



## Caffeine Increases Muscle Performance During a Bench Press Training Session

by

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Previous investigations have established the ergogenic effect of caffeine on maximal muscle strength, power output and strength-endurance. However, these investigations used testing protocols that do not replicate the structure of a regular strength training session. Thus, the aim of this study was to investigate the effect of acute caffeine ingestion on muscle performance during a simulated velocity-based training workout. In a double-blind, randomized and counterbalanced experiment, 12 participants performed two experimental trials after ingesting 3 mg/kg/b.m. of caffeine or a placebo. The trials consisted of 4 sets of 8 repetitions of the bench press exercise at 70% of their one-repetition maximum performed at maximal velocity. Bar velocity was recorded with a rotatory encoder and force, power output and work were calculated. Regarding the whole workout, caffeine increased mean bar velocity (+7.8%;  $p=0.002$ ), peak bar velocity (+8.7%;  $p=0.006$ ), mean force (+1.5%;  $p=0.002$ ), mean power output (+10.1%;  $p=0.003$ ) and peak power output (+8.2%;  $p=0.004$ ) when compared to the placebo. The total work performed in the caffeine trial was superior to the placebo trial ( $7.01\pm 2.36$  vs  $6.55\pm 2.20$  kJ,  $p=0.001$ ). These results suggest that the acute intake of 3 mg/kg/b.m. of caffeine before a velocity-based strength workout increased muscle performance and the total work performed across the whole training session. Thus, caffeine can be considered as an effective strategy to enhance muscle performance during the bench press training sessions.

**Key words:** resistance exercise, muscle strength, strength training, exercise, ergogenic aid.

### Introduction

Caffeine (1,3,7 trimethylxanthine) is a natural alkaloid with a potent ergogenic effect on several forms of exercise of maximum intensity (Grgic, Grgic, et al., 2019; Salinero et al., 2019). For this reason, this substance is commonly found in the post-competition urine samples of elite athletes (Aguilar-Navarro et al., 2019), suggesting a wide use of caffeine to increase sports performance. Among the sports with the highest urinary caffeine concentration is weightlifting, probably due to the high body of research that confirms the effects of caffeine on several aspects

of resistance-based exercise performance (Grgic, Sabol, et al., 2019). Briefly, there is ample evidence supporting that acute caffeine intake (habitually from 3 to 9 mg/kg/b.m.) increases maximal muscle strength (Diaz-Lara et al., 2016), power output (Mora-Rodríguez et al., 2015; Venier et al., 2019; Wilk et al., 2020) and strength-endurance (Diaz-Lara et al., 2016; Wilk et al., 2019). These same effects have been found in women (Fett et al., 2018; Romero-Moraleda, Del Coso, Gutiérrez-Hellín, and Lara, 2019) although research to date suggests that the magnitude of caffeine's ergogenicity on resistance exercise may be of

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lower magnitude than in men (Mielgo-Ayuso et al., 2019). Interestingly, acute caffeine intake causes a slightly different response to upper and lower body exercise (Tallis and Yavuz, 2018), while higher doses of caffeine may be needed for individuals habituated to caffeine (Wilk, Krzysztofik, et al., 2019b, 2019a), likely due to the progressive tolerance to the ergogenic effect of caffeine (Lara et al., 2019). On the contrary, the source of administered caffeine (e.g., coffee, energy drink, gel, etc) seems to have little effect on the ergogenic effect of this substance on resistance exercise performance (Del Coso et al., 2012; Richardson and Clarke, 2016; Venier et al., 2019).

