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Original Article

The effect of caffeine gum on the performance and salivary testosterone and cortisol levels in male fencers during a simulated competition round

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Abstract

Background: Numerous studies have investigated the effects of caffeine consumption in various sports, but there are few studies that have used caffeine gum. In this research the effects of consuming caffeine gum during a simulated fencing competition in two parts of periodic and eliminating matches were examined.

Methods: Fourteen epee weapon male fencers mean age 21.35 ± 2.02 years, the average height 178.05 ± 4.96 centimeters, and mean weight 77.47 ± 7.16 kg completed this double-blind, randomized, counterbalanced study. Fencers divided into placebo group (n=7) (PLC) and caffeine group (n=7) (CAF). Before simulated periodic and before eliminating fencing competitions, players chewed either CAF (400 mg) gum or PLC gum for 5 minutes. Salivary testosterone and cortisol concentrations, and performance (repetitious running test) were measured at baseline, pre-periodic competition, post-periodic competition, pre-eliminated competition, and post-eliminated competition.

Results: Caffeine consumption between periodic and elimination competitions had no effect on sprint performance (p=0.995). Sprint time increased after the first attempt in both tests (p=0.003). The first sprint was 3% slower than the initial speed (p=0.004). intake caffeine between periodic and elimination matches influenced salivary testosterone responses (p=0.021, partial-eta2 = 0.471), about 70 percent more in caffeine group vs. placebo group. No further between-trial effects were observed. Also, salivary testosterone increased throughout fencing competition (p= 0.001, partial-eta2 = 0.538), about 38% more than baseline values. No differences were observed between baseline and pre-periodic phase (p =0.769). Fencing competitions affected the concentration of salivary cortisol (p=0.032) showing a significant increase from the baseline level before the second survey (p=0.020) and after the second survey (p=0.023). Caffeine consumption between the two halves had no significant effect on salivary cortisol concentration (p=0.098).

Conclusions: Athletes and coaches can choose caffeine gum between competition or practice bouts because of the increases in salivary testosterone observed; we must notice that many factors such as caffeine doses and psychological propellant associated with increased motivation and high-intensity exercise performance.

Key words: Fencing, Cortisol, Testosterone, performance.

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Introduction

In training and competitions, fencers endure a lot of pressure, especially on the preferable part of their body. Fencing sport requires a high level of strength and control. In addition, perceptual and psychological factors are changed during matches based on the opponent's performance. The fencers must anticipate the opponent's moves and make the main action with the unrealistic cover game. Central and peripheral fatigue prevention are very important (1).

Caffeine is a widely used medicinal factor found in coffee, tea, and drinks, and most of its popularity is related to its effect on the nervous system, such as its ability to increase the rate of dopamine release (2). Caffeine also activates the stress axis, increasing glucocorticoids and catecholamines. Thus, caffeine consumption during stress may contribute to the duration and extent of blood pressure and endocrine responses to stress (3). Caffeine affects the arousal of non-endurance athletes. According to the inverted U principle, performance improves with increasing arousal until an optimal level of arousal is reached. If the arousal is more than desired, the performance will decrease (4). Because sports or activities that require fine motor skills or a high level of muscle control have more sensitive functional response to arousal (5).

Physiological arousal is influenced by caffeine, as it is classified as a stimulant that leads to activation of the CNS. Caffeine consumption causes the release of catecholamines and cortisol. Cortisol helps regulate energy balance. By regulating adrenergic synthesis, it maintains autonomic function and receptor sensitivity. If disturbances in the daily pattern of cortisol secretion continue for a long time, it has harmful consequences (6).

Caffeine in food increases the secretion of adrenocorticotropin (ACTH) and cortisol in humans. Therefore, the effect of caffeine on the regulation of glucocorticoids has the potential to change the circadian rhythm and correlate with stress reactions (7).

The benefits of caffeine consumption include improving mood and alertness, weight loss, antioxidant properties and memory improvement. High consumption of caffeine can cause restlessness, insomnia, dehydration and heart abnormalities. Adverse effects on the cardiovascular, nervous and endocrine systems have also been published (8). There is evidence that caffeine and its metabolites affect various pathways, including those related to testosterone biosynthesis (9).

