jump in athletics), either during competition or training sessions.

REFERENCES

1. Balsalobre-Fernández C, Glaister M, Lockey RA. The validity and reliability of an iPhone app for measuring vertical jump performance. *J Sport Sci* 2015; 33(15):1574-1579.
2. Stanton R, Wintour SA, Kean CO. Validity and intra-rater reliability of MyJump app on iPhone 6s in jump performance. *J Sci Med Sport* 2017; 20(5):518–523.
3. Pfeiffer DR, Arvin KM, Herschberger CN, Haynes NJ, Renfrow MS. A Low Dose Caffeine and Carbohydrate Supplement does not Improve Athletic Performance during Volleyball Competition. *Int J Exerc Sci* 2017; 10(3):340-353. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5421974/>
4. 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 Sport Physiol* 2019; 14(9):1170–1177.
5. Bobbert MF, Van Soest AJ. Why do people jump the way they do? *Exerc Sport Sci Rev* 2001; 29(3):95-102.
6. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement jump tests. *J Strength Cond Res* 2004; 18(3):551-555.
7. Rodacki ALF, Fowler NE, Bennett SJ. Multi-segment coordination: Fatigue effects. *Med Sci Sport Exer* 2001; 33(7):1157-1167.
8. Lara B, Gonzalez-Millán C, Salinero JJ, Abian-Vicen J, Areces F, Barbero-Alvarez JC, et al. Caffeine-containing energy drink improves physical performance in female soccer players. *Amino Acids* 2014; 46(5):1385-1392.
9. Doherty M, Smith PM. Effects of caffeine ingestion on rating of perceived exertion during and after exercise: A meta-analysis. *Scand J Med Sci Spor* 2005; 15(2):69-78.

10. Davis JM, Zhao Z, Stock HS, Mehl KA, Buggy J, Hand GA. Central nervous system effects of caffeine and adenosine on fatigue. *Am J Physiol-Reg I* 2003; 284(2):R399-R404.
11. López-González LM, Sánchez-Oliver AJ, Mata F, Jodra P, Antonio J, Domínguez R. Acute caffeine supplementation in combat sports: A systematic review. *J Int Soc Sport Nutr* 2018; 15(1):60-70.
12. Pérez-López A, Salinero JJ, Abian-Vicen J, Valades D, Lara B, Hernández C et al. Caffeinated energy drinks improve volleyball performance in elite female players. *Med Sci Sport Exer* 2015; 47(4):850-856.
13. Zbinden-Foncea H, Rada I, Gomez J, Kokaly M, Stellingwerff T, Deldicque L et al. Effects of caffeine on countermovement-jump performance variables in elite male volleyball players. *Int J Sport Physiol* 2018; 13(2):145-150.
14. Diaz-Lara FJ, Del Coso J, García JM, Portillo LJ, Areces F, Abian-Vicen J. Caffeine improves muscular performance in elite Brazilian Jiu-jitsu athletes. *Eur J Sport Sci* 2016; 16(8):1079-1086.
15. Lara B, Ruiz-Vicente D, Areces F, Abian-Vicen J, Salinero JJ, González-Millán C et al. Acute consumption of a caffeinated energy drink enhances aspects of performance in sprint swimmers. *Brit J Nutr* 2015; 114(6):908-914.
16. Abian P, Del Coso J, Salinero JJ, Gallo-Salazar C, Areces F, Ruiz-Vicente et al. The ingestion of a caffeinated energy drink improves jump performance and activity patterns in elite badminton players. *J Sport Sci* 2015; 33(10):1042-1050.
17. Andrade-Souza VA, Bertuzzi R, De Araujo GG, Bishop D, Lima-Silva AD. Effects of isolated or combined carbohydrate and caffeine supplementation between 2 daily training sessions on soccer performance. *Appl Physiol Nutr Me* 2015; 40(5): 457-463.
18. Abian-Vicen J, Puente C, Salinero JJ, González-Millán C, Areces F, Muñoz G et al. A caffeinated energy drink improves jump performance in adolescent basketball players. *Amino Acids* 2014; 46(5):1333-1341.

- 1 19. Jacobson BH, Hester GM, Palmer TB, Williams K, Pope Z, Sellers J et al. Effect
2 of energy drink consumption on power and velocity of selected sport
3 performance activities. *J Strength Cond Res* 2018; 32(6):1613-1618.
4
5
- 6 20. Ministerio de Sanidad y Consumo. Real Farmacopea Española. Madrid; 2005.
7
- 8 21. Van Hooren B, Zolotarjova J. The Difference between Countermovement and
9 Squat Jump Performances: A Review of Underlying Mechanisms with Practical
10 Applications. *J Strength Cond Res* 2017; 31(7):2011-2020.
11
12
- 13 22. Tallis J, Yavuz HCM. The effects of low and moderate doses of caffeine
14 supplementation on upper and lower body maximal voluntary concentric and
15 eccentric muscle force. *Appl Physiol Nutr Me* 2018; 43(3):274-281.
16
17
- 18 23. Gonzalez-Badillo JJ, Marques MC. Relationship between kinematic factors and
19 countermovement jump height in trained track and field athletes. *J Strength Cond*
20 *Res* 2010; 24(12):3443-3447.
21
22
- 23 24. Barker LA, Harry JR, Mercer JA. Relationships between countermovement jump
24 ground reaction forces and jump height, reactive strength index, and jump time. *J*
25 *Strength Cond Res* 2018; 32(1):248-254.
26
27
- 28 25. Kirby TJ, McBride JM, Haines TL, Dayne AM. Relative net vertical impulse
29 determines jumping performance. *J Appl Biomech* 2011; 27(3):207-214.
30
31
- 32 26. Thorlund JB, Michalsik LB, Madsen K, Aagaard P. Acute fatigue-induced
33 changes in muscle mechanical properties and neuromuscular activity in elite
34 handball players following a handball match. *Scand J Med Sci Spor* 2008;
35 18(4):462-472.
36
37
- 38 27. García-Pinillos F, Molina-Molina A, Latorre-Román P. Impact of an incremental
39 running test on jumping kinematics in endurance runners: can jumping kinematic
40 explain the post-activation potentiation phenomenon? *Sport Biomech* 2016;
41 15(2):103-115.
42
43
- 44 28. Papaioakovou G, Fotis K, Nikodelis T, Panoutsakopoulos V, Kollias I. Influence
45 of the ankle joint dorsiflexion on the execution of vertical jumps. *ISBS -*
46
47
48
49
50
51
52
53
54
55

