Effects of caffeinated chewing gum on functional firefighting balance ability after GABA supplementation

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Project summary

This study simulated the effects of chronic insomnia by administering γ-aminobutyric acid (GABA) and then observed whether chewing caffeine-containing gum could effectively improve firefighters' balance under conditions of brain fatigue. This study recruited 14 healthy adult male active-duty firefighters as participants and used a crossover double-blind design, dividing them into a CAF trial and a PL trial. On the first day of the experiment, after the participants had taken sufficient time off and had a full night's sleep, they rested for 3 hours after dinner on the second day. Following the collection of saliva samples, baseline heart rate variability and firefighting ability tests were conducted. After the tests, the participants ingested 800 mg of GABA and rested for 30 minutes. After that, the participants chewed caffeinated gum containing 3 mg/kg (CAF trial) or caffeine-free placebo gum (PL trial) for 10 minutes, spit it out, rested for 15 minutes. The participants underwent eight firefighting balance tests, during which heart rate variability was measured. After the tests were completed, saliva samples were collected again. Differences between the two trials were analyzed using a paired sample t-test and significance was set at $\alpha<0.05$.

Introduction

Firefighters belong to a specialized profession that requires a combination of physical fitness, muscle strength, cognitive abilities, and specialized firefighting skills. In this profession, prolonged exposure to high stress, shift work, and hazardous environments may impair firefighters' physiological and psychological functions (1), thereby increasing risks during duty. Regarding physiological function, tactical physical training has been shown to effectively enhance the physiological performance of professional firefighters (2). However, with respect to cognitive function and firefighting-specific skills, addressing how to mitigate sleep disturbances caused by shift work and further improve cognitive abilities and firefighting-specific skills remains a challenge that needs to be overcome.

Caffeine (1,3,7-trimethylxanthine) is a popular dietary supplement among many groups, including athletes and firefighters. Caffeine supplementation has been found to

effectively maintain better cognitive function and motor control while reducing fatigue levels (3). Consequently, an article published by the International Society of Sports Nutrition has clearly demonstrated that caffeine can effectively enhance performance in both aerobic and anaerobic exercise, as well as improve cognitive function, even under conditions of sleep deprivation (4). Based on this, caffeine supplementation may have a significant positive effect on firefighters' tactical and technical abilities, cognitive function, and firefighting-specific skills.

It has been found that shift work among firefighters has a negative impact on sleep quality(5). For firefighters, work schedules are irregular. Taking GABA as a sleep-aid supplement before bedtime may impair their cognitive function (6). On the other hand, prolonged sleep deprivation can also lead to a buildup of GABA in the brain (7), which can similarly affect cognitive function. Therefore, using caffeine to enhance cognitive performance may be a solution to counteract the cognitive decline caused by sleep deprivation or GABA intake. Therefore, the purpose of this study is to investigate the effects of chewing caffeinated gum on firefighting performance following GABA supplementation.

Methods

Study design

In this study, a double-blind crossover experimental design was used, in which participants were randomised to either the caffeinated chewing gum trial (CAF) or the placebo chewing gum trial (PL). After a seven-day washout period, the participants were switched to another trial of experiments.

Participants

Fifteen trained professional firefighters served as participants in this study. Eligibility criteria: 1. Active-duty members of the Special Search and Rescue Brigade. 2. Regularly perform firefighting and disaster relief duties. 3. Have fully recovered from sports injuries such as strains or sprains for at least 3 months. Exclusion criteria: 1. Members who are not part of the Special Search and Rescue Brigade. 2. Individuals who do not regularly perform firefighting and disaster relief duties. 3. Participants who have not fully recovered from sports injuries for at least 3 months, or who suffer from epilepsy, hypertension, hyperlipidemia, heart disease, joint disease, osteoporosis, brain injury, or have a history of caffeine allergy.

Protocol

All formal experiments are scheduled to take place on the participants' days off. After at least 8 hours of sleep, participants arrive at the laboratory at 9:00 a.m., 1:00 p.m., and 5:00 p.m. to receive breakfast, lunch, and dinner, respectively. After dinner, participants rest in the laboratory for approximately 3 hours. During this time, they may read, watch television, play video games, or engage in other non-exercise activities, but they are not allowed to sleep. At 8:00 PM, participants will collect a saliva sample and undergo baseline heart rate variability and cognitive function tests. After the tests, they will take 800 mg of GABA and rest for 30 minutes to reach peak blood GABA concentrations. Once the time elapsed, participants chewed either caffeine-containing gum (3 mg of caffeine per kilogram of body weight; CAF trial) or decaffeinated placebo gum (PL trial) for 10 minutes before discarding it. During this period, participants followed rapid-response procedures, donning full firefighting gear and preparing for the test in a room maintained at 30°C with 50% humidity. The experimental protocol simulated a scenario where firefighters, after multiple days of shifts, might have accumulated high levels of GABA in the brain or improved sleep quality through GABA supplementation, only to receive a call to respond at the peak of the drug's effects. The study aimed to observe whether the use of caffeine gum would affect firefighting performance under these conditions. The participants then underwent a functional balance test while wearing full firefighting gear. After the test, they provided another saliva sample, thereby completing the entire experiment.