Caffeine half-life is 5 h, and all of caffeine intake is metabolized in the body, and only 3 percent or less excreted in urine. The cytochrome P450 enzymes in the liver, mainly CYP1A2, are responsible for the metabolism of caffeine, and population level differences in P450 enzymes are known to contribute to variations in caffeine metabolism (10).

The main route of metabolism in humans (70–80 percent) is through N-3-demethylation to paraxanthine, also known as 1,7-dimethylxanthine or 17X. 1-N-demethylation of caffeine to theobromine accounts for approximately 7 to 8 percent of caffeine metabolism, and 7-N- emethylation to theophylline also around 7 to 8 percent (11). The remaining 15% of caffeine undergoes C-8 hydroxylation to form 1,3,7- trimethyluric acid.

Testosterone has a role in anabolic processes. Its correlate with increased strength and muscle size directly (12). Post-exercise testosterone response is often investigated to enhance muscle adaptation. Up to 30-60 minutes after exercise testosterone elevates, and contribute to muscle adaptation. These responses include increased protein synthesis, satellite cell number, neurotransmitter synthesis and myonuclei concentration (13). These enhanced responses may be due to increases in the concentration and half-life of androgen receptors (14).

Increased androgen receptor density facilitates anabolic effects by increasing androgen binding .Higher testosterone responses due to caffeine consumption may improve recovery. This is seen through increase in repetitions to fatigue as well as a decrease in perceived pain 24 hours later (15).

Thus, the aim of this study was to evaluate the effect of caffeine consumption on salivary testosterone and cortisol concentration in male fencers. Specifically, we sought to investigate the effects of caffeine on these variables and their interrelationships during performance in a round of simulated periodic and knockout fencing competitions.

Materials and methods

The present study was a randomized, placebo-controlled crossover study to investigate the effects of caffeine gum used during a period of fencing competitions.

Fourteen male fencers volunteered to participate in this study. The participants had at least 4 years of training experience in epee weapon fencing and were injury-free and did 3 training sessions per week. The participants signed a written informed consent to participate

in the research.

In this research, 14 male fencing players randomly participated in two groups of 7 people who consumed caffeine gum and placebo (gum without caffeine). The average age was 21.35 ± 2.02 years, the average height was 178.05 ± 4.96 centimeters, and their average weight was 77.47 ± 7.16 kg. After pre-exercise measurements, players in the placebo group (PLA) chewed a placebo gum for 5 minutes before warming up and players in the caffeine group (CAF) chewed a 400 ml caffeinated gum as well. Then each fencers played 6 matches of 5 hits in their periodic table. Again, the athletes in the placebo group chewed a placebo gum for 5 minutes and the athletes in the caffeine group chewed a 400 mg caffeinated gum. After that, due to the equalization of the number of 15-hit elimination matches, 5 competitions were considered for each fencer. Salivary testosterone and cortisol were measured at the beginning, after and at the end of periodic competitions. Before and after the elimination competition, the athletes warmed up and cooled down their bodies for 10 to 15 minutes.

In order to unify the performance of the participants from the repeated speed test, six 40-meter tests (with a 180-degree turn in 20 meters) with an active recovery of 20 seconds between each attempt, once after the end of the periodic games and once after the simulated elimination matches, were used (16). Before the two tests, each fencer had a 30-minute rest.

Before performing the protocol, all items were explained to the fencers. The fencers used their previous diet but were forbidden to use caffeine on the test day.

Saliva sample 2 hours before the start of the competition, before and after the periodic competition and before and after the elimination competition in the form of saliva discharge (2 ml) in a sterile vial (SalivaBio; Salimetrics LLC, State College, PA, USA) Done. All samples were stored at minus 80 degrees Celsius after collection. After melting the samples, centrifugation was performed for 5 minutes at 3000 rpm. Before the analysis of cortisol concentration (indirect enzyme-linked immunosorbent assay kits; Salimetrics Europe Ltd., United Kingdom, Suffolk) was performed.

