Caffeine: Friend or foe in the modern combat environment?

by

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B.S., University of North Dakota, 2013
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AN ABSTRACT OF A DISSERTATION

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DOCTOR OF PHILOSOPHY

Department of Kinesiology
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Abstract

This dissertation identified critical tasks (CTs) executed in modern combat environments and determined caffeine's effect on CT performance. Job task analyses have identified CTs performed by specific military occupations, but have yet to identify CTs from combat environments. A job task analysis was conducted in Study 1 to identify CTs performed in modern combat environments. Subject matter experts meeting international criteria developed a job analysis questionnaire (JAQ). The JAQ contained 19 combat-relevant tasks that were evaluated for task frequency and importance by 137 veterans from the Global War on Terror. Eighty-nine percent of combat-relevant tasks were CTs that spanned multiple domains of physical fitness and tactical proficiencies. The most important CTs were: "sprint all-out in a single or repeated-bout < 30-s," "sprint, jump, or dive under combat load," and "aim, fire, and prepare a weapon in support of operations." Optimizing soldier performance during CTs is key to mission-success and soldier survivability. Soldiers utilize caffeine as a countermeasure during sustained operations; yet, caffeine's utility during these CTs remain unknown. In Study 2, we determined the effects of acute caffeine supplementation on exercise tolerance during repeated-sprint exercise. Ten physically active men were randomized in a double-blind crossover study to consume caffeine (5 mg/kg) or placebo before an intermittent critical velocity test. Subjects performed 3 sets of repeated-sprints (10 s running, 10 s rest) until exhaustion at 110%, 120%, and 130% of peak velocity (PV) achieved during a graded exercise test. Caffeine supplementation prolonged exercise duration at 110% PV (294-s *vs.* 392-s, $p = 0.020$), but not at 120% and 130% PV. Study 2 found that caffeine was ergogenic at approximately 400-s – similar in duration to tactical combat engagements – and gave precedence for the final investigation. Study 3 combined CTs "sprint, jump, or dive under combat load" and "aim, fire, and prepare a weapon in support of operations” to develop a tactical combat movement simulation and determine caffeine’s effects on CT performance. Thirty-nine healthy subjects were randomized in a double-blind, crossover study to chew caffeine gum (4 mg/kg) or placebo before a tactical combat movement simulation that included a fire-and-move battle drill and a marksmanship with cognitive workload assessment. Subjects wore a weight vest (~25-kg) during the simulation to mimic a combat load. Sprint durations from the fire-and-move simulation were used to model susceptibility to enemy fire. Sprint duration and susceptibility to enemy fire increased by 9.3% and 7.8%, respectively during the tactical combat movement simulation ($p = 0.001$). Cognitive performance also decreased during the tactical combat movement simulation ($p < 0.05$). Caffeine had no effect on sprint duration, susceptibility to enemy fire, marksmanship or cognitive performance. Overall, caffeine may provide benefit for some CTs when performed in isolation at select running velocities, but not when CTs are performed concurrently.

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Dedication

I dedicate these words to the courageous soldiers of past, present, and future. Your service to the freedom of America is unparalleled, and at times demanded some to give the ultimate sacrifice. I mourn with you and I am motivated by this unpayable debt. To you, I bring evidence for returning fellow warfighters back to their loved ones and the country they so valiantly protected.

Chapter 1 - Introduction

Overview

Warfighters must execute at the boundaries of human performance during combat operations both physically and mentally to ensure mission success and survival. Understanding the demands of the operational environment is the highest research priority area highlighted by key stakeholders in military science at the 2014 and 2017 International Congresses of Soldiers' Physical Performance (16). However, the U.S. has managed little headway in identifying the critical tasks performed by military personnel operating in modern combat environments. Additionally, stakeholders at the 2017 International Congresses of Soldiers' Physical Performance also identified nutrition as an emerging research priority in military science (16). Military personnel engage in unprecedented amounts of dietary supplement use; yet, the efficacy of dietary supplements on critical tasks performed in modern combat environments remains unknown (30). Ostensibly, caffeine represents an ideal dietary supplement for investigation among military populations given its availability through military food systems, its high-consumption among military personnel, and its touted ergogenic properties. The research conducted in this dissertation highlights the critical tasks soldiers execute while operating in modern combat environments and the effects of acute caffeine supplementation on critical task performance.

Job Tasks Analysis and the Warfighter

Employment standards developed by the U.S. military are used to evaluate a soldiers knowledge (e.g., Armed Services Vocational aptitude Battery), skills (e.g., marksmanship courses), and abilities (e.g., physical-readiness testing) (12,28). While a job task analysis forms the basis of employment standards, the U.S. military has not always utilized a formal job task analyses process (12). A careful construction of employment standards is important to ensure development of a legally defensible employment standard and mitigate potential threats to employees (10).