Caffeine and placebo gum

The caffeinated chewing gum employed in the present study (Military Energy Gum, Arctic Mint flavour; Stay Alert, Chicago, USA) has been utilised in previous studies(8, 9). It is estimated that a single piece of gum contains approximately 5 grams and 100 milligrams of caffeine. The placebo gum was a commercially available blue mint gum (Lotte Gum Mint., Ltd., Tokyo,Japan). In order to administer a dose of 3 mg/kg of caffeine per unit of body weight, it was necessary to crush, grind, blend, reshape and flavor all chewing gums with 0.3 g of peppermint-flavored powder. The process was designed to ensure that the new chewing gums were comparable to the original in terms of appearance, color, flavor, weight and size. Previous studies have demonstrated that this method renders it impossible for the participant to distinguish the type of gum (8, 10).

Statistical analysis

Data in this study are presented as mean ± standard deviation. The data were first tested for normality using the Shapiro-Wilk normality test. When data met the assumption of

normality, cognitive function measures and salivary biochemical data at baseline and following caffeine or placebo intervention were analyzed using two-way ANOVA with repeated measures, with post-hoc comparisons performed using the Bonferroni method. Performance indices (PI) from the Functional Balance Assessment were analyzed using paired t-tests. If the data did not follow a normal distribution, Generalized Estimating Equations (GEE) were used to analyze cognitive function measures and salivary biochemical data, while the Wilcoxon signed-rank test was used to analyze performance indices (PI) from the functional balance test. The level of significance was set at $P \leq 0.05$.

Reference

1. Morris CE, Chander H. The impact of firefighter physical fitness on job performance: A review of the factors that influence fire suppression safety and success. Safety. 2018;4(4):60.
2. Sharp P, Caperchione CM, Brown GA, Stadnyk A, Marin E, Hulin B, et al. A pragmatic strength and conditioning intervention for firefighters: Feasibility of the Tactical Athlete Resilience Program (TARP). Health Promotion Journal of Australia. 2023;34(1):60-9.
3. Duncan MJ, Dobell AP, Caygill CL, Eyre E, Tallis J. The effect of acute caffeine ingestion on upper body anaerobic exercise and cognitive performance. European Journal of Sport Science. 2019;19(1):103-11.
4. Guest NS, VanDusseldorp TA, Nelson MT, Grgic J, Schoenfeld BJ, Jenkins ND, et al. International society of sports nutrition position stand: caffeine and exercise performance. Journal of the International Society of Sports Nutrition. 2021;18(1):1.
5. Mehrdad R, Haghighi KS, Esfahani AHN. Sleep quality of professional firefighters. International journal of preventive medicine. 2013;4(9):1095.
6. Lim LW, Aquili L. Gaba supplementation negatively affects cognitive flexibility independent of tyrosine. Journal of Clinical Medicine. 2021;10(9):1807.
7. Szabadi E. Drugs for sleep disorders: mechanisms and therapeutic prospects. British journal of clinical pharmacology. 2006;61(6):761-6.
8. Shiu Y-J, Chen C-H, Tao W-S, Nai H-F, Yu C-Y, Chiu C-H. Acute ingestion of caffeinated chewing gum reduces fatigue index and improves 400-meter performance in trained sprinters: a double-blind crossover trial. Journal of the International Society of Sports Nutrition. 2024;21(1):2414871.
9. Morris C, Viriot SM, Mirza QUF, Morris GA, Lynn A. Caffeine release and absorption from caffeinated gums. Food & function. 2019;10(4):1792-6.

10. Liu H-S, Liu C-C, Shiu Y-J, Lan P-T, Wang A-Y, Chiu C-H. Caffeinated Chewing Gum Improves Basketball Shooting Accuracy and Physical Performance Indicators of Trained Basketball Players: A Double-Blind Crossover Trial. Nutrients. 2024;16(9):1256.