Statistical analyses

All data were presented as mean and standard deviation. A significance level of $p<0.05$ was considered. Paired t-tests and analysis of variance with two-way repeated measurements were used for statistical analysis. SPSS software version 27 was used.

Results

The results of the running test of the first half of the caffeine and placebo groups are presented in Figures 1 and 2. The results of the second running test of the caffeine and placebo groups are presented in Figures 3 and 4. Caffeine consumption between periodic and elimination competitions had no effect on sprint performance (p=0.995). Sprint time increased after the first attempt in both tests (p=0.003). The first sprint was 3percent slower than the initial speed (p=0.004).

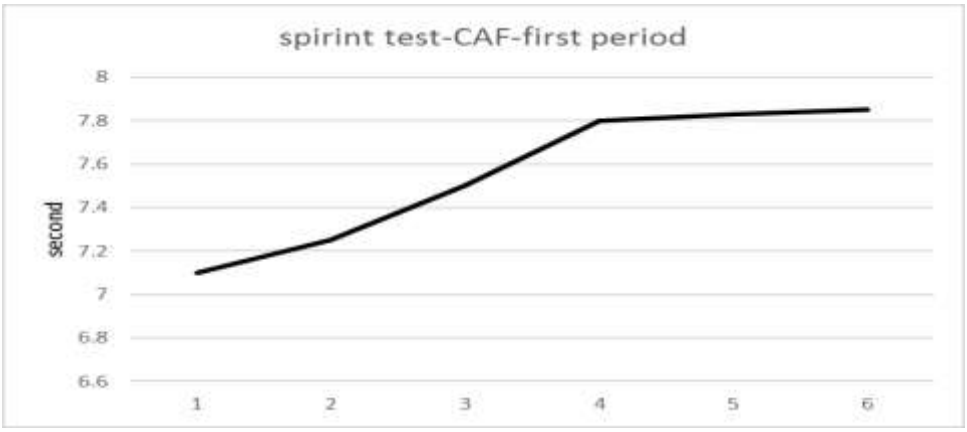

Figure 1. Results of sprint test - caffeine group

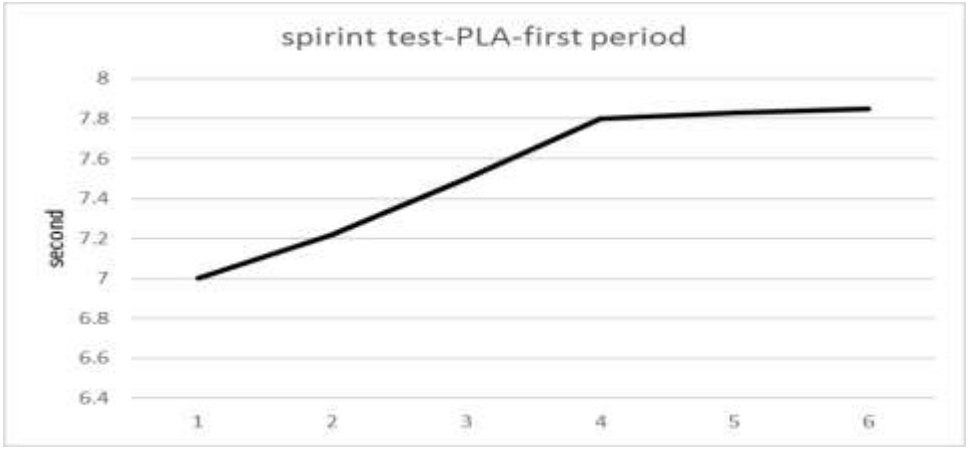