Conference Proceedings Archive 2007.

29. Del Coso J, Salinero JJ, González-Millán C, Abian-Vicen J, Pérez-González B. Dose response effects of a caffeine-containing energy drink on muscle performance: A repeated measures design. *J Int Soc Sport Nutr* 2012; 9(1):21-30.
30. Warren GL, Park ND, Maresca RD, McKibans KI, Millard-Stafford ML. Effect of caffeine ingestion on muscular strength and endurance: A meta-analysis. *Med Sci Sport Exer* 2010; 42(7):1375-1387.
31. San Juan AF, López-Samanes Á, Jodra P, Valenzuela PL, Rueda J, Veiga-Herreros P et al. Caffeine supplementation improves anaerobic performance and neuromuscular efficiency and fatigue in Olympic-level boxers. *Nutrients* 2019; 11(9): 2120-2134.

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NOTES

Conflicts of interest.— The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contributions.— The study was designed by PJ and RD; data were collected and analyzed by AL-R, PJ, SB, and RD; data interpretation and manuscript preparation were undertaken by AL-R, SB, and RD. All authors approved the final version of the paper.

TABLES

Table I.— *CMJ performance variables recorded for PLAC versus CAFF. Data are expressed as the mean $\pm$ standard deviation [95% confidence interval, CI].*

	PLAC		CAFF		$\Delta\%$	t	p	d
	M + SD [95% CI]	CV (%)	M + SD [95% CI]	CV (%)				
Height (cm)	32.1 $\pm$ 4.71 [29.59, 34.61]	0.15	33.34 $\pm$ 4.44 [30.98, 35.71]	0.13	3.86	- 2.609	0.02*	0.65
T_{Ecc} (s)	0.59 $\pm$ 0.13 [0.52, 0.66]	0.22	0.58 $\pm$ 0.12 [0.52, 0.65]	0.21	-1.69	0.331	0.745	0.08
T_{Iso}^a (s)	0.022 $\pm$ 0.036 [0.003, 0.041]	1.64	0.012 $\pm$ 0.006 [0.008, 0.015]	0.5	- 45.45		0.082	0.29
T_{Con} (s)	0.15 $\pm$ 0.07 [0.12, 0.19]	0.47	0.18 $\pm$ 0.07 [0.14, 0.22]	0.39	20	- 0.916	0.374	0.23

PP	51.54 ± 4.62	0.09	53.34 ± 6.00	0.11	3.49	-	0.004**	0.86
(N/kg)	[49.08, 54.00]		[50.14, 56.54]			3.427		
AP	28.59 ± 3.45	0.12	29.97 ± 3.67	0.12	4.83	-	0.006**	0.81
(N/kg)	[26.75, 30.43]		[28.01, 31.92]			3.235		
V_{max}	2.68 ± 0.16 [2.59,	0.06	2.72 ± 0.17 [2.63,	0.06	1.49	-	0.023*	0.63
(m/s)	2.77]		2.81]			2.522		
IF (N)	1.33 ± 0.3 [1.17,	0.23	1.44 ± 0.3 [1.28,	0.21	8.27	-	0.06	0.51
	1.49]		1.59]			2.038		
F_{max} (N)	2.49 ± 0.25 [2.36,	0.1	2.59 ± 0.32 [2.41,	0.12	4.02	-	0.053	0.52
	2.63]		2.76]			2.101		

Abbreviations: CV: coefficient of variation; Δ%: percentage difference versus PLAC; t: contrast statistic; p: p-value; d_z: *Cohen's d_z* effect size; TT: total duration; T_{Ecc}: duration eccentric phase; T_{Iso}: duration isometric phase; T_{Con}: duration concentric phase; PP: peak power; AP: average power; V_{max}: maximum velocity; IF: initial force; F_{max}: maximum force; ^a: data distribution for the variable T_{Iso} was non-normal so the Wilcoxon signed rank test was used; *: p < 0.05; **: p < 0.01.

TITLES OF FIGURES

Figure 1.— *The main results of this study are shown in this figure. Panel A shows jump height (cm), Panel B peak velocity (m/s), Panel C peak power (N/kg), and panel D average power (N/kg). In all panels, bars represent average values for each supplementation condition (PLAC vs. CAFF), and lines show individual results. Abbreviations: PLAC = placebo; CAFF = caffeine. * indicates significant differences for PLAC vs CAFF at p < 0.05 and ** at p < 0.01.*

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