Job task analyses, also known as work analyses, are used to determine the knowledge, skills, abilities and other characteristics necessary for job success and employee safety (32). Job task analyses identify the critical tasks performed by the employee and are used develop evaluations which form the minimal acceptable performance standards used to determine the basis of employment (26). Employment standards, in theory, correctly place and retain individuals in the correct occupation while barring others from unnecessary risk associated with unsuccessful execution of critical job tasks (23).

The U.S. Army Physical Fitness Test, previously known as the Army Physical Readiness Test, was a physical abilities employment standard that received significant scrutiny for lacking combat-relevance (17). Yet, the Army Physical Fitness test was changed in FM 21-20 as the Army transitioned from a "Vietnam-era combat readiness focus" to reemphasizing general physical fitness (4). Arguably, the Army Physical Fitness Test rapidly became an invalid employment standard given the high casualty rates from the Global War on Terror. Given the rapid evolution of warfare technology since the Vietnam War, revisiting critical tasks that underscored previous evaluations was necessary.

Critical Tasks and the Warfighter

Critical tasks are the tasks necessary for safe and successful completion of a job and are the fundamental building block of a legally defensible employment standard (20,26). Critical tasks are determined by job tasks analyses which have utilized both subjective (i.e., interviews, surveys/questionnaires, subject matter expert consultation, focus groups) and objective approaches (i.e., quantification of task demands, job observation) (3). After gathering information from a job task analysis, a decision on the critical tasks necessary for safe execution of the job must be established. Typically, criteria are set during job task analyses that form the basis of which tasks will be identified as critical tasks (26). It is noteworthy that these criteria have no agreed-upon standard and are described as "objectively subjective"; thus, the decision to discern critical versus non-critical tasks must be made in good faith to ensure protection of the employee. The most common job task analysis performed are job analysis questionnaires where current or previous employees rate job tasks for frequency, difficulty, and importance (3). After acquiring data from job analysis questionnaires, critical tasks are identified (e.g. the most frequent, difficult, or important job tasks) (3,26).

Techniques to identify critical tasks have varied among emergency personnel, such as the military, with no standardized approach for critical task identification (22). To complicate matters, the nature of combat yields some job task analyses unavailable (i.e., job observations, inability to consult casualties). The U.S. military has utilized both subject matter expert consultation (11) and job analysis questionnaires (8) during job task analyses. The two most recent job task analyses conducted by the U.S. Army identified critical tasks based on the most common tasks executed (i.e., frequency) among combat military occupational specialties and the most difficult tasks executed during training exercises (7,11). However, critical tasks have yet to be identified using task importance ratings, which may be important when evaluating tasks performed during combat operations.

The unstandardized approach – even within the same branch of the U.S. Armed Forces – for critical task identification places soldiers at risk; especially, when failure to execute critical tasks can result in casualty (22). Arguably, critical tasks with such dire implications should refrain from using frequency- or difficulty-based approaches since emergencies (e.g., ambush) may occur infrequently and require soldiers to execute tasks that may not be perceived as physically demanding (e.g., deliver suppressive fire, throw a grenade) (22). Thus, establishing critical task criteria based on importance ratings may be more appropriate for wartime environments.

While some studies have identified the critical tasks necessary for soldiers, it is unclear what critical tasks are necessary when based on task importance criteria across different military occupations. Establishing critical tasks based on importance is essential given the dire nature of combat. Moreover, the use of a diverse military group is important because opposing forces are not concerned of military occupations. Therefore, further investigation is necessary to determine the critical tasks performed by soldiers operating in modern combat environments (Chapter 2).

Caffeine: An Ergogenic Target for Warfighters

Nearly 70% of military personnel consume dietary supplements and this is increased during deployments (13,31). Caffeine – a dietary supplement available through military food systems – is consumed at high-levels with soldiers self-reporting consumption at nearly 300 mg of caffeine per day (15). Caffeine consumption, similar to other dietary supplements, also increases in deployed settings to help offset the deleterious effects of sleep deprivation during night operations (19).