Figure 2. Sprint test results - placebo group

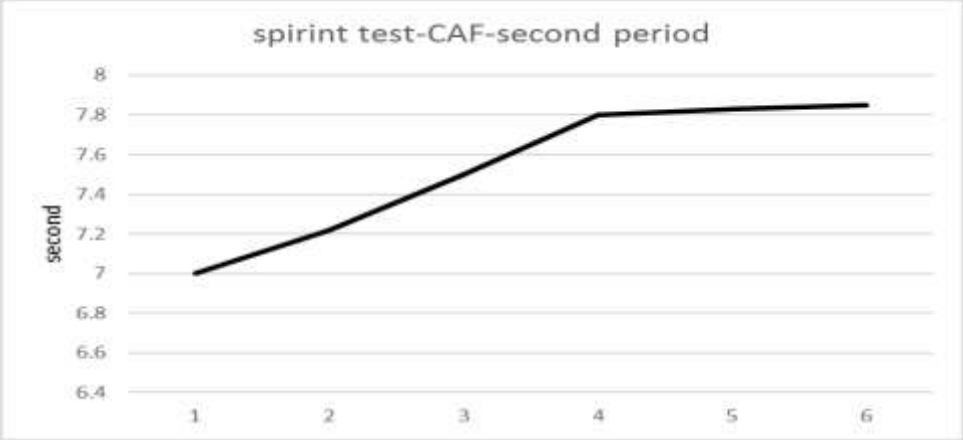

Figure 3. Results of sprint test - caffeine group

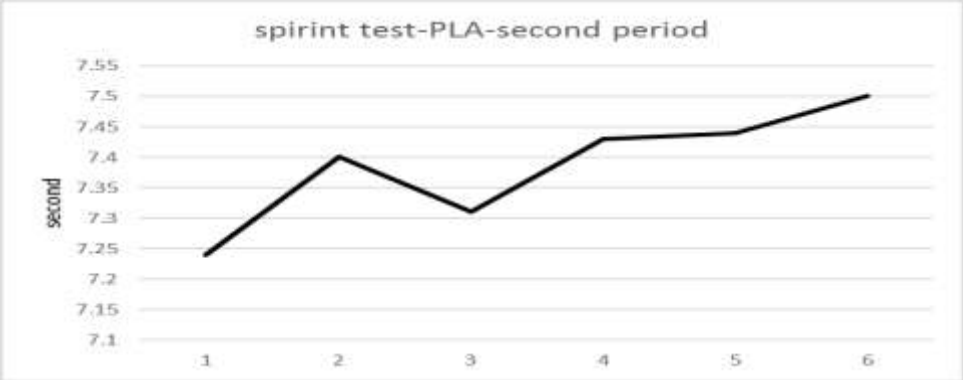

Figure 4. Sprint test results - placebo group

Intake caffeine gum between periodic and elimination matches influenced salivary testosterone responses (p=0.021, partial-eta2 = 0.471), about 70 percent more in caffeine group vs. placebo group. No further between-trial effects were observed. Also, salivary testosterone increased throughout fencing competition (p= 0.001, partial-eta2 = 0.538), about 38 percent more than baseline values. No differences were observed between baseline and pre-periodic phase (p =0.769).

Figure 5. shows Salivary testosterone in caffeine group.

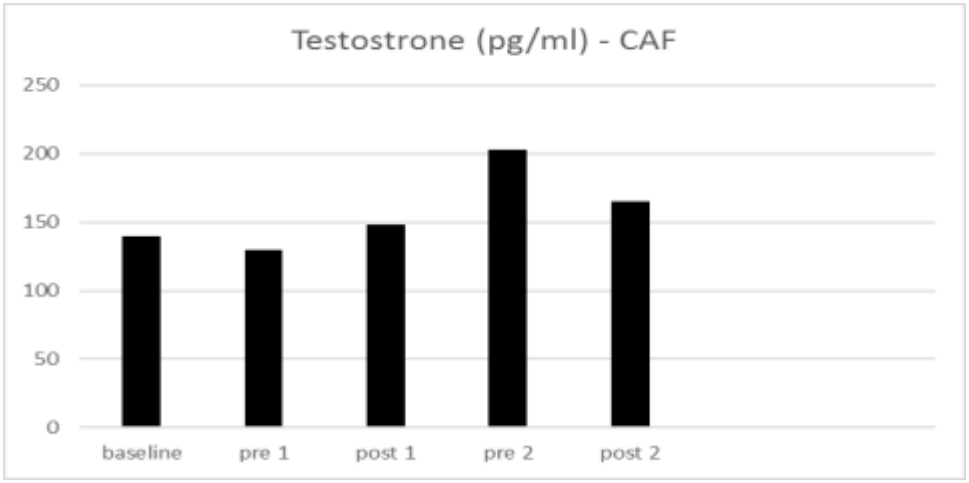

Figure 5. Salivary testosterone - caffeine group

Figure 6. shows Salivary testosterone in placebo group.

