

RESEARCH ARTICLE

Effect of caffeine ingestion on competitive rifle shooting performance

Håvard Nygaard ^{*}, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold

Department of health and exercise physiology, Inland Norway University of Applied Sciences, Lillehammer, Norway

* havard.nygaard@inn.no

Abstract

Purpose

The purpose of the present study was to test if caffeine ingestion affects rifle shooting accuracy in trained shooters.

Methods

Twenty trained shooters performed 4 shooting tests in a randomized, double-blinded, placebo controlled crossover design; 2 identical tests after placebo ingestion and 2 after ingestion of 300 mg caffeine. The tests consisted of 30 shots in prone position and 30 in standing position on a 10 ring electronic target, on a distance of 50 metres, without any time limit, at rest.

Results

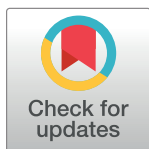
Caffeine supplementation entailed a mean decrease in shooting performance by 11.8 points (95% CI: 6.7 to 17.0, effect size: 0.9). This was primarily a result of an 11.3 (95% CI: 7.2 to 15.4, effect size: 0.9) point decrease during shooting in standing position and not in prone position (0.6 point decrease, 95% CI: -2.1 to 3.2, effect size: 0.1).

Conclusions

We conclude that prior ingestion of 300 mg caffeine impairs rifle shooting accuracy in trained shooters when performed in standing but not in prone position.

Introduction

Caffeine is the most used psychoactive stimulant in the world, occurring naturally in coffee, tea and cacao and as an additive in beverages, such as soda and energy drinks [1]. It is widely used by athletes, probably due to its well-known positive effects on physical performance [2]. The ergogenic effect of caffeine is indicated by numerous studies on different aspects of physical performance, such as motor skills, strength, power and especially endurance performance [3–5].



OPEN ACCESS

Citation: Nygaard H, Riksaasen S, Hjelmevoll LM, Wold E (2019) Effect of caffeine ingestion on competitive rifle shooting performance. PLoS ONE 14(10): e0224596. <https://doi.org/10.1371/journal.pone.0224596>

Editor: Moacir Marocolo, Universidade Federal de Juiz de Fora, BRAZIL

Received: October 30, 2018

Accepted: October 17, 2019

Published: October 31, 2019

Copyright: © 2019 Nygaard et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

Athletes, hunters and soldiers all over the world perform rifle shooting. Theoretically caffeine can either increase rifle shooting performance by increased attention, cognitive function and motor skill performance [3] or it can decrease the performance by increased heart rate [6], muscle tremor [7] and postural sway [8]. Several studies have explored the effects of caffeine on shooting performance in a combat setting, typically finding shorter target detection time [9], especially during fatigue and sleep deprivation [10–12], but not increased shooting accuracy. Nor is pistol steadiness and pistol shooting accuracy improved after caffeine ingestion [13, 14]. The effects of caffeine on rifle shooting accuracy in a noncombat setting seem to be sparsely studied. To our knowledge, the only previous study in this field was a small sample experiment including only two air rifle shooters [6]. Our purpose was therefore to test the hypothesis that caffeine ingestion affects rifle shooting accuracy in trained shooters.

Methods

Participants

We recruited the participants using posters and information to Norwegian biathlon teams in January 2018. We included biathletes aged 18–30 years. Twenty participants, 10 women and 10 men, 21 ± 1 years old, 69.0 ± 8.4 kg body weight, all Norwegian, completed the study. They had competed for an average of 11 ± 3 years, whereof 15 participants at national level and 5 in junior world championships in addition to national level. At time of study, seven were in the junior class and 13 in senior. They had fired an average of 7662 ± 2878 shots the year preceding enrolment, of which $66.3 \pm 9.9\%$ were fired at rest without time limit. Average weekly caffeine intake assessed by questionnaire was 613 ± 514 mg. The study was performed according to the ethical standards established by the Helsinki declaration and was approved by the local ethics committee at Inland Norway University of Applied Sciences. All participants gave their written informed consent.

Experimental design

We performed the study in a randomized, double-blinded, placebo controlled crossover design. Each participant underwent 4 shooting tests on 4 different days, 2 with prior placebo and 2 with prior caffeine ingestion, Fig 1. Each test was separated by minimum 2 days and maximum 5 days. Each test for each participant was performed at the same time of the day. Order of prone and standing shooting position was randomized in a balanced way, thus one of the tests with caffeine and one of the tests with placebo started with 30 shots in prone position before 30 shots in standing position, and the other way around. Coefficient of variation for the shooting results were 2.0% for the test days with placebo and 2.5% for the days with caffeine.