Caffeine is a psychoactive drug that acts on multiple target tissues. Caffeine is known to increase vigilance, attention, wakefulness, and arousal (18). At moderate doses, such as during human consumption of caffeine, caffeine's ergogenic properties act through adenosine-receptor antagonism. As an adenosine-receptor antagonist, caffeine reduces the perception of pain and exertion, and increases feelings of wakefulness, dopaminergic drive, and neural firing rates

(2,18). Either by modifying K^+ and Ca^{2+} kinetics (1,21) or augmentation of blood flow and tissue oxygenation (24,30), caffeine may also increase physical performance. Caffeine is an ergogenic aid for physical performance that is recognized and regulated by sporting agencies (5). Much of the evidence supporting caffeine's ergogenic properties are established in endurance-based exercise; however, emerging evidence suggests that caffeine may enhance aspects of muscular strength and power, and delay fatigue during repeated-sprint exercise (6,9,26,32). Lastly, caffeine improves marksmanship accuracy and reaction time, which depreciate in stressful environments (18,19). Enhancing these physical capabilities in soldiers may be vital in the modern combat-environment that some characterize as an "anaerobic battlefield" (14).

Soldiers perform physically demanding tasks in combat roles, but also require other skills such as marksmanship (7,28). Soldiers may abstain from caffeine before shooting activities because of anecdotal reports of it causing nervousness and poor marksmanship. This, however, is at odds with research demonstrating improvements in marksmanship reaction time and no effect on accuracy (28). Indeed, caffeine may be necessary to maintain marksmanship performance during operations when stress is high and known to affect accuracy (25).

Caffeine represents a promising ergogenic aid to improve physical capabilities and marksmanship skills required to operate in combat environments. However, because critical tasks performed in modern combat environments have not been established, it is difficult to assess the ergogenic potential of caffeine or any other compound. Moreover, critical tasks may occur in isolation or concurrently with one another while under duress. And while others have evaluated caffeine's effects on soldier performance, they may not accurately reflect the demands of the combat (18,19). Thus, determining caffeine's ergogenic properties on physically demanding critical tasks performed in isolation (Study 2) and in concert with on another under simulated combat conditions (Study 3) is necessary.

Purpose

Despite efforts to optimize warfighter performance, there is little information regarding the critical tasks performed in modern combat environments to justify testing and recommending ergogenic aids. This lack of knowledge may compromise mission readiness and success. Therefore, the purpose of this dissertation was to identify the critical tasks executed in modern combat environments and determine caffeine's effect on critical task performance.

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Chapter 2 - Critical tasks from the Global War on Terror: A combat-relevant job task analysis

Currently under review as Stein, JA, Hepler, TC, Cosgrove, SJ, Heinrich KM. Critical tasks from the Global War on Terror: A combat-relevant job task analysis. *Applied Ergonomics* (JERG-D-20-00535).

Abstract

Purpose: Our study aimed to identify critical tasks (CTs) performed in combat operations during the Global War on Terror. **Methods**: A job analysis questionnaire (JAQ) was developed by subject matter experts meeting international criteria for evaluating military related tasks. The JAQ was distributed online and participants (n=137; deployments = 2 ± 1; missions=126.8 ± 72.1) were asked to rate 19 tasks for frequency (0 = never to 4 = always) and importance (1 = not important to 5 = vital to survive. Criticality scores were generated for each task [Criticality = (2* Importance) + Frequency]. CTs were identified if the mean criticality score was ≥ 5.00 or mean importance rating ≥ 3.00. **Results**: Seventeen CTs were identified for criticality and 11 of those for importance. The additional CTs identified for criticality were tasks with moderate importance and low frequency. **Conclusions**: The top CTs were physically demanding or required tactical proficiencies with a weapon. All but two combat-relevant tasks were identified for criticality indicating that the identified list of tasks on the JAQ were relevant for survey participants. Future research should investigate the physical fitness levels required to meet the demands of our CTs.

Introduction

Human performance during combat operations is critical for warfighters operating in conditions described as volatile, uncertain, complex, ambiguous, and unconventional.[1] Accordingly, identifying the skills and abilities necessary for the ever-changing combat-environment remains important for mission success, combat-survivability, and national security.[2] Military forces use information from job task analyses (JTA) to identify critical tasks (CTs), which are tasks deemed necessary for safe and successful completion of a job.[3] Physical employment standards have recently emphasized combat-relevant tasks which have been the focal point of recent United States (U.S.) military evaluations.[4–9]

The U.S. military represents one of the largest fighting forces worldwide and has completed two investigations to aid in the development of combat-relevant physical employment standards.[5,7] The U.S. Army Research Institute of Environmental Medicine and U.S. Army Training and Doctrine Command conducted the U.S. Army Physical Demands Study and the Soldier Baseline Physical Readiness Requirements Study to understand the physical demands of soldiers in combat military occupational specialties (MOS) and the physical capabilities necessary to complete warrior tasks and battle drills and common soldiering tasks.[6,10] These studies utilized a job analysis questionnaire (JAQ) to identify CTs. [6,10] JAQs are a JTA method that characterize job tasks using information regarding task frequency, importance, criticality, duration, and difficulty.[11] However, there is not an agreed-upon standard to identify CTs from JAQs, warranting a thorough review for combat-relevant employment standards.[8,11]