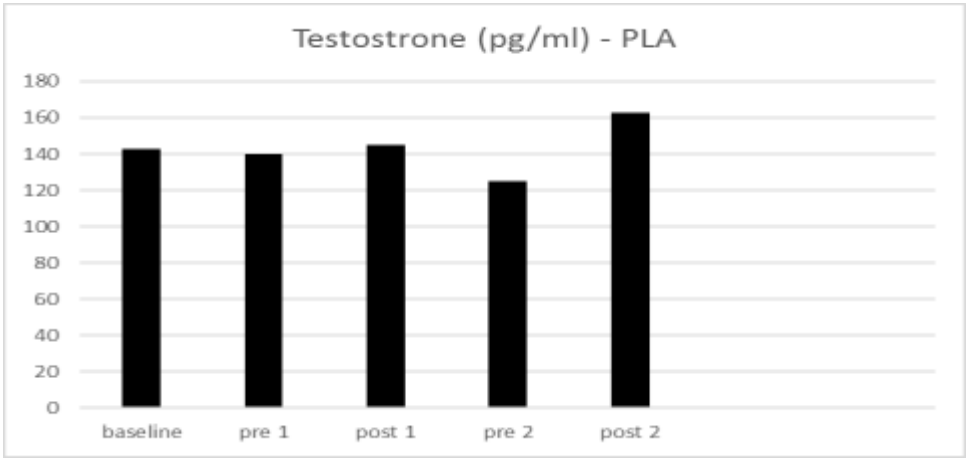

Figure 6. Salivary testosterone - placebo group

Fencing competitions affected the concentration of salivary cortisol (p=0.032) showing a significant increase from the baseline level before the second survey (p=0.020) and after the second survey (p=0.023). Caffeine consumption between the two halves had no significant effect on salivary cortisol concentration (p=0.098).

Figure 7. shows Salivary cortisol in caffeine group.

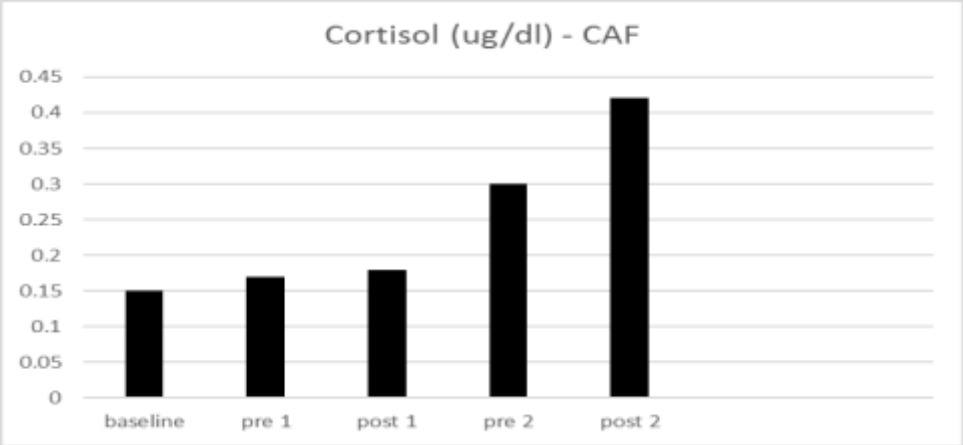

Figure 7- Salivary cortisol concentration - caffeine group

Figure 8. shows Salivary cortisol in placebo group.