Tests

We instructed the participants not to ingest caffeine-containing food or beverages for 48 hours, and not to eat for 2 hours, prior to each test. They were also instructed to use ammunition with the same lot number on all tests, which were performed in an indoor shooting arena. The participants ingested placebo pills or pills containing 300 mg caffeine (Kraggerø Tablettproduksjon AS, Kraggerø, Norway) and water 60 minutes prior to start of each test, Fig 1. We registered weight with a bathroom scale (Coline B-198, Clas Ohlson AB, Sweden) and the participants reported their caffeine beverage habits in a questionnaire made by the authors, which from we calculated individual weekly caffeine intake. Intake of cola (150 mg/L), energy drinks (320 mg/L) and coffee (anticipated 100 mg caffeine per cup), were reported. The time period from 30 to 10 minutes prior to test start was used for an unlimited number of zeroing shots, and the last 10 minutes for rest and individual mental preparation, Fig 1.

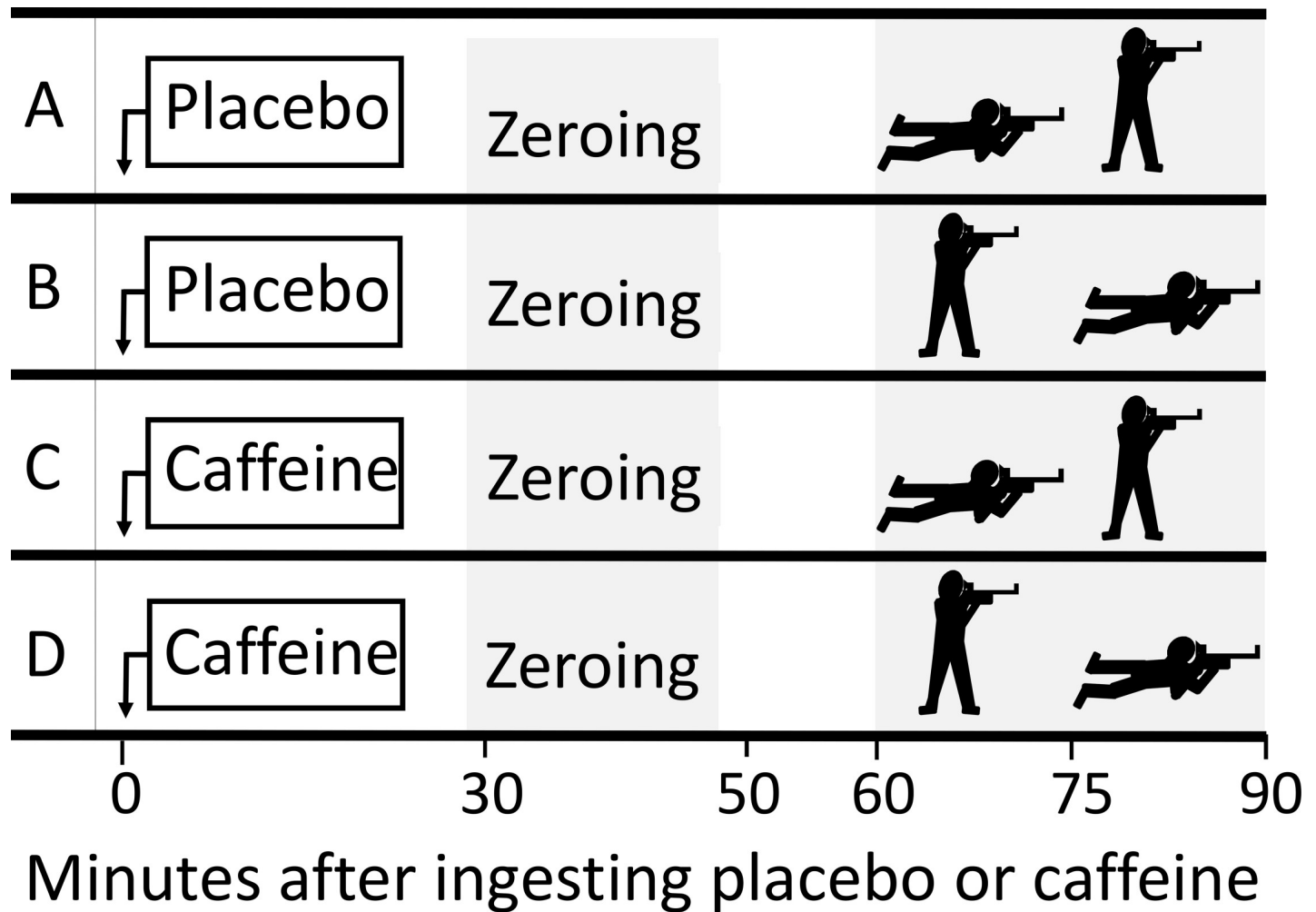


Fig 1. Overview of the shooting tests. In random order, each participant underwent 4 tests (A, B, C and D) on 4 different days, 2 with placebo and 2 with caffeine ingestion 60 minutes prior to start of the shooting tests. One of the tests with caffeine and one of the tests with placebo started with shooting in prone position before shooting in standing position and the other way around.

<https://doi.org/10.1371/journal.pone.0224596.g001>

The shooting test, which is developed by the Norwegian Biathlon Association, consisted of 60 shots on 50 metres on a 10 ring electronic target (maximum 10 points per shot, 10. ring diameter of 10.4 mm, Megalink AS, Vestby, Norway). During each test occasion, 60 shots were fired (30 prone + 30 standing or 30 standing + 30 prone) with the participants personal biathlon rifles (calibre 22 LR, weight of weapon ≥ 3.5 kg and trigger pull ≥ 0.5 kg). To blind the participants for their own results, the monitor of the electronic scoring system was not visible during the tests. There was no time limit. After each test, we asked each participant whether he/she believed that he/she had ingested placebo or caffeine. The participants wore heart rate monitors (Polar A300, Polar Electro Oy, Kempele Finland) during the tests and a mean value from heart rates recorded 5 and 17 minutes after test start were used in analysis.

Statistical analysis

Data were analysed with a linear mixed model in IBM SPSS statistics 24. We used subject ID as the clustering “subject” variable, scaled identity as covariance structure and we used random intercept. Test condition (control vs. caffeine) were used as a fixed factor. Residuals were

checked for homogeneity. The effect of caffeine dose were calculated by including mg caffeine per kg body weight as a fixed covariate in the model. We calculated effect sizes (ES) for the effect of caffeine using Cohen's d_z for repeated measures [15], and interpreted the result according to Hopkins et al. [16]: $d \geq 0.2$ = small effect, $d \geq 0.6$ = moderate effect, $d \geq 1.2$ = large effect.

Results

Caffeine supplementation entailed a mean decrease in shooting performance by 11.8 points (95% CI: 6.7 to 17.0). This was primarily a result of a 11.3 (95% CI: 7.2 to 15.4) point decrease during shooting in standing position, and not prone position (0.6 point decrease, 95% CI: -2.1 to 3.2), Fig 2. The effect of caffeine was 10.8 points larger (95% CI: 4.5 to 17.0) during shooting in standing position compared to prone position. Effect sizes for the effect of caffeine on shooting performance were moderate for total and standing position and negligible for prone (effect size = 0.9, 0.9 and 0.1 respectively). The amount of caffeine ingested relative to body weight ranged from 3.7 to 5.7 mg/kg. Within this range, total shooting performance decreased 10.5 points per mg ingested caffeine per kilo bodyweight (95% CI: 1.2 to 19.9) Fig 3. When adjusted for reported caffeine intake per week, the effect of the caffeine intervention on total shooting performance changed to a decrease of 15.9 points (95% CI: 7.8 to 24.0). Adjustment for correct guess on the question "whether he/she believed that he/she were on placebo of caffeine" did not affect the results, although correct answer were given in 55 out of 80 tests. Heart rate was 1

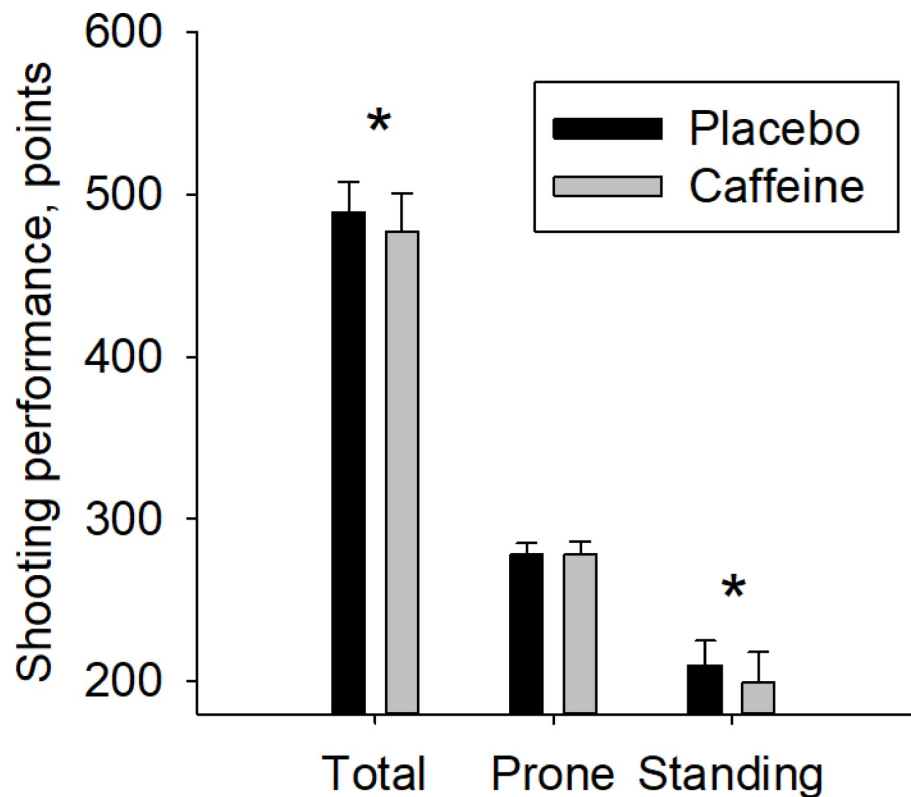


Fig 2. Effect of caffeine on shooting performance in function of shooting position. Total results and separate results from the shooting in prone and standing position with prior ingestion of placebo or caffeine. Mean \pm standard deviation. * = $p < 0.001$ for the difference between placebo and caffeine.

<https://doi.org/10.1371/journal.pone.0224596.g002>

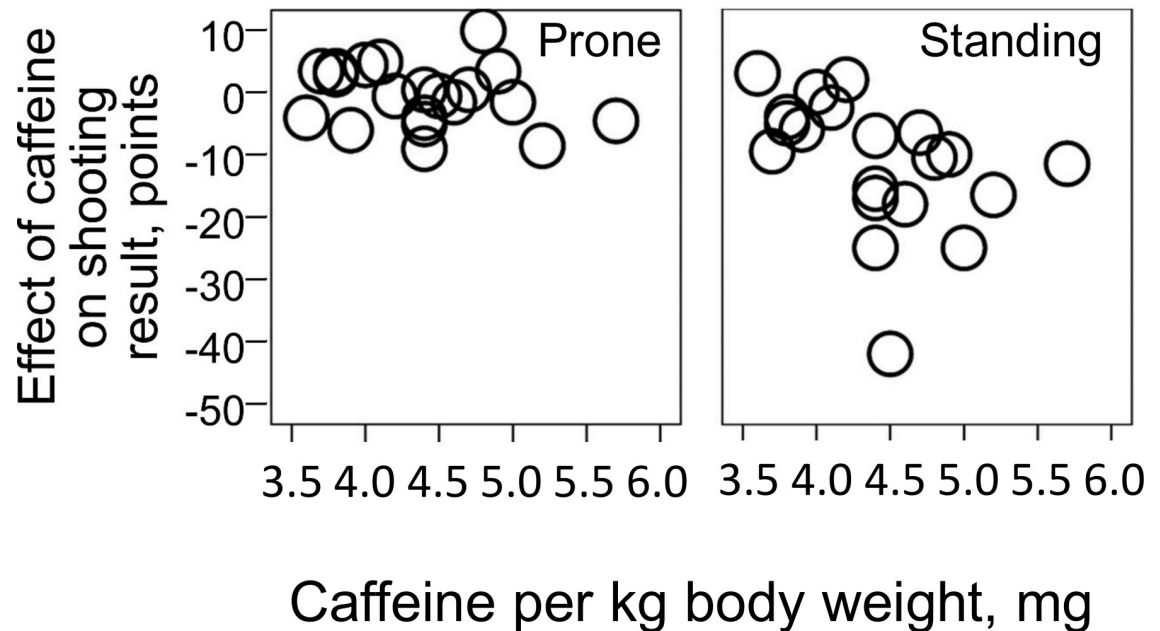


Fig 3. Effect of the amount of caffeine per kg bodyweight on shooting performance. Effect of the relative dose of caffeine ingested before shooting (300 mg caffeine divided by bodyweight on the x axis in both plots) on the difference between shooting results after caffeine and placebo ingestion (y axis), for the results from prone and standing position separately.

<https://doi.org/10.1371/journal.pone.0224596.g003>

beat per minute (95% CI: -4 to 2) lower during shooting with caffeine compared to placebo. This was a result of 0 (95% CI: -5 to 4) difference in prone position and 2 beats lower per minute (95% CI: -6 to 1) with caffeine compared to placebo in the standing position. There were no significant interaction between heart rate and the effect of caffeine on shooting performance.

Discussion

The main finding in this study was a moderate decrease in rifle shooting accuracy at rest as a result of caffeine ingestion. This effect was present during shooting in standing position, while the results from shooting in prone position were unaffected by caffeine. The strength of the study is the double-blinded randomized controlled design, which points to causality between the intervention and the results. Furthermore, causality is supported by the observed dose-response relationship between caffeine dose and the negative effect on performance in standing position and lack thereof in prone position. Although shooting techniques and context are diversified, previous studies also seem to support the observation of no ergogenic effect of caffeine on shooting accuracy, e.g. in pistol shooting [13, 14], clay target shooting [17] and shooting in combat settings with varying degrees of fatigue and sleep deprivation [9–12]. Shooting performance seem to be improved by caffeine only when the result depend on target detection time [10–12], which is typical for a combat setting. The most comparable study to the present one is the study by Ebrahimi et al. [6] on eight shooters, in which 6 were pistol shooters and 2 were rifle shooters. They found decreased shooting performance after ingestion of 5 mg but not 3 mg caffeine per kg body weight. However, the lack of effect of 3 mg might be attributed to lack of statistical power with such a low sample size.

The present study is also limited by a relatively low number of participants, but on the other hand, caffeine is tested against placebo in duplicate, increasing the robustness of the results. An another weakness in the present study might have been that the blinding of the participants was inefficient, since a greater part answered correct on the question whether he/she had

ingested placebo or caffeine on each shooting test. However, adjustment for correct answer did not affect the results. The effect of caffeine should therefore be interpreted as physiological and not the participants' awareness of what they had consumed. The purpose of the study was not to explore the physiological mechanisms of action. However, some assumptions can be done. Since the negative effect of caffeine occurred during standing shooting only, it may be attributed to increased postural sway, which occurs after caffeine ingestion [8]. Postural sway is likely to affect the stability of hold and cleanness of triggering, two main determinants of rifle shooting performance in the standing position [18–20]. Increased muscle tremor might also be a candidate, however most previous studies have failed to show caffeine induced muscle tremor [7]. Furthermore, the decrease in shooting performance during shooting in the standing position cannot be attributed to increased heart rate, since the heart rate did not increase. The lack of effect of caffeine on heart rate is also supported by previous studies [21, 22]. Interestingly, the effect seemed to be independent of the participants habitual caffeine intake, supporting the notion that “resistance” to the ergogenic effect of caffeine is a myth [23]. However, the lack of interaction between caffeine habits and the effect of caffeine intervention might be influenced by the 48-hour withdrawal from caffeine prior to shooting tests.

The present study implicates that prior caffeine ingestion should be done with caution when shooting in standing position. The participants were biathletes. However, since we performed the study in a resting context with no time limit, we cannot conclude whether this finding can be generalized to situations involving strenuous exercise and timekeeping. Indeed, a positive effect on total biathlon performance or performance in other situations requiring physical or mental performance might still occur. With regard to endurance, there are numerous studies showing increased performance after intake of 3–6 mg/kg caffeine [5]. Previous studies have also shown that intake of >3 mg/kg caffeine can increase maximal strength and power [4], and there are some studies indicating increased motor skills, attention and cognitive function [3]. In general, the effect of caffeine on performance seem to be influenced by the degree of physical or mental fatigue in the test situation [3, 5, 24]. The results of the present study should therefore be generalized to shooting accuracy at rest only. The results seems relevant for expert shooters competing at rest also because the participants had performed the major part of their shooting training in a rested condition. The observed dose—response relationship between caffeine per kg bodyweight and shooting performance indicates that the negative influence of caffeine disappears at low doses. However, our results are limited at this point, since we used an absolute dose of caffeine. Thus, only a few of the participants ingested a caffeine dose in “the lower area of caffeine per kg bodyweight”. Normalization of caffeine dose to body mass would represent a better approach to conclude on the effect of a given dose per kg. Previous studies have also found that the positive effect of caffeine on endurance performance and attention might be preserved at relatively low doses, e.g. 200 mg or <3 mg/kg [25]. Thus, we cannot exclude that a low dose of caffeine can be optimal for rifle shooting performance or rifle shooting in combination with endurance exercise, despite our observation of impaired shooting performance after ingestion of 300 mg caffeine.

Conclusions

Prior intake of 300 mg caffeine impairs rifle shooting accuracy at rest in trained shooters when performed in standing but not in prone position.

Supporting information

S1 Dataset.
(XLSX)

Author Contributions

Formal analysis: Håvard Nygaard, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold.

Investigation: Håvard Nygaard, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold.

Methodology: Håvard Nygaard, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold.

Project administration: Håvard Nygaard, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold.

Supervision: Håvard Nygaard.

Writing – original draft: Håvard Nygaard, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold.

Writing – review & editing: Håvard Nygaard, Steinar Riksaasen, Leif Malvin Hjelmevoll, Endre Wold.

References

1. Evans J, Battisti AS. Caffeine. StatPearls. Treasure Island (FL): StatPearls Publishing StatPearls Publishing LLC.; 2018.
2. Del Coso J, Munoz G, Munoz-Guerra J. Prevalence of caffeine use in elite athletes following its removal from the World Anti-Doping Agency list of banned substances. Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme. 2011; 36(4):555–61. Epub 2011/08/23. <https://doi.org/10.1139/h11-052> PMID: 21854160.
3. Baker LB, Nuccio RP, Jeukendrup AE. Acute effects of dietary constituents on motor skill and cognitive performance in athletes. Nutr Rev. 2014; 72(12):790–802. Epub 2014/11/18. <https://doi.org/10.1111/nure.12157> PMID: 25400063.
4. Grgic J, Mikulic P, Schoenfeld BJ, Bishop DJ, Pedisic Z. The Influence of Caffeine Supplementation on Resistance Exercise: A Review. Sports Med. 2018. Epub 2018/10/10. <https://doi.org/10.1007/s40279-018-0997-y> PMID: 30298476.
5. Southward K, Rutherford-Markwick KJ, Ali A. Correction to: The Effect of Acute Caffeine Ingestion on Endurance Performance: A Systematic Review and Meta-Analysis. Sports Med. 2018. Epub 2018/08/11. <https://doi.org/10.1007/s40279-018-0967-4> PMID: 30094798.
6. Ebrahimi M, Pordanjani AF, Ahmadabadi F. The effect of different doses of caffeine on cardiovascular variables and shooting performance. Biomedical Human Kinetics. 2015; 7(1). <https://doi.org/10.1515/bhk-2015-0007>
7. Lakie M. The influence of muscle tremor on shooting performance. Experimental physiology. 2010; 95(3):441–50. Epub 2009/11/20. <https://doi.org/10.1113/expphysiol.2009.047555> PMID: 19923157.
8. Franks HM, Hagedorn H, Hensley VR, Hensley WJ, Starmer GA. The effect of caffeine on human performance, alone and in combination with ethanol. Psychopharmacologia. 1975; 45(2):177–81. Epub 1975/12/31. <https://doi.org/10.1007/bf00429058> PMID: 1215448.
9. Gillingham R, Keefe AA, Keillor J, Tikuisis P. Effect of caffeine on target detection and rifle marksmanship. Ergonomics. 2003; 46(15):1513–30. Epub 2003/12/12. <https://doi.org/10.1080/0014013032000121606> PMID: 14668172.
10. Tikuisis P, Keefe AA, McLellan TM, Kamimori G. Caffeine restores engagement speed but not shooting precision following 22 h of active wakefulness. Aviation, space, and environmental medicine. 2004; 75(9):771–6. Epub 2004/10/06. PMID: 15460628.
11. Gillingham RL, Keefe AA, Tikuisis P. Acute caffeine intake before and after fatiguing exercise improves target shooting engagement time. Aviation, space, and environmental medicine. 2004; 75(10):865–71. Epub 2004/10/23. PMID: 15497366.
12. Tharion WJ, Shukitt-Hale B, Lieberman HR. Caffeine effects on marksmanship during high-stress military training with 72 hour sleep deprivation. Aviation, space, and environmental medicine. 2003; 74(4):309–14. Epub 2003/04/12. PMID: 12688447.
13. Monaghan TP, Jacobson BH, Sellers JH, Estrada CA. Effects of Energy Beverage Consumption on Pistol Aiming Steadiness in Law Enforcement Officers. J Strength Cond Res. 2017; 31(9):2557–61. Epub 2017/08/05. <https://doi.org/10.1519/JSC.0000000000002015> PMID: 28777245.

14. Pomportes L, Brisswalter J, Hays A, Davranche K. Effects of Carbohydrate, Caffeine and Guarana on Cognitive Performance, Perceived Exertion and Shooting Performance in High Level Athletes. *International journal of sports physiology and performance*. 2018;1–26. Epub 2018/10/10. <https://doi.org/10.1123/ijsp.2017-0865> PMID: 30300016.
15. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in psychology*. 2013; 4:863. <https://doi.org/10.3389/fpsyg.2013.00863> PMID: 24324449; PubMed Central PMCID: PMC3840331.
16. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Medicine and science in sports and exercise*. 2009; 41(1):3–13. <https://doi.org/10.1249/MSS.0b013e31818cb278> PMID: 19092709.
17. Share B, Sanders N, Kemp J. Caffeine and performance in clay target shooting. *Journal of sports sciences*. 2009; 27(6):661–6. <https://doi.org/10.1080/02640410902741068> PMID: 19308789
18. Ihalainen S, Kuitunen S, Mononen K, Linnamo V. Determinants of elite-level air rifle shooting performance. *Scandinavian journal of medicine & science in sports*. 2016; 26(3):266–74. Epub 2015/04/09. <https://doi.org/10.1111/sms.12440> PMID: 25850700.
19. Ihalainen S, Laaksonen MS, Kuitunen S, Leppavuori A, Mikkola J, Lindinger SJ, et al. Technical determinants of biathlon standing shooting performance before and after race simulation. *Scandinavian journal of medicine & science in sports*. 2018; 28(6):1700–7. Epub 2018/02/16. <https://doi.org/10.1111/sms.13072> PMID: 29446507.
20. Ihalainen S, Linnamo V, Mononen K, Kuitunen S. Relation of Elite Rifle Shooters' Technique-Test Measures to Competition Performance. *International journal of sports physiology and performance*. 2016; 11(5):671–7. Epub 2015/11/13. <https://doi.org/10.1123/ijsp.2015-0211> PMID: 26559498.
21. Glaister M, Gissane C. Caffeine and Physiological Responses to Submaximal Exercise: A Meta-Analysis. *International journal of sports physiology and performance*. 2018; 13(4):402–11. Epub 2017/09/06. <https://doi.org/10.1123/ijsp.2017-0312> PMID: 28872376.
22. Daniels JW, Mole PA, Shaffrath JD, Stebbins CL. Effects of caffeine on blood pressure, heart rate, and forearm blood flow during dynamic leg exercise. *Journal of applied physiology*. 1998; 85(1):154–9. Epub 1998/07/09. <https://doi.org/10.1152/jappl.1998.85.1.154> PMID: 9655769.
23. Goncalves LS, Painelli VS, Yamaguchi G, Oliveira LF, Saunders B, da Silva RP, et al. Dispelling the myth that habitual caffeine consumption influences the performance response to acute caffeine supplementation. *Journal of applied physiology*. 2017; 123(1):213–20. Epub 2017/05/13. <https://doi.org/10.1152/jappphysiol.00260.2017> PMID: 28495846.
24. Azevedo R, Silva-Cavalcante MD, Gualano B, Lima-Silva AE, Bertuzzi R. Effects of caffeine ingestion on endurance performance in mentally fatigued individuals. *European journal of applied physiology*. 2016; 116(11–12):2293–303. Epub 2016/10/04. <https://doi.org/10.1007/s00421-016-3483-y> PMID: 27695980.
25. Spriet LL. Exercise and sport performance with low doses of caffeine. *Sports Med*. 2014; 44 Suppl 2: S175–84. Epub 2014/10/31. <https://doi.org/10.1007/s40279-014-0257-8> PMID: 25355191; PubMed Central PMCID: PMC4213371.