Most of the research supporting the effect of caffeine on muscle performance during resistance exercise has used testing protocols that do not replicate the structure of a regular strength training workout. Traditionally, to assess caffeine's ergogenicity, a one-repetition maximum (1RM) protocol is used for maximal muscle strength (Wilk, Krzysztofik, et al., 2019b), a load-velocity curve for power output (Del Coso et al., 2012) and the number of repetitions performed with a submaximal load for strength-endurance (Grgic et al., 2020). To the author's knowledge, only two investigations have determined the effect of caffeine on simulated workouts of the bench press exercise. Salatto et al., (2020) investigated the effect of 9 mg/kg/b.m. of caffeine on muscle performance during 3 sets to failure with a load equivalent to 80% of 1RM. In that investigation, the participants completed a significantly higher number of repetitions during the normal and inclined bench press exercise with caffeine. Similarly, Rahimi, (2019) found that 6 mg/kg/b.m. of caffeine increased the number of repetitions during 3 sets to failure at 85% of 1RM, although in this investigation, only individuals with AA genotype in the CYP1A2 -1 63C>A polymorphism obtained the ergogenic effect of caffeine. However, repetition-to-failure workouts might not always be the optimum approach for resistance exercise training (Karsten et al., 2019). Furthermore, the use of velocity-based workouts with a given number of sets and repetitions is becoming an effective alternative to traditional resistance training (Martínez-Cava et al., 2020), while the evidence of caffeine's ergogenicity on this type of exercise is lacking. Thus, the aim of

this investigation was to determine the effect of acute caffeine intake on muscle performance variables during a bench press training session that included 4 sets of 8 repetitions at 70% 1RM performed at maximal velocity. We hypothesised that acute caffeine intake would increase muscle performance, especially in the last set of the bench press exercise protocol.

## Methods

### Participants

Twelve young and healthy participants (9 men and 3 women) volunteered to take part in the current study (age=  $29 \pm 8$  years, body mass=  $72.2 \pm 9.8$  kg, height=  $1.75 \pm 0.07$  m, body fat =  $18.6 \pm 8.9$  %). All of the participants fulfilled the following inclusion criteria: a) age between 18 and 45 years; b) low caffeine consumption (i.e., < 100 mg/day); c) previous resistance exercise training experience. Participants were excluded if they reported a) any type of upper body injury within the previous three months; b) positive smoking status; c) medication or dietary supplements usage within the previous month; d) previous history of cardiopulmonary diseases, e) oral contraceptive use; f) allergy to caffeine. Participants were included because they had been enrolled in a 4-week velocity-based training program of the bench press exercise and thus, they were familiarized with the experimental testing. Before enrolment in the study, all participants were fully informed of the experimental procedures and risks, and they all signed an informed written consent. The study was approved by the Camilo José Cela University Research Ethics Committee and was conducted in accordance with the last version of the Declaration of Helsinki.

### Experimental Design

A double-blind, placebo-controlled randomized and counterbalanced experimental design was used in this investigation. Each participant took part in a pre-experimental session followed by two identical experimental trials separated by at least five days to allow complete recovery, testing reproducibility, and substances wash-out. The participants acted as their own controls to produce a crossover design with repeated measures. In the experimental trials, the participants ingested: (a) 3 mg of caffeine per kg of body mass (3 mg/kg/b.m; Bulk

Powders, 100% purity; United Kingdom) or the same amount of an inert substance acting as a placebo (cellulose, Guinama, Spain). The substances were ingested in identical unidentifiable capsules with 200 mL of water one hour before the onset of the experimental testing. Each trial consisted of a 15-min standardized warm-up followed by 4 sets of 8 repetitions of the bench press exercise with a load equivalent to 70% of their 1RM (as measured in the pre experimental session). The participants were encouraged to perform their lifts with maximal velocity during each bench press repetition. This protocol was designed to simulate a velocity-based workout out with a fixed volume of training. In each repetition, bar velocity during the concentric phase of the exercise was recorded and force, power and work were calculated by using bar velocity and the load in kg. The trials were performed at the same time of the day and in a laboratory setting with controlled ambient temperature (~21°C) and relative humidity (~40%).

#### *Pre experimental trial*

Once participants fulfilled all the inclusion/exclusion criteria and signed the informed consent, they were encouraged to avoid nutritional supplements and sympathetic-adrenergic stimulants for the duration of the study. One week before the first experimental trial, the participants performed a pre experimental session aimed to assess 1RM in the bench press exercise and to familiarize the subjects with the experimental protocols. Upon arrival, the participants were weighed unclothed ( $\pm 50$  g, Radwag, Poland) in order to properly calculate caffeine dosage for the experimental trials and body fat percentage was evaluated afterwards with bioimpedance (model BC-418, Tanita, Japan). For the 1 RM measurement, the participants performed a 15-min warm-up and commenced with sets of increasing load estimated to be between 20 and 90% of 1RM (Romero-Moraleda, Del Coso, Gutiérrez-Hellín, Ruiz-Moreno, et al., 2019). Then, bench press 1RM was sought with a maximum of five maximal attempts permitted and three minutes of recovery between attempts. The 1RM was identified as the last successful lift with a correct technique and this value was used to standardize the load in the subsequent experimental trials. The 1RM test was

performed on the same Smith Machine used for the experimental trials.

#### *Experimental trials*

The participants were instructed to meet the following conditions 24-h before each experimental trial: (i) to avoid vigorous exercise, (ii) to adopt a similar diet and drink intake, (iii) to refrain from the consumption of alcohol, caffeine, and other stimulants. On the day of the experimental trials, the study participants arrived at the laboratory in the morning (between 10.00 and 12.00 am) in a fed state (~3 hours after their last meal). Upon arrival, the capsule with the experimental treatment (caffeine or placebo) was provided and ingested by the participant. Then, the participants rested supine for 45 min to allow for substance absorption. Thereafter, they underwent a standardized 15-min warm-up including upper body exercises and the bench press exercise executions at a progressive speed with submaximal loads. Then, they performed 4 sets of 8 repetitions of the bench press exercise on a Smith Machine (Technogym, Barcelona, Spain) with a load that represented 70% of their 1RM, as measured in the pre experimental trial. The participants were encouraged to perform each repetition at their maximal velocity during the concentric phase of the movement. The movement tempo during the exercise protocol was 1/2/X/1 (2 s for the eccentric phase, a 1 s pause during the transition phase from the eccentric to the concentric phase, with X referring to the maximum possible velocity during the concentric phase of movement, and the last digit indicated a 1 s pause between the concentric and eccentric phases; (Wilk et al., 2019). 3-min recovery periods were introduced between sets. Execution technique and motivation were standardized and monitored by 2 experienced researchers for reliability of the experimental conditions. During each attempt, the barbell displacement and duration of the concentric phase of the movement (e.g., time under tension) was recorded with a rotatory encoder and associated software (Isocontrol, EV-Pro, Spain) and mean and peak strength (N), mean and peak velocity (m/s) and mean and peak power output (W) were calculated for each repetition. The time to obtain peak values in the previously mentioned variables were also calculated. The work (J) produced in each repetition was assessed by using mean power

output and duration of the concentric phase of the movement. The total work performed in the workout (kJ) was calculated by adding the work produced in each of the 32 repetitions executed in the trial.

### Statistical Analysis

The study's data were blindly introduced into the statistical package SPSS (SPSS, v. 22.0, IBM SPSS Statistics, IBM Corporation) and subsequently analysed. The Shapiro-Wilk test was used to confirm the normality of the quantitative variables and, consequently, parametric statistics were used to determine differences among trials. A two-way analysis of variance (ANOVA) (treatment  $\times$  repetition) was performed to all muscle performance variables under investigation. After a significant F test was obtained for the main effect of caffeine (Greenhouse–Geisser correction), differences in all pairwise caffeine-placebo comparisons were identified by LSD *post hoc* tests. A paired t-test was used to detect differences in the caffeine-placebo comparison of the total amount of work produced during the workout. In all statistical tests, a significance level of  $p < 0.05$  was set. The data are presented as mean  $\pm$  standard deviation.

### Results

Table 1 contains the effect of caffeine on muscle performance variables during the whole workout. Overall, and compared to the placebo trial, there was a main effect of the caffeine to increase mean bar velocity ( $p = 0.002$ ) and peak bar velocity ( $p = 0.006$ ) across the workout. Similarly, there was a main effect of caffeine to increase mean force ( $p = 0.002$ ), mean power output ( $p = 0.003$ ), peak power output ( $p = 0.004$ ), and the work performed ( $p = 0.004$ ), although the main effect of caffeine did not reach statistical significance for peak force ( $p = 0.129$ ). On the contrary, the main effect of caffeine reduced the time to reach peak velocity ( $p = 0.048$ ), the time to reach peak power output ( $p = 0.024$ ) with no main effect of caffeine on the time to reach peak force ( $p = 0.910$ ) nor on the time under tension ( $p = 0.081$ ). In most of these variables there was a main effect of repetition indicating that the values of these variables changed across the workout. However, there was no treatment  $\times$  repetition interaction in any of the performance variables (Table 1).

Figure 1 depicts peak velocity and mean

velocity in each repetition during the workout to allow a more comprehensive view of the effect of caffeine on muscle performance. Briefly, caffeine increased peak velocity over placebo in 30 out of 32 repetitions performed during the training session while the effect was similarly present in all 4 sets (all  $p < 0.05$ ). Likewise, caffeine increased mean velocity in 26 out of 32 repetitions performed during the training session (all  $p < 0.05$ ). Figure 3 depicts the total work performed during the workout session as a result of the addition of the mechanical work performed in each repetition. Overall, caffeine increased the total work performed in the workout ( $p < 0.05$ ) with 11 out of 12 athletes presenting higher values of total work with caffeine than with placebo.

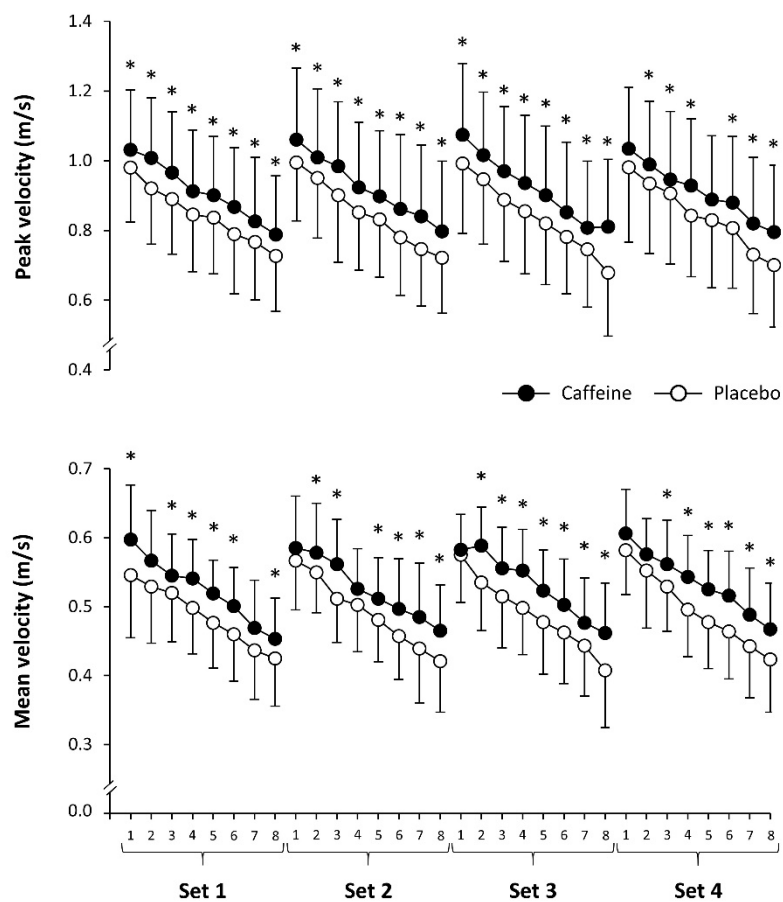
### Discussion

The aim of this study was to investigate the effect of acute caffeine intake on muscle performance during a velocity-based bench press workout that included 4 sets of 8 repetitions at 70% 1RM. This research question was designed to determine whether caffeine is ergogenic during resistance exercise training with a given set of volume, as all the previous investigations in this field used repetitions-to-failure testing (Rahimi, 2019; Salatto et al., 2020). The outcomes of this investigation indicate that the intake of 3 mg/kg/b.m. of caffeine one hour before exercise increased mean and peak bar velocity, mean force and, mean power and peak power across the workout. As a result, caffeine increased the total mechanical work performed in the workout which suggests that caffeine can be considered as an effective ergogenic aid to increase muscle performance during a velocity-based strength training session in the bench press exercise.

Despite the contradictory results of early investigation on the effect of caffeine on bench press exercise performance (Jacobs et al., 2003; Beck et al., 2006; Astorino et al., 2008), most recent investigations have contributed to establish caffeine's ergogenic effects on bench press performance (Diaz-Lara et al., 2016; Grgic and Mikulic, 2017; Wilk et al., 2019, 2020). However, even the most recent investigation on this topic is difficult to apply to real strength training scenarios as the assessments used in these investigations (e.g., 1 RM, load-velocity curve and strength-endurance tests) are rarely used in

workouts aimed to obtain strength training adaptations. In this regard, one of the most common used criteria for designing resistance training workouts is the 1RM continuum zone with a different number of repetitions to obtain strength gains (i.e., 2-5 repetitions), hypertrophy (6-12 repetitions) and strength-endurance (> 12 repetitions) (Sheppard and Tripplet, 2016). In addition, greater improvements in muscle power performance can be obtained in workouts

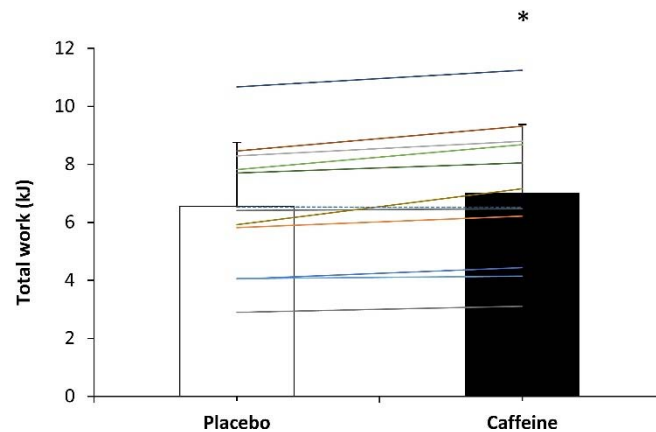
composed of sets that are performed with maximal movement velocity instead of repetitions-to-failure (Karsten et al., 2019). With this background, the current study indicates that caffeine is effective to enhance muscle performance during a velocity based bench press training session.



**Figure 1**

*Peak velocity and mean velocity during a bench press exercise session consisting of 4 sets of 8 repetitions at 70% of 1 repetition-maximum after the ingestion of 3 mg/kg/b.m. of caffeine or a placebo.*

*Data is shown as mean  $\pm$  SD for each repetition performed in a bench press training session in 12 individuals. (\*) Significant differences between caffeine and placebo at  $p < 0.05$ .*



**Figure 2**

Total work executed during a bench press training session, consisting of 4 sets of 8 repetitions at 70% of 1RM after the ingestion of 3 mg/kg/b.m. of caffeine or a placebo. The total work performed in the workout was calculated by adding the work produced in each repetition of the bench press exercise. Each line represents one individual from a sample of 12 individuals; continuous lines depict individuals with higher total work performed with caffeine and the dashed line depicts the individual with higher total work performed with placebo. (\*) Significant differences between caffeine and placebo at  $p < 0.05$ .

**Table 1**

Muscle performance variables during a bench press training session consisting of 4 sets of 8 repetitions at 70% of 1RM after the ingestion of 3 mg/kg/b.m. of caffeine or a placebo.

Variables (units)	Placebo	Caffeine	$\Delta$ (%)	Treatment	Repetition	Interaction
Mean velocity (m/s)	0.49 ± 0.07	0.53 ± 0.06	+7.8	0.002	<0.001	0.329
Peak velocity (m/s)	0.84 ± 0.17	0.92 ± 0.19	+8.7	0.006	<0.001	0.585
Mean force (N)	506 ± 203	514 ± 206	+1.5	0.002	<0.001	0.311
Peak force (N)	665 ± 282	673 ± 289	+1.2	0.129	0.462	0.507
Mean power (W)	240 ± 86	264 ± 96	+10.1	0.003	<0.001	0.464
Peak power (W)	427 ± 147	462 ± 161	+8.2	0.004	<0.001	0.583
Work (J)	205 ± 70	220 ± 75	+7.2	0.003	<0.001	0.286
Time to peak velocity (ms)	656 ± 154	632 ± 114	-3.7	0.048	0.001	0.398
Time to peak force (ms)	21.0 ± 20.3	20.5 ± 17.1	-2.7	0.910	0.509	0.495
Time to peak power (ms)	622 ± 125	592 ± 119	-4.8	0.024	0.001	0.359
Time under tension (ms)	873 ± 115	850 ± 88	-2.7	0.081	<0.001	0.176

Data is shown as mean ± SD for all the repetitions (i.e., 32) performed in the workout in 12 individuals.

As depicted in Table 1, the acute intake of caffeine produced an ergogenic effect in almost all the muscle performance variables under investigation. Interestingly, the effect of caffeine velocity- and power-based variables was superior to the effect on force-based variables. Due to the tempo movement set for this investigation (1/2/X/1), which included a 2-s pause before the all-out concentric phase of the exercise, peak values of force were achieved in the first ~20 ms of the movement. In contrast, peak values of velocity and power were obtained at 70-75% of the total time under tension indicating that the effect of caffeine was more pronounced once the barbell has been accelerated. These data may indicate that acute caffeine intake is more effective to produce velocity- and power-related enhancements induced by resistance training, although this speculation requires further exploration. In any case, the presence of the main effect of caffeine, together with the lack of treatment  $\times$  repetition interaction in the muscle performance variables investigated suggest that the effect of caffeine was similarly present across the session (Figure 1).

The experimental design employed in this investigation contains several limitations. First, the experimental training session contained 4 sets of 8 repetitions at 70% 1RM performed at maximal velocity, but it is necessary to determine if caffeine also enhanced muscle performance in other resistance-training scenarios of lower/higher number of sets and repetitions and with lower/higher number of sets. Second, the study did not include blood and tissue samples and thus we were unable to determine if the serum caffeine concentration was similar in all individuals, thus confirming the main mechanism behind caffeine's ergogenicity. Third of all, we used a group of individuals with low habituation to caffeine. As there is tolerance to caffeine ergogenic effect in endurance and anaerobic-like exercise (Lara et al., 2019), it is probable that the effect found in this investigation is smaller in individuals habituated

to caffeine. In this regard, athletes habituated to caffeine may need  $> 6$  mg/kg/b.m. to obtain ergogenic effects of caffeine (Wilk, Krzysztofik, et al., 2019b), although this also depends on their level of habituation. Lastly, we did not obtain information about the side effects induced by the ingestion of caffeine. As several side effects are commonly reported after acute caffeine intake of similar doses (Salinero et al., 2014), the study of the prevalence of side effects is necessary before recommending caffeine to increase muscle performance during a resistance exercise workout.

In summary, the acute intake of 3 mg/kg/b.m. of caffeine before a velocity-based resistance exercise training session, increased force, velocity, power and work during a 4 $\times$ 8-70% 1RM workout. The magnitude of the main effect of caffeine (Table 1) and the continued enhancement of resistance exercise performance through all sets and repetitions (Figure 1) indicate that caffeine was an effective aid to improve muscle performance across the workout. As recent evidence suggest, resistance training not to failure is more favourable for upper-body power gains in comparison to training programs to-failure (Karsten et al., 2019), the use of caffeine may be useful to enhance the multiple muscle and central adaptations derived from workouts with a given number of sets and repetitions performed at maximal velocity. In addition, it is probable that caffeine may be useful to offset part of the muscle performance decline within a set found when using traditional resistance exercise training (Latella et al., 2019). Future investigations should determine if the acute effect of caffeine to enhance muscle performance variables during a single workout is translated in long-term adaptations, such as hypertrophy, strength gains, and power increases if resistance exercise training is preceded by acute ingestion of caffeine.

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## References

- Aguilar-Navarro M, Muñoz G, Salinero JJ, Muñoz-Guerra J, Fernández-Álvarez M, Plata MDM, Del Coso J. Urine Caffeine Concentration in Doping Control Samples from 2004 to 2015. *Nutrients*, 2019; 11(2): 286
- Astorino TA, Rohmann RL, Firth K. Effect of caffeine ingestion on one-repetition maximum muscular strength. *Eur J Appl Physiol*, 2008; 102(2): 127–132
- Beck TW, Housh TJ, Schmidt RJ, Johnson GO, Housh DJ, Coburn JW, Malek MH. The acute effects of a caffeine-containing supplement on strength, muscular endurance, and anaerobic capabilities. *J Strength Cond Res*, 2006; 20(3): 506–510
- Del Coso J, Salinero JJ, González-Millán C, Abián-Vicén J, Pérez-González B. Dose response effects of a caffeine-containing energy drink on muscle performance: A repeated measures design. *J Int Soc Sports Nutr*, 2012; 9
- Diaz-Lara FJ, Del Coso J, García JM, Portillo LJ, Areces F, Abián-Vicén J. Caffeine improves muscular performance in elite Brazilian Jiu-jitsu athletes. *Eur J Sport Sci*, 2016; 1–8
- Fett CA, Aquino NM, Schantz Junior J, Brandão CF, De Araújo Cavalcanti JD, Fett WC. Performance of muscle strength and fatigue tolerance in young trained women supplemented with caffeine. *J Sports Med Phys Fitness*, 2018; 58(3): 249–255
- 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*, 2019; 54(11): 681–688
- Grgic J, Mikulic P. Caffeine ingestion acutely enhances muscular strength and power but not muscular endurance in resistance-trained men. *Eur J Sport Sci*, 2017; 17(8): 1029–1036
- Grgic J, Pickering C, Bishop DJ, Coso J Del, Schoenfeld BJ, Tinsley GM, Pedisic Z. ADORA2A C Allele Carriers Exhibit Ergogenic Responses to Caffeine Supplementation. *Nutrients*, 2020; 12(3):
- Grgic J, Sabol F, Venier S, Tallis J, Schoenfeld BJ, Coso J Del, Mikulic P. Caffeine Supplementation for Powerlifting Competitions: an Evidence-Based Approach. *J Hum Kinet*, 2019; 68(1): 37–48
- Jacobs I, Pasternak H, Bell DG. Effects of ephedrine, caffeine, and their combination on muscular endurance. *Med Sci Sports Exerc*, 2003; 35(6): 987–994
- Karsten B, Fu Y (Leon), Larumbe-Zabala E, Seijo M, Naclerio F. Impact of Two High-Volume Set Configuration Workouts on Resistance Training Outcomes in Recreationally Trained Men. *J Strength Cond Res*, 2019; 1
- Lara B, Ruiz-Moreno C, Salinero JJ, Del Coso J. Time course of tolerance to the performance benefits of caffeine. *PLoS One*, 2019; 14(1): e0210275
- Latella C, Teo WP, Drinkwater EJ, Kendall K, Haff GG. The Acute Neuromuscular Responses to Cluster Set Resistance Training: A Systematic Review and Meta-Analysis. *Sport Med*, 2019, December 1; Springer International Publishing
- Martínez-Cava A, Hernández-Belmonte A, Courel-Ibáñez J, Morán-Navarro R, González-Badillo JJ, Pallarés JG. Reliability of technologies to measure the barbell velocity: Implications for monitoring resistance training. *PLoS One*, 2020; 15(6): e0232465
- 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(10): 2313
- Mora-Rodríguez R, Pallarés JG, López-Gullón JM, López-Samanes Á, Fernández-Elías VE, Ortega JF. Improvements on neuromuscular performance with caffeine ingestion depend on the time-of-day. *J Sci Med Sport*, 2015; 18(3): 338–342
- Rahimi R. The effect of CYP1A2 genotype on the ergogenic properties of caffeine during resistance exercise: a randomized, double-blind, placebo-controlled, crossover study. *Ir J Med Sci*, 2019; 188(1): 337–345
- Richardson DL, Clarke ND. Effect of coffee and caffeine ingestion on resistance exercise performance. *J Strength Cond Res*, 2016; 30(10): 2892–2900
- Romero-Moraleda B, Del Coso J, Gutiérrez-Hellín J, Lara B. The Effect of Caffeine on the Velocity of Half-Squat Exercise during the Menstrual Cycle: A Randomized Controlled Trial. *Nutrients*, 2019; 11(11): 2662



- Romero-Moraleda B, Del Coso J, Gutiérrez-Hellín J, Ruiz-Moreno C, Grgic J, Lara B. The Influence of the Menstrual Cycle on Muscle Strength and Power Performance. *J Hum Kinet*, 2019; 68 123–133
- Salatto RW, Arevalo JA, Brown LE, Wiersma LD, Coburn JW. Caffeine's Effects on an Upper-Body Resistance Exercise Workout. *J Strength Cond Res*, 2020; 34(6): 1643–1648
- Salinero J., Lara B, Del Coso J. Effects of acute ingestion of caffeine on team sports performance: a systematic review and meta-analysis. *Res Sport Med*, 2019; 27(2): 238–256
- Salinero JJ, Lara B, Abian-Vicen J, Gonzalez-Millán C, Areces F, Gallo-Salazar C, ... Del Coso J. The use of energy drinks in sport: Perceived ergogenicity and side effects in male and female athletes. *Br J Nutr*, 2014; 112(9): 1494–1502
- Sheppard J, Tripplet N. Design for resistance training. In *Essential of Strength Training and Conditioning*, 2016; (pp. 439–470) Champaign, IL: Human Kinetics
- Tallis J, Yavuz HCM. The effects of low and moderate doses of caffeine supplementation on upper and lower body maximal voluntary concentric and eccentric muscle force. *Appl Physiol Nutr Metab*, 2018; 43(3): 274–281
- Venier S, Grgic J, Mikulic P. Caffeinated gel ingestion enhances jump performance, muscle strength, and power in trained men. *Nutrients*, 2019; 11(4):
- 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(2): 406
- 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(7):
- Wilk M, Golas A, Krzysztofik M, Nawrocka M, Zajac A. The effects of eccentric cadence on power and velocity of the bar during the concentric phase of the bench press movement. *J Sport Sci Med*, 2019; 18(2): 191–197
- Wilk M, Krzysztofik M, Filip A, Zajac A, Del Coso J. Correction: Wilk et al. "The Effects of High Doses of Caffeine on Maximal Strength and Muscular Endurance in Athletes Habituated to Caffeine" *Nutrients*, 2019, 11(8), 1912. *Nutrients*, 2019a; 11(11):
- 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*, 2019b; 11(8): 1912

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