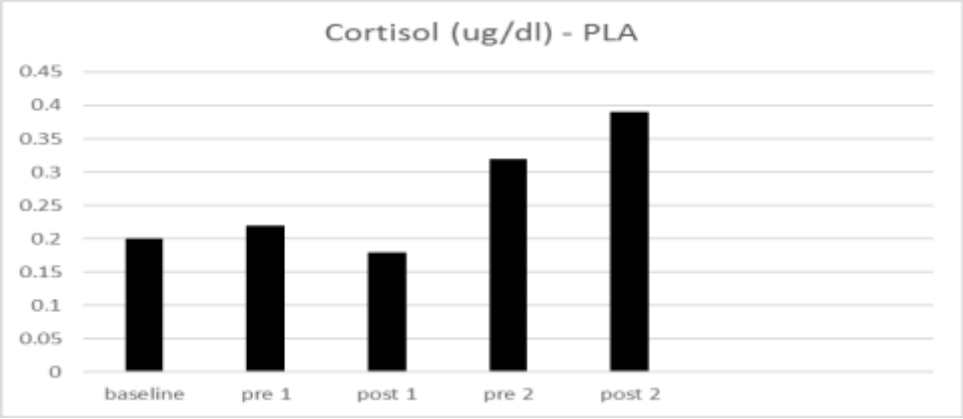

Figure 8- Salivary cortisol concentration - placebo group

Discussion

The purpose of this study was to investigate the effect of caffeine gum on the performance and salivary testosterone and cortisol levels of male fencers during a simulated competition round.

Our findings showed that salivary testosterone concentrations were elevated more than placebo levels at the onset of a second sprint test after consumption of caffeine in gum form ($p<0.05$). But no changes in performance (running tests) were observed ($p>0.05$), and no salivary cortisol differences were observed ($p>0.05$).

In a review article in 2022 using data from a cross-sectional study of 372 adult men, the researchers set out to characterize the association between serum testosterone levels,

caffeine, and 14 caffeine metabolites. multivariable, weighted linear regression revealed a significant inverse association between caffeine and testosterone (17). Cole and his coworkers in 2023 found no significant main effects of regular caffeine use on baseline cortisol or reactivity. However, in a significant Caffeine Use * Stress * Quadratic Time effect, (est=0.94, p=0.02), caffeine users in the negative-evaluative condition had greater cortisol reactivity than non-users (18).

Despite the lack of performance-enhancing effects of caffeine in this study, caffeine gum appears to be an appropriate way of administration, especially at times such as between halves of a game where enough time to consume caffeine via pills, drinks, etc are limited. Repeated running activity and the pattern of testosterone and cortisol concentration, indicating the intensity of exercise, are in a same way with previous authors (19).

Caffeine consumption of less than 10-15 mg/kg of body weight per day exerts its physiological effects by blocking adenosine A1 and A2a receptors. Caffeine counteracts the hypnotic effects of adenosine in the central nervous system to increase alertness, improve mood, and possibly increase HPAC activation. Caffeine increases the secretion of cortisol by increasing the production of ACTH in the pituitary gland of the brain, although the exact mechanisms are still unclear (20). Cortisol secretion is regulated by the HPAC, such that neurosecretory cells in the paraventricular nucleus of the hypothalamus release corticotropin-releasing factor into the pituitary stalk, which causes ACTH to be released by the anterior pituitary, thereby increasing the rate of adrenal cortisol production. will be This action, in turn, is inhibited by the negative feedback of cortisol in the pituitary, hypothalamus and hippocampus. A chronic increase in cortisol secretion can cause negative effects on a person's health, such as depression, changes in the response of the central nervous system and limbic system, changes in declarative memory, and changes in the function of the frontal lobe (20).

Several mechanisms suggest a relationship between caffeine and testosterone. The main mechanism of action of caffeine is antagonism of adenosine receptors and it acts on all four subtypes of adenosine receptors in the brain (A1, A2a, A2b, A3). In addition to those found in the brain, adenosine receptors have also been in the testes (21).

Following activation of these receptors, the cAMP/protein kinase pathways, which are normally activated by testosterone production, are downregulated and can cause decreased testosterone production (22).

An innovation about this study was the use of the 400 mg caffeine gum throughout a simulated bout of fencing competition. As reported by Paton et al. (23), the caffeine gum was not related with any symptoms of gastrointestinal distress. So, despite an absence of performance elevation in this study, chewing gum is a convenient way to use caffeine, especially when the time is limited, to traditional use of caffeine such as pills, drinks etc.

a delayed phase; 40 minutes from stimulation to systemic appearance of testosterone has been noted, in rats, direct neuronal connections between the paraventricular nucleus of the hypothalamus and the testes have been identified (24). The rapid increase in testosterone could be caused by a direct neural pathway.

The time of using caffeine gum and the dose used (400 mg), the history of caffeine consumption in athletes are also important in interpreting the results.

The use of repeated running test is representative of previous research (25) and standardizes the physiological demands elicited between repeated trials, so enhancing the repeatability of exercise responses. In addition, repeated sprint ability is related to activity rates (26) and the pattern of blood lactate concentrations, a marker of exercise intensity (27) demonstrates that primarily passive half-time practices are insufficient to improve performance or physiological responses back to the level of a comparable time point in the first half. The dose of caffeine used in this study (400 mg) may have contributed to the absence of performance enhancing effects but the safety implications of chewing more than 4 pellets of gum at once had to be considered. Also the effects of supplementation were adjusted by habitual caffeine ingesting and the needs to avoid from caffeinated products in the immediate presampling period. But the effects of caffeine gum intake, should consider with athletes and coaches to use of caffeine gum; partly due to the possible ergogenic effect that an increase in salivary testosterone could have thereafter (28).

References:

Doyle T.P., Lutz R.S. Pellegrino J.K., et al. The effects of caffeine on arousal response time, accuracy , and performance in division I collegiate fencers. Journal of Strength and Conditioning Research. 2016: 30(11)/3228–3235.

Daly JW, Fredholm BB. Caffeine: an atypical drug of dependence. Drug Alcohol Depend 1998;5:199–206. [PubMed: 9716941]

Lovallo WR, al'Absi M, Pincomb GA. Caffeine raises blood pressure during extended mental stress in borderline hypertensive men. Int J Behav Med 2000;7:183–8.

Arent, SM and Landers, DM. Arousal, anxiety, and performance: A Reexamination of the Inverted-U hypothesis. Res Q Exerc Sport 74: 436–444, 2003.

Landers, DM and Arent, SM. Arousal-performance relationships. In: Applied Sport Psychology: Personal Growth to Peak Performance. JM Williams, ed. Mountain View, CA: Mayfield, 2001. pp. 206–228.

Starkman MN, Schteingart DE, Schork MA. Cushing's syndrome after treatment: changes in cortisol and ACTH levels, and amelioration of the depressive syndrome. Psychiatry Res 1986;19:177–88. [PubMed: 3025905]

Lovallo WR, al'Absi M, Blick K, Whitsett TL, Wilson MF. Stress-like adrenocorticotropin responses to caffeine in young healthy men. Pharmacol Biochem Behav 1996;55:365–9. [PubMed: 8951977]

Temple JL, Bernard C, Lipshultz SE, Czachor JD, Westphal JA, Mestre MA. The Safety of Ingested Caffeine: A Comprehensive Review. Front Psychiatry. 2017;8:80-. doi: https:// doi. org/ 10. 3389/ fpsyt. 2017. 00080. PubMed PMID: 28603504

Ryu KY, Roh J. The Effects of High Peripubertal Caffeine Exposure on the Adrenal Gland in Immature Male and Female Rats. Nutrients. 2019;11(5). Epub 2019/05/01. doi: https:// doi. org/ 10. 3390/ nu110 50951. PubMed PMID: 31035471; PMCID: PMC6566528.

Guessous I, Dobrinas M, Kutalik Z, Pruijm M, Ehret G, Maillard M, Bergmann S, Beckmann JS, Cusi D, Rizzi F, Cappuccio F, Cornuz J, Paccaud F, Mooser V, Gaspoz J-M, Waeber G, Burnier M, Vollenweider P, Eap CB, Bochud M. Caffeine intake and CYP1A2 variants associated with high caffeine intake protect non-smokers from hypertension. Hum Mol Genet. 2012;21(14):3283–92. https:// doi. org/ 10. 1093/ hmg/ dds137.

Kot M, Daniel WA. Caffeine as a marker substrate for testing cytochrome P450 activity in human and rat. Pharmacological reports : PR. 2008;60(6):789–97 Epub 2009/02/13 PubMed PMID: 19211970.

