# *Caffeine Ingestion Enhances Repetition Velocity in Resistance Exercise: A Randomized, Crossover, Double-Blind Study Involving Control and Placebo Conditions*

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# Caffeine Ingestion Enhances Repetition Velocity in Resistance Exercise: A Randomized, Crossover, Double-Blind Study Involving Control and Placebo Conditions

*by*
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*We aimed to examine the effects of placebo and caffeine compared to a control condition on mean velocity in the bench press exercise. Twenty-five resistance-trained men participated in this randomized, crossover, double-blind study. The participants performed the bench press with loads of 50%, 75%, and 90% of one-repetition maximum (1RM), after no supplementation (i.e., control), and after ingesting caffeine (6 mg/kg), and placebo (6 mg/kg of dextrose). At 50% 1RM, there was a significant effect of caffeine on mean velocity compared to control (effect size [ES] = 0.29; p = 0.003), but not when compared to placebo (ES = 0.09; p = 0.478). At 75% 1RM, there was a significant effect of caffeine on mean velocity compared to placebo (ES = 0.34; p = 0.001), and compared to control (ES = 0.32; p < 0.001). At 90% 1RM, there was a significant effect of caffeine on mean velocity compared to placebo (ES = 0.36; p < 0.001), and compared to control (ES = 0.46; p < 0.001). There was no significant difference between placebo and control in any of the analyzed outcomes. When evaluated pre-exercise and post-exercise, 20% to 44% and 28% to 52% of all participants identified caffeine and placebo trials beyond random chance, respectively. Given that the blinding of the participants was generally effective, and that there were no significant ergogenic effects of placebo ingestion, the improvements in performance following caffeine ingestion can be mainly attributed to caffeine's physiological mechanisms of action.*

***Keywords***: *ergogenic aid; supplements; mean repetition velocity.*

## Introduction

Caffeine is one of the most commonly ingested psychoactive substances in the world (Mitchell et al. 2014). A national survey from the U.S. indicated that 85% of the population ingests at least one caffeinated beverage per day (Mitchell et al. 2014). Caffeine is also a well-researched ergogenic aid, with relevant studies dating back to 1907 (Rivers and Webber, 1907). For research purposes, caffeine is generally ingested in doses from 3 to 6 mg/kg, approximately 60 minutes before exercise (Grgic et al. 2020a). Current evidence indicates that caffeine ingestion, compared to placebo, may acutely enhance muscle and aerobic endurance, muscle strength, and power, as well as speed and jumping performance (Grgic et al. 2020a).

Generally, studies that explore the effects of caffeine on exercise performance include two trials. In one trial, the participants consume the caffeine dose, while in the other, they consume a placebo. It is assumed that placebo ingestion does not influence exercise test results, so any increases in performance are attributed to caffeine's physiological mechanisms. However, there are several instances where isolated placebo ingestion provided an ergogenic effect (Beedie and Foad, 2009). For example, Pollo et al. (2008) found that placebo administration (along with the suggestion that it was caffeine), enhanced total work

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in a set of leg extensions. Duncan et al. (2009) used a design where the researchers informed participants that they ingested caffeine on one occasion and placebo on another, even though they ingested placebo in both cases. Increases in muscle endurance were observed when the participants thought that they ingested caffeine. Given that placebo may enhance performance, researchers have suggested that future studies should include a non-supplement, control trial in their designs (Beedie et al. 2018). A study that includes all three trials (i.e., caffeine, placebo, and control) would inform and quantify the isolated effects of caffeine and placebo on exercise performance (Beedie et al. 2018).

A recent meta-analysis found a significant ergogenic effect of caffeine ingestion on repetition velocity in resistance exercise (Raya-González et al. 2020). However, all 12 studies included in the meta-analysis only compared the effects of caffeine vs. placebo. In other words, no available studies explored the isolated effects of caffeine and placebo on repetition velocity. Accordingly, we aimed to examine the effects of placebo and caffeine compared to a control condition on mean repetition velocity in resistance exercise. Based on previous research (Duncan et al. 2009; Pollo et al. 2008), we hypothesized that caffeine and placebo ingestion would enhance performance compared to a control condition.

## Methods

### *Design and Procedures*

This study employed a randomized, crossover, double-blind study design, where the participants were required to visit the laboratory on four occasions. In the first visit, the participants filled out a validated questionnaire for estimating their habitual caffeine intake (Bühler et al. 2014). In line with the validation study, this questionnaire utilized a 24-hour recall for the assessment of habitual caffeine intake (Bühler et al. 2014). Additionally, one-repetition maximum (1RM) in the bench press was estimated using the methods by Balsalobre-Fernández et al. (2018). The participants were also familiarized with the test, which involved an assessment of repetition velocity in the bench press with loads of 50%, 75%, and 90% of 1RM. After the first visit, the participants were randomized to the three experimental conditions: (a) placebo; (b) caffeine; and (c) control. Before every session, the participants were instructed to give maximum effort in the exercise tests. A minimum of 3 and a maximum of 6 days was provided between trials. All testing sessions were conducted in the morning hours (between 07:00 and 09:00 am), and all participants performed the trials in a fasted state. Both caffeine and placebo were provided in gelatin capsules of identical appearance, 60 minutes before starting the testing session. Caffeine was provided in the dose of 6 mg/kg, while the placebo contained 6 mg/kg of dextrose. In the control condition, the participants came to the laboratory and waited for 60 minutes before beginning the testing session; however, they did not ingest any capsule.

### *Participants*

Power analysis was performed using G*Power (version 3.1.9.2, University Düsseldorf, Germany) and the following parameters: "ANOVA, repeated measures, within factors" was assumed as the statistical test, expected effect size (*f*) for repetition velocity was 0.15, alpha = 0.05, the statistical power = 80%, *r* = 0.85, one group of participants, and three experimental conditions. The power analysis indicated that a sample of 23 participants was required for this study. To account for potential drop-outs, we recruited 26 participants. All participants were "resistance-trained," defined as having a minimum of one year of resistance training experience and being able to lift at least 100% of their body mass in the bench press exercise. None of the participants used targeted caffeine supplementation in the last six months before the study commenced. One participant experienced nausea after caffeine ingestion and could not complete the testing protocol. Therefore, 25 participants were included in the analysis (mean ± SD: age 23 ± 2 years; height 183 ± 7 cm; body mass 83 ± 11 kg; habitual caffeine intake: 1.0 ± 1.2 mg/kg/day, range: 0 to 4.4 mg/kg/day; 1RM in the bench press: 104.2 ± 15.7 kg). Ethical approval for the study was obtained from the Committee for Scientific Research and Ethics of the Faculty of Kinesiology at the University of Zagreb (approval number: 48/2019). Additionally, participants were informed about the study risks and benefits, and all provided written informed consent.

### *Exercise tests*

Fifty minutes after capsule ingestion (placebo

or caffeine) or after passive rest (control condition), the participants performed ten minutes of self-selected warm-up. In each session, the participants were instructed to keep the warm-up consistent. In the three experimental conditions, mean repetition velocity was assessed using a valid and reliable *PowerLift* mobile phone application (Balsalobre-Fernández et al. 2017). This device has high test-retest reliability, as demonstrated by intra-class correlation coefficients for mean repetition velocity that ranged from 0.93 to 0.99 (Balsalobre-Fernández et al. 2017). The *PowerLift* mobile phone application allows:

1. Video recording of the lift in slow motion,
2. Frame-by-frame inspection of the recorded video material,
3. Manual selection of the beginning and the end of the concentric portion of the movement.

The push-off phase was considered as the beginning of the movement. The end of the movement was considered the moment when the participants fully extended the elbows. The eccentric phase lasted two seconds in each repetition and the participants were instructed to perform the eccentric action in a controlled manner. The application calculated the time (in m/s) between two frames and provided mean repetition velocity data. In each session, the participants performed two, one, and one repetition of the bench press exercise with loads of 50%, 75%, and 90% of their 1RM, respectively. For 50% of 1RM, the better repetition, in the context of higher mean velocity, was used for the analysis. All repetitions were carried out with maximal intended concentric velocity. A three-minute rest interval was provided between sets or loads.