JTAs performed in the Physical Demands Study and the Soldier Baseline Physical Readiness Requirements Study identified the most recent perceptions of the CTs for U.S. military personnel in the combat-environment.[5,7] Some job tasks from the Physical Demands

Study and Soldier Baseline Physical Readiness Requirements Study did not enter the later phases of physical employment standard development because they were uncommon, required high skill/technical attributes, or were not physically demanding.[5,7] These decisions may result in severe omissions of CTs. Emergency services personnel (i.e., law enforcement, firefighter) perform very important tasks infrequently, which would not be captured in a frequency-based JTA. The majority of physical employment standard investigations identify CTs based on task difficulty alone; however, the most physically demanding tasks performed in a combat-environment may not be necessary for mission success or soldier survivability.[11] Only utilizing training tasks (i.e., warrior tasks, battle drills and common soldiering tasks) as a proxy for combat-related tasks may fail to capture all CTs. Identifying the CTs from combat-environments derived on job task importance may better serve military leaders preparing soldiers for combat operations.

The use of criticality scores for CT identification provides a potential solution for emergency scenarios that occur during combat deployments (e.g., receiving fire from enemy forces). Calculation of criticality scores (the sum of task frequency ratings and twice the importance rating) is a JTA method that identifies CTs that frequently occur but have minimal importance (i.e., day-to-day operations) and CTs that infrequently occur but have high importance (i.e., emergency scenarios).[3,14] However, CTs performed in modern combat-environments have yet to be identified from a JAQ using importance or criticality ratings.

To our knowledge, no investigations have developed a combat-relevant JAQ that identifies CTs based on importance or criticality ratings in the modern combat-environment. Ostensibly, these CT identification techniques are an improvement from CTs performed in scenarios that may result in casualties. The purpose of our investigation was to develop a combat-relevant JAQ and identify CTs through a JTA utilizing importance and criticality ratings. We hypothesized that the JTA would reveal a majority of combat-relevant tasks from the JAQ as CTs.

Methods

The Kansas State University Institutional Review Board approved the study procedures (#8685).

Part 1: Development of the Job Analysis Questionnaire (JAQ)

At the time of study development, no combat-relevant JAQ existed and was needed before CT identification could commence. A JAQ from special weapons and tactics personnel was used as a template for a combat-relevant JAQ given the similarities in emergency response.[15] A subject matter expert (SME), SFC Hepler (retired) modified the special weapons and tactics JAQ to reflect combat-relevant tasks that occurred in the combat-environment. Using internationally agreed-upon criteria for selecting SMEs,[12] eight additional SMEs were identified and possessed at least two of nine criteria:1) experience performing the task during military exercise or training, 2) experience performing the task during military deployment domestically, 3) experience performing the task during military deployment internationally, experience performing the task during an emergency situation, 5) experience in a position of leadership where you have directed subordinates to perform the task and have observed the task being performed, 6) have witnessed the task being performed in an acceptable manner, 7) have witnessed the task being performed unsuccessfully and can attest to the reasons for, and the consequences of, this failure, 8) experience witnessing and/or performing the task using several techniques and can comment on the advantages and disadvantages of these techniques, and 9) experience delivering formal training on the task.[12] The SMEs deliberated regarding their perceptions of the most important combat-relevant tasks. Deliberation continued until all SMEs reached unanimous consensus, thereby validating the combat-relevant task inventory to be included in the JAQ.

Part 2: Job Task Analysis (JTA) and Critical Task (CT) Identification

Upon agreement of the combat-relevant task inventory, an online JAQ was designed using Qualtrics software (Qualtrics Labs Inc., Provo, UT, USA). The online survey was available for five weeks and distributed to U.S. military personnel via e-mail, social media, and shared with personal military contacts. The survey was terminated if the respondent had not completed 1) at least one combat deployment to Iraq or Afghanistan following the events of 11SEP2001 or 2) had not left the safety of forward operating base. All participants were provided a descriptive overview of the questionnaire prior to providing consent through the online survey.

The JAQ was separated into three main sections: demographics, military experience, and combat-relevant task evaluation. The demographics section determined age, sex, and ethnicity. The military experience section determined military branch, rank at the end of last of deployment, number of combat deployments, and total frequency of leaving the safety of the forward operating base (i.e., any forward military position that is used to support tactical operations) across all deployments. Participants rated task frequency and task importance in the combat-relevant task evaluation section of the JAQ. Participants rated combat-relevant task frequency by indicating "how many times did you do any of the following tasks while 'outside the wire.'" Task frequency was evaluated with a 0-4 scale (0 = never, 1 = sