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Sublingual Caffeine Supplementation on Physical Performance in United States Military Personnel



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14. ABSTRACT The objectives of this study were to (1) measure the effects of sublingual caffeine ingestion on physical performance and perceptions of fatigue in highly fit military personnel and (2) measure the effects of sublingual caffeine ingestion on neuromuscular function, specifically reaction time following physically demanding work common to military personnel operating in the field. Results of this pilot study indicate that no difference occurred in the outcomes measured in subjects at baseline, placebo, or treatment groups. Although subjects may have differed in physical ability, each subject served as his/her own control, which is accounted for in the linear mixed model analysis. The results of this study show that caffeine at low doses (i.e., 6 mg/kg bodyweight) does not negatively impact physical or neuromuscular performance outcomes, even after engaging in muscle-fatiguing exercise (i.e., pullups, pushups, weighted vest walking test). Subjects showed consistent performance across all three groups and had similar responses (i.e., pushups in round 1 were greater than rounds 2 and 3 both pre- and post-treadmill walking). Consistent with previous investigations, future research may include use of sublingual caffeine throughout exercise and differing doses of caffeine (i.e., 9 mg/kg bodyweight), based upon the results of this investigation. Additionally, this study may benefit from adding more subjects and controlling for fitness, hydration, and the time interval between visits.					
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1.0 SUMMARY

The objectives of this study were to measure the effects of sublingual caffeine ingestion on physical performance and perceptions of fatigue on highly fit military personnel and on neuromuscular function, specifically reaction time, following physically demanding work common to military personnel operating in the field. Results of this pilot study indicate that no difference occurred in the outcomes measured in subjects at baseline, placebo, or treatment groups. Although subjects may have differed in physical ability, each subject served as his/her own control, which was accounted for in the linear mixed model analysis.

Physiological parameters measured included the following: (1) exercise heart rate, (2) muscular strength, power, and endurance, (3) neuromuscular function, (4) subjective rating of perceived exertion, (5) exercise heart rate, and (6) blood lactate.

The results of this study show that caffeine at low doses (i.e., 6 mg/kg bodyweight) does not negatively impact physical or neuromuscular performance outcomes, even after engaging in muscle-fatiguing exercise (i.e., pullups, pushups, weighted vest walking test). Subjects showed consistent performance across all three groups and had similar responses (i.e., pushups in round 1 were greater than rounds 2 and 3 both pre- and post-treadmill walking).

2.0 INTRODUCTION

The physical performance, focus, and cognition of military personnel operating in battlefield environments are imperative to mission success. Physically demanding work coupled with insufficient or inconsistent rest can alter decision-making skills during critical situations. Diminished neuromuscular function may lead to military personnel being unable to perform at optimal capacity, placing themselves and other team members at greater risk of injury or death in the battlefield [1].

Caffeine is the most commonly consumed stimulant in the world, with effective doses ranging from 3 to 9 mg/kg bodyweight [2]. Various delivery methods of caffeine are available including capsule, liquid, and chewing gum. The use of caffeine to attenuate physical and mental fatigue is common. Extensive research has been conducted on the ergogenic benefits of caffeine including increased time to exhaustion and improved time trial performance [3,4]. Caffeine is commonly known to increase wakefulness. However, little is known about the effect of caffeine on neuromuscular function, specifically reaction time following physically demanding work common to military personnel in the field. Sublingual caffeine may be a viable option for military use in the field [2,5].

Caffeine's cardiovascular effects depend on an individual's prior use of it. For example, a caffeine-naïve person could experience increases in blood pressure and heart rate, while the caffeine-tolerant person may experience little or no change in blood pressure or heart rate [6]. It has no effect on short-term, high-intensity work and maximal oxidative capacity, but it may increase endurance capabilities. Additionally, sensitive individuals could experience atrial or ventricular arrhythmias at high levels of intake [6].

The objectives of this study were to measure the effects of sublingual caffeine ingestion on physical performance and perceptions of fatigue on highly fit military personnel and on neuromuscular function, specifically reaction time, following physically demanding work common to military personnel operating in the field.

3.0 BACKGROUND

Interest in the effects of caffeine on exercise performance dates back almost 100 years, but it is only in the last 30 years that controlled studies have been conducted and extensively reviewed [2,3,5,7]. Caffeine is methylxanthine that stimulates the respiratory, cardiovascular, and central nervous systems, as well as the skeletal and smooth muscles. Caffeine has been reported to increase muscular endurance performance in well-trained athletes through the sparing of muscle glycogen and increased mobilization of free-fatty acids. However, the notion of caffeine is under dispute [3,7].

The most likely mechanism for increased endurance performance is caffeine's action on adenosine and ryanodine (RyR1) receptors in the brain. These receptors control the release of calcium and initiate contractions in the skeletal muscle and myocardium [8]. Therefore, the performance-enhancing effects of caffeine are through increased calcium mobilization or stimulation of the central nervous system. Although the mechanisms of action of caffeine are well known, caffeine-related human performance improvements are also dependent upon the person's nutritional status, sensitivity to caffeine, genetics, dose and timing of caffeine, and overall physical condition [8].

Scientific literature on sublingual caffeine supplementation is sparse. Yarnell and Deuster reported that more studies are needed to evaluate whether 6 mg/kg bodyweight is the optimal dose of caffeine needed to improve physical and cognitive performance parameters [8]. Although this group of researchers examined the effects of caffeine in absolute doses (mg) in regard to operational military performance, researchers suggest 200 mg of caffeine as an optimal dose for an acute effect on marksmanship in sleep-deprived individuals (e.g., after 72 hours of Hell Week) and 300 mg of caffeine as a performance enhancer for up to 8 hours [2,5]. The intake of 200 mg of caffeine helped reduce sighting time to target, but not accuracy, in SEAL trainees after 72 hours of Hell Week [1]. Therefore, caffeine intake in appropriate doses may be beneficial for marksmanship of special operations forces during missions in which sleep deprivation and other operational stressors may negatively affect mission success.

Caffeine doses ranging from 4 to 9 mg/kg bodyweight have been found to have substantial ergogenic benefits on endurance performance in the laboratory [7]. For example, Cox and associates found that 6 mg/kg bodyweight improved time trial (TT) cycling endurance performance. The same athletes in this study were also following a diet rich in carbohydrates throughout the time trials [7]. Cox et al. [7] reported increased submaximal exercise capacity with caffeine intakes of 4 to 9 mg/kg bodyweight 60 minutes prior to the start of exercise; similar results are also reported by Kovacs and colleagues in which 60 minutes of cycling TT was improved after subjects ingested caffeine both prior to and after exercise [4]. Unlike the present investigation, Cox et al. found a synergistic effect of athletes consuming Coca-Cola as a replacement for electrolyte sports drinks during the latter stages of a TT endurance-cycling event [7]. Additionally, when provided in a double-blind design, the Coca-Cola protocol produced an enhancement of a TT performance at the end of the 120-minute cycling event, with the benefits largely due to the ingestion of small amounts of caffeine (~1.5 mg/kg bodyweight). The results from this study suggest that all exercise protocols of caffeine use equally benefit prolonged cycling performance [7]. Yarnell and Deuster reported that improvements in human performance primarily occur in trained athletes and elite performers [8]. In contrast, caffeine does not enhance performance in non-athletes or participants who are defined "out of shape."

4.0 METHODS

Although the present study proposes to use caffeine in one dose (6 mg/kg bodyweight), consistent with previous investigations [3,4,7], future research may include use of sublingual caffeine throughout exercise and differing doses of caffeine, based upon the results of this investigation.

Subjects who participated in this training study were as “well-trained” according to the American College of Sports Medicine’s Guidelines for Exercise Testing and Prescription [9]. Fifteen healthy, active duty male/female military personnel participated in this study. Each subject was required to sign an informed consent document prior to enrolling in the study.

Subjects attended five different testing days, lasting approximately 2-5 hours each visit over a period of approximately 6 weeks. The first of these visits consisted of baseline testing including required informed consent document paperwork. Subjects who met study inclusion criteria and scored above 50 mL/kg/min for males and 43 mL/kg/min for females on their maximal oxygen consumption qualified for participation.

Subjects were instructed to ingest the directed dose of caffeine 60 minutes prior to baseline testing. Thirty minutes after caffeine ingestion, subjects were asked to perform a Dynavision test to measure reaction time and fine-motor skill performance. The subjects then performed three rounds of alternating between maximal pushups and maximal pullups for 60 seconds or until reaching volitional fatigue with 30 seconds rest between each exercise to measure physical performance. Immediately following, subjects dressed in their battlefield dress uniform including a 40-pound ruck gear and performed a 10-mile ruck march on a treadmill.

While ruck marching, subjects drank water *ad libitum*. Rating of perceived exertion and blood lactate were collected at 2.5, 5, 7.5, and 10 miles. Subjects then performed pushup, pullup, and Dynavision protocols. The remaining testing days were under either placebo or caffeine tab condition in a randomized double-blind placebo scenario.

Physical performance was measured by three tasks using Dynavision technology to assess peripheral reaction time using both the left and right hands and three rounds of muscular endurance, strength, and power exercises to include bodyweight pushups and pullups. Participants’ muscular endurance performance was tested both before and after completion of a 10-mile walk on a treadmill. Results from the linear mixed model (LMM) compared measures in the three scenarios.

Data were provided in Microsoft Excel, which was converted to a comma separated value (csv) format. The csv format was then transformed from wide to long format by stacking the results from visits 2, 3, and 4. Visit 2 was considered baseline due to no caffeine being given to participants, but all performance measures were completed. Participants in visits 3 and 4 were either provided treatment (caffeine = 1) or placebo (caffeine = 2). Fifty-four outcome variables were measured using an LMM to compare mean differences in performance measures among scenarios with the alpha established *a priori* at the 0.05 level. Fixed effects of the LMM were treatment groups (baseline, placebo, and treatment) and the random effects accounted for correlated errors.

5.0 RESULTS

The results of this study show that caffeine at low doses (i.e., 6 mg/kg bodyweight) does not negatively impact physical or neuromuscular performance outcomes, even after engaging in muscle-fatiguing exercise (i.e., pullups, pushups, weighted vest walking test). Subjects showed consistent performance across all three groups and had similar responses (i.e., pushups in round 1 were greater than rounds 2 and 3 both pre- and post-treadmill walking).

Results from the LMM comparing performance measures in three scenarios showed small differences in the fixed effects among baseline (0.38), placebo (0.37), and caffeine (0.36). Muscular endurance, strength, and power tests were measured using pullups and pushups. With regard to pushups, most participants showed little statistical difference in pre- and post-treadmill walking. Participants responded similarly with round 1 of pullups and pushups achieving the highest count and a decreased number of pushups in rounds 2 and 3. Participants 8, 9, and 10 showed a larger decrement than the other participants in the number of pushups achieved in round 1 when comparing pre- and post-treadmill walking, whereas rounds 2 and 3 did not appear to have been impacted as greatly by treadmill walking as the first round.

Pullups had a higher variance than pushup counts. Participants performed as expected, with the highest number of pullups in round 1 and decreased numbers in rounds 2 and 3. Furthermore, participants 3, 5, and 12 showed a larger decrement when compared to other participants in the number of pullups achieved in round 1 when comparing pre- and post-treadmill walking. Additionally, three of the participants were unable to complete any pullups in at least one testing round.

The LMMs indicate that the variance was similar, and minimal change occurred in the median in all groups both pre- and post-treadmill exercise. Participants were measured during the treadmill exercise wearing a weighted vest on exercise heart rate, rating of perceived exertion and blood lactate at 0, 2.5, 5, 7.5, and 10 miles. The effect of treatment (caffeine or placebo) was measured to determine the difference in outcomes when participants were given either a placebo or caffeine. The treatment effect all showed little difference from the placebo, with most of the results bordering zero. Furthermore, the treatment effect comparison among baseline, caffeine treatment, and placebo showed little change among the three groups. There was no linear relationship indicating that the sublingual caffeine supplement cannot be used to explain the outcomes.

Although the dose of caffeine administered to subjects in this study did not result in significant improvements in reaction time, Van Handel and colleagues concluded that caffeine did help improve reaction time, increase alertness, and heighten a sense of well-being [10]. Furthermore, Van Handel and colleagues suggest that caffeine may be of benefit in such sports as shooting and archery. The effects appear to be dose related and affected by the caffeine habituation of subjects (i.e., the normal caffeine intake of the subjects). On the other hand, high doses were seen to have detrimental effects on the same performance parameters, and it seems that the response of individual subjects may be quite variable, as was the case in this study.

6.0 DISCUSSION/CONCLUSIONS

The overall objectives of this study were met. However, we believe a higher dose of sublingual caffeine, as clearly stated in the primary scientific literature, could significantly enhance effects on physical and cognitive performance on a homogenous group of Special Forces operators during sustained operations missions. For this study, we were conservative in using caffeine in one dose (6 mg/kg bodyweight). Consistent with previous investigations, future research may include use of sublingual caffeine throughout exercise and differing doses of caffeine (i.e., 9 mg/kg bodyweight), based upon the results of this investigation [3,4,7]. Additionally, this study may benefit from adding more subjects and controlling for fitness, hydration, and the time interval between visits.

This investigation presented a number of limitations due to the practical nature of this study, which was designed to simulate real work special operations training evolutions related to fatigue and its effects on cognitive function. For example, it is unknown how much caffeine participants regularly consumed and therefore the sensitivity to caffeine after a brief period of restriction. Additionally, the recovery time for each participant also varied due to unexpected official travel and military duties. Since the time interval between participants' visits was not held constant, some participants may have had more recovery time and therefore fewer changes in blood lactate, reaction time, rating of perceived exertion, and exercise heart rate.

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LIST OF ABBREVIATIONS AND ACRONYMS

csv	comma separated value
LMM	linear mixed model
TT	time trial