***Assessment of blinding***

The effectiveness of the blinding was tested pre- and post-exercise in the placebo and caffeine trials (Saunders et al. 2017). For this assessment, we asked participants the following question: "Which supplement do you think you have ingested?" This question had three possible answers: (a) "caffeine"; (b) "placebo"; (c) "do not know".

***Statistical analysis***

The differences between the caffeine, placebo, and control trials in mean velocity at 50%, 75%, and 90% of 1RM were examined using one-way repeated measures ANOVA. In the case of a significant main effect, post hoc analysis was performed using pairwise comparisons between each condition with a paired t-test. We initially set the statistical significance threshold at $p < 0.05$. However, because of the multiple comparisons, the Holm-Bonferroni correction was used to adjust the alpha value. Based on the rank of *p*-values, the statistical significance threshold was set at 0.05, 0.025, and 0.017 for rank 3, 2, and 1, respectively. Hedges' g effect size (ES) for repeated measures was calculated and presented with their respective 95% confidence intervals (CI). ES interpretation was based on the following classification: "trivial" <0.20, "small" 0.20–0.49, "moderate" 0.50–0.79, and "large" ≥0.80. The effectiveness of the blinding was explored using the Bang's Blinding Index (Bang et al. 2004). Values in this index range from –1 (opposite guessing) to 1 (complete lack of blinding). Here, these data are reported as a percentage of individuals who identified the correct treatment condition beyond chance. All analyses were performed using the *Statistica* software (version 13.4.0.14; TIBCO Software Inc., Palo Alto, CA, USA).

## Results

***Mean velocity outcomes***

The results of the one-way repeated measures ANOVA for mean velocity at 50% of 1RM indicated a significant main effect of condition, $p < 0.009$. There was no significant difference between placebo and caffeine (ES = 0.09; 95% CI: –0.10, 0.28; $p = 0.478$; alpha = 0.05; +1.2%; Table 1 and Table 2), or between placebo and control conditions (ES = 0.19; 95% CI: 0.00, 0.42; $p = 0.036$; alpha = 0.025; +2.5%). There was a significant effect of caffeine compared to control (ES = 0.29; 95% CI: 0.09, 0.50; $p = 0.003$; alpha = 0.017; +3.7%).

The results of the one-way repeated measures ANOVA for mean velocity at 75% of 1RM indicated a significant main effect of condition, $p < 0.001$. There was no significant difference between placebo and control (ES = 0.00; 95% CI: –0.20, 0.20; $p = 0.666$; alpha = 0.05; 0.0%). There was a significant effect of caffeine compared to placebo (ES = 0.34; 95% CI: 0.12, 0.58; $p = 0.001$; alpha = 0.025; +5.7%), and compared to

control (ES = 0.32; 95% CI: 0.13, 0.53; $p < 0.001$; alpha = 0.017; +5.7%).

The results of the one-way repeated measures ANOVA for mean velocity at 90% of 1RM indicated a significant main effect of condition, $p < 0.001$. There was no significant difference between placebo and control (ES = 0.11; 95% CI: –0.06, 0.29; $p = 0.376$; alpha = 0.05; +3.0%). There was a significant effect of caffeine compared to placebo (ES = 0.36; 95% CI: 0.15, 0.60; $p < 0.001$; alpha = 0.025; +8.8%), and compared to control (ES = 0.46; 95% CI: 0.22, 0.71; $p < 0.001$; alpha = 0.017; +12.1%).

***Effectiveness of blinding***

When evaluated pre-exercise, 20% and 44% of all participants identified caffeine and placebo trials beyond random chance, respectively. When evaluated post-exercise, 28% and 52% of all participants identified caffeine and placebo trials beyond random chance, respectively.

**Table 1**

*Mean repetition velocity at 50%, 75%, and 90% of one-repetition maximum (1RM) in the three experimental conditions.*

| Variable | Caffeine trial | Placebo trial | Control trial |
|---|---|---|---|
| Mean repetition velocity at 50% 1RM (m/s) | 0.83 ± 0.11 | 0.82 ± 0.11 | 0.80 ± 0.09 |
| Mean repetition velocity at 75% 1RM (m/s) | 0.56 ± 0.09 | 0.53 ± 0.08 | 0.53 ± 0.09 |
| Mean repetition velocity at 90% 1RM (m/s) | 0.37 ± 0.08 | 0.34 ± 0.08 | 0.33 ± 0.09 |

Data are reported as mean ± standard deviation; 1RM: one repetition maximum

**Table 2**

*All pairwise comparisons and their p-values and the adjusted p-values using the Holm-Bonferroni correction. For each outcome, p-values are ranked from highest to lowest*

| Variable | Pairwise comparison | Paired t-test *p*-value | Rank | Adjusted statistical significance threshold |
|---|---|---|---|---|
| Mean velocity at 50% of 1RM | Caffeine vs. placebo | 0.478 | 3 | 0.05 |
| | Placebo vs. control | 0.036 | 2 | 0.025 |
| | Caffeine vs. control | 0.003 | 1 | 0.017 |
| Mean velocity at 75% of 1RM | Placebo vs. control | 0.666 | 3 | 0.05 |
| | Caffeine vs. placebo | 0.001 | 2 | 0.025 |
| | Caffeine vs. control | 0.0003 | 1 | 0.017 |
| Mean velocity at 90% of 1RM | Placebo vs. control | 0.376 | 3 | 0.05 |
| | Caffeine vs. placebo | 0.0002 | 2 | 0.025 |
| | Caffeine vs. control | 0.0001 | 1 | 0.017 |

1RM: one repetition maximum

## Discussion

The main finding of this study is that caffeine ingestion, compared to placebo, was ergogenic for mean velocity in the bench press exercise at 75% and 90% of 1RM. When compared to the control condition, caffeine ingestion was ergogenic for mean velocity across all analyzed loads. However, there were no significant differences between placebo and control conditions, suggesting that isolated placebo ingestion may not be ergogenic for mean repetition velocity in resistance exercise.

The results presented herein are not in agreement with previous research that explored the effects of placebo ingestion on resistance exercise-related outcomes. Specifically, Pollo et al. (2008) and Duncan et al. (2009) reported that placebo ingestion was ergogenic for total work and muscle endurance in the leg extension exercise, respectively. Additionally, Costa et al. (2018) also reported that placebo ingestion, coupled with a suggestion that the capsule contains caffeine, was ergogenic for movement velocity at 50%, but not at 60%, 70%, or 80% of 1RM. These results are in contrast to those presented herein likely because of the methodological differences in the studies. Specifically, previous research used a design whereby a placebo was provided to the participants together with the suggestion that the capsules contained caffeine (even though caffeine was not ingested in any of the trials). However, in the present study, we used a double-blind study design, where neither the investigators nor the participants knew the content of the capsules, and there were no suggestions provided to the participants that may influence their exercise performance.

Caffeine ingestion may result in side-effects (both positive and negative), such as increased heart rate, headache, and increased focus (Juliano and Griffiths, 2004). Due to these side-effects, some participants may be able to correctly identify the content of the capsules. This is important to consider as correct supplement identification may influence the outcomes of an exercise task and lead to bias in the results, despite the "double-blind" study design (Saunders et al. 2016). Therefore, for studies that examine the effects of caffeine on exercise performance, it is essential to explore the effectiveness of the blinding of the participants to the caffeine and placebo trials. Many studies do not even perform this procedure (Grgic, 2018; Grgic et al. 2018). Some studies that also used 6 mg/kg of caffeine reported that 75% to 92% of all participants were able to correctly identify the caffeine trial (Carr et al. 2011; Tarnopolsky and Cupido, 2000). In this study, the blinding effectiveness was high, given that only 20% to 28% of the participants were able to correctly identify the caffeine condition beyond random chance. Given the effective blinding and the lack of the ergogenic effects of placebo ingestion, it seems that the improvements following caffeine ingestion are mainly due to caffeine's physiological effects, such as increased motor unit recruitment (Bazzucchi et al. 2011). The study by Tallis et al. (2016) further confirms this idea. Here, the participants were tested on four occasions: (a) "told caffeine – given caffeine"; (b) "told caffeine – given placebo"; (c) "told placebo – given placebo"; and (d) "told placebo – given caffeine". Improvement in isokinetic torque was observed only on the two occasions when the participants truly ingested caffeine (i.e., "told caffeine, given caffeine" and "told placebo, given caffeine" conditions).

When assessing the effects of caffeine on repetition velocity, it is important to use different loads, as some authors have hypothesized that caffeine's effects on repetition velocity might be external-load-dependent (Grgic et al. 2019). Interestingly, the ES of caffeine (when compared to both control and placebo trials) increased with the increases in external load lifted. At 50%, 75%, and 90% of 1RM, ES ranged from 0.19–0.29, 0.32–0.34, and 0.36–0.46, respectively. These results suggest that the ES of caffeine on repetition velocity is the greatest when the force production requirements are highest. We observed a similar pattern in our recent study where ES ranged from 0.20–0.29 for loads up 50% of 1RM, 0.36–0.50 at 75% 1RM, and 0.57–0.61 at 90% 1RM (Grgic et al. 2020b). Nevertheless, it warrants mention that the 95% CIs in the present study somewhat overlapped between the analyses for different loads and the loads used in each testing session were increased from lowest to highest (i.e., the order of loads was not randomized). These limitations make drawing firm conclusions on the relationship between caffeine ES and load lifted difficult.

There are several limitations to the present study that need to be considered when drawing practical inferences. Even though the blinding can generally be classified as effective, we should also consider that the number of participants that correctly identified caffeine or placebo was higher when the blinding was evaluated post-exercise vs. pre-exercise. In this context, an argument can be made that the pre-exercise responses are more important, because the improvements during the testing session (or lack thereof) may influence the post-exercise responses. We instructed the participants to provide maximum effort in each session. However, there might have been a lack of motivation in some participants in the control condition as there was no substance ingestion associated with this trial. The participants performed all testing sessions in a fasted state, which is not a very common practice for most individuals performing resistance exercise and is not in accord with the current sports nutrition guidelines (Aird et al. 2018). This also has relevance because caffeine's effects may be smaller when caffeine is ingested in a fed vs. fasted state (McLellan et al. 2016). Additionally, given that the study was conducted in a sample of young resistance-trained men, the findings cannot necessarily be generalized to older populations, women, and those who are untrained. Finally, the included participants were generally "low" habitual caffeine users with a median intake of 0.6 mg/kg/day (Filip et al. 2020). Therefore, future research is needed to explore this topic among participants with higher habitual caffeine intake.

## Conclusion

In this study, we found that caffeine ingestion, compared to placebo, provided an ergogenic effect on mean velocity in the bench press exercise at loads of 75% and 90% of 1RM. When compared to the control condition, caffeine ingestion was ergogenic for mean velocity across all analyzed loads. No significant differences were found between placebo and control conditions. Given that the blinding of the participants was generally effective, and that there were no significant ergogenic effects of placebo ingestion, it seems that the improvements in performance following caffeine ingestion can be mainly attributed to caffeine's physiological mechanisms of action.

## References

Aird TP, Davies RW, Carson BP. Effects of fasted vs fed-state exercise on performance and post-exercise metabolism: A systematic review and meta-analysis. *Scand J Med Sci Sports,* 2018; 28(5): 1476–93

Balsalobre-Fernández C, Marchante D, Baz-Valle E, Alonso-Molero I, Jiménez SL, Muñóz-López M. Analysis of Wearable and Smartphone-Based Technologies for the Measurement of Barbell Velocity in Different Resistance Training Exercises. *Front Physiol,* 2017; 8: 649

Balsalobre-Fernández C, Marchante D, Muñoz-López M, Jiménez SL. Validity and reliability of a novel iPhone app for the measurement of barbell velocity and 1RM on the bench-press exercise. *J Sports Sci,* 2018; 36(1): 64–70

Bang H, Ni L, Davis CE. Assessment of blinding in clinical trials. *Control Clin Trials,* 2004; 25(2): 143–56

Bazzucchi I, Felici F, Montini M, Figura F, Sacchetti M. Caffeine improves neuromuscular function during maximal dynamic exercise. *Muscle Nerve,* 2011; 43(6): 839–44

Beedie C, Benedetti F, Barbiani D, Camerone E, Cohen E, Coleman D, Davis A, Elsworth-Edelsten C, Flowers E, Foad A, Harvey S, Hettinga F, Hurst P, Lane A, Lindheimer J, Raglin J, Roelands B, Schiphof-Godart L, Szabo A. Consensus statement on placebo effects in sports and exercise: The need for conceptual clarity, methodological rigour, and the elucidation of neurobiological mechanisms. *Eur J Sport Sci,* 2018; 18(10): 1383–9

Beedie CJ, Foad AJ. The placebo effect in sports performance: a brief review. *Sports Med.* 2009; 39(4): 313–29

Bühler E, Lachenmeier DW, Schlegel K, Winkler G. Development of a tool to assess the caffeine intake among teenagers and young adults. *Ernährungs Umschau,* 2014; 61: 58–63

Carr AJ, Gore CJ, Dawson B. Induced Alkalosis and Caffeine Supplementation: Effects on 2,000-m Rowing Performance. Int J Sport Nutr Exerc Metab. 2011; 21(5): 357–64

Costa GCT, Galvão L, Bottaro M, Mota JF, Pimentel GD, Gentil P. Effects of placebo on bench throw performance of Paralympic weightlifting athletes: a pilot study. *J Int Soc Sports Nutr*, 2019; 16(1): 9

Duncan MJ, Lyons M, Hankey J. Placebo effects of caffeine on short-term resistance exercise to failure. *Int J Sports Physiol Perform,* 2009; 4(2): 244–53

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 15; 12(4): 1087.

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(11): 681–8

Grgic J, Mikulic P, Schoenfeld BJ, Bishop DJ, Pedisic Z. The Influence of Caffeine Supplementation on Resistance Exercise: A Review. *Sports Med,* 2019; 49(1): 17–30

Grgic J, Pickering C, Bishop DJ, Schoenfeld BJ, Mikulic P, Pedisic Z. CYP1A2 genotype and acute effects of caffeine on resistance exercise, jumping, and sprinting performance. *J Int Soc Sports Nutr,* 2020; 17(1): 21

Grgic J, Trexler ET, 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: 11

Grgic J. Caffeine ingestion enhances Wingate performance: a meta-analysis. Eur J Sport Sci, 2018; 18(2): 219–25

Juliano LM, Griffiths RR. A critical review of caffeine withdrawal: empirical validation of symptoms and signs, incidence, severity, and associated features. *Psychopharmacology (Berl),* 2004; 176(1): 1–29

McLellan TM, Caldwell JA, Lieberman HR. A review of caffeine's effects on cognitive, physical and occupational performance. *Neurosci Biobehav Rev,* 2016; 71: 294–312

Mitchell DC, Knight CA, Hockenberry J, Teplansky R, Hartman TJ. Beverage caffeine intakes in the U.S. *Food Chem Toxicol,* 2014; 63: 136–42

Pollo A, Carlino E, Benedetti F. The top-down influence of ergogenic placebos on muscle work and fatigue. *Eur J Neurosci,* 2008; 28(2): 379–88

Raya-González J, Rendo-Urteaga T, Domínguez R, Castillo D, Rodríguez-Fernández A, Grgic J. Acute Effects of Caffeine Supplementation on Movement Velocity in Resistance Exercise: A Systematic Review and Meta-analysis. *Sports Med,* 2020; 50(4): 717–29

Rivers WH, Webber HN. The Action of Caffeine on the Capacity for Muscular Work. *J Physiol,* 1907; 36(1): 33–47

Saunders B, de Oliveira LF, da Silva RP, de Salles Painelli V, Gonçalves LS, Yamaguchi G, Mutti T, Maciel E, Roschel H, Artioli GG, Gualano B. Placebo in sports nutrition: a proof-of-principle study involving caffeine supplementation. *Scand J Med Sci Sports,* 2017; 27(11): 1240–7

Tallis J, Muhammad B, Islam M, Duncan MJ. Placebo effects of caffeine on maximal voluntary concentric force of the knee flexors and extensors. *Muscle Nerve,* 2016; 54(3): 479–86

Tarnopolsky M, Cupido C. Caffeine potentiates low frequency skeletal muscle force in habitual and nonhabitual caffeine consumers. *J Appl Physiol,* 2000; 89(5): 1719–24

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