Beaven CM, Cook CJ, Gill ND. Significant strength gains observed in rugby players after specific resistance exercise protocols based on individual salivary testosterone responses. *J Strength Cond Res* 2008;22(2):419–25.

Sinha-Hikim I, Roth SM, Lee MI, Bhasin S. Testosterone-induced muscle hypertrophy is associated with an increase in satellite cell number in healthy, young men. *Am J Physiol Endocrinol Metab* 2003;285(1):E197-205.

Spiering BA, Kraemer WJ, Vingren JL, et al. Elevated endogenous testosterone concentrations potentiate muscle androgen receptor responses to resistance exercise. *J Steroid Biochem Mol Biol* 2009;114(3–5):195–9.

Lee WJ, McClung J, Hand GA, Carson JA. Overload-induced androgen receptor expression in the aged rat hindlimb receiving nandrolone decanoate. *J Appl Physiol* 2003;94(3):1153–61.

Impellizzeri, FM, Rampinini, E, Castagna, C, Bishop, D, Ferrari Bravo, D, Tibaudi, A, and Wisloff, U. Validity of a repeated-sprint test for football. Int J Sports Med 29: 899–905, 2008.

Glover, F.E., Caudle, W.M., Giudice, F.D., et al. The association between caffeine intake and testosterone: NHANES 2013–2014. Glover et al. Nutrition Journal (2022) 21:33.

Cole E, Grillo A, Vrshek-Schallhorn S. The Moderating Effects of Regular Caffeine Use on Cortisol Reactivity under Explicit Negative-Evaluative Stress. Psychoneuroendocrinology. 2023. 153, Supplement, 106202

Magkos, F and Kavouras, SA. Caffeine use in sports, pharmacokinetics in man, and cellular mechanisms of action. Crit Rev Food Sci Nutr 45: 535–562, 2005.

Lupien SJ, Gillin CJ, Hauger RL. Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: a dose-response study in humans. Behav Neurosci 1999;113:420–30.

Monaco L, Conti M. Localization of Adenosine Receptors in Rat Testicular Cells1. Biol Reprod. 1986;35(2):258–66. https:// doi. org/ 10. 1095/ biolr eprod 35.2. 258.

Dufau ML, Tsuruhara T, Horner KA, Podesta E, Catt KJ. Intermediate role of adenosine 3':5'-cyclic monophosphate and protein kinase during gonadotropin- induced steroidogenesis in testicular interstitial cells. Proc Natl Acad Sci U S A. 1977;74(8):3419–23. Epub 1977/08/01. doi: https:// doi. org/ 10. 1073/ pnas. 74.8. 3419. PubMed PMID: 198785; PMCID: PMC431588.

Russell, M, West, DJ, Harper, LD, Cook, CJ, and Kilduff, LP. Halftime strategies to enhance second-half performance in team-sports players: A review and recommendations. Sports Med 45: 353–364, 2016.

Ryan, EJ, Kim, CH, Fickes, EJ,Williamson, M, Muller, MD, Barkley, JE, Gunstad, J, and Glickman, EL. Caffeine gum and cycling performance: A timing study. J Strength Cond Res 27: 259–264, 2013.

Russell, M, West, DJ, Briggs, MA, Bracken, RM, Cook, CJ, Giroud, T, Gill, N, and Kilduff, LP. A passive heat maintenance strategy implemented during a simulated half-time improves lower body power output and repeated sprint ability in professional Rugby Union players. PLoS One 10: e0119374, 2016.

Smart, D, Hopkins, WG, Quarrie, KL, and Gill, N. The relationship between physical fitness and game behaviours in rugby union players. Eur J Sport Sci 1(14 Suppl): S8–S17, 2014.

Duthie, G, Pyne, D, and Hooper, S. Applied physiology and game analysis of rugby union. Sports Med 33: 973–991, 2003.

Russell M, Reynold NA, Crowther BT, Cook, CJ, and Kilduff LP. Physiological and performance effects of caffeine consumed during a simulated half-time by professional academy rugby union players. Journal of Strength and Conditioning Research. 2020. 34(1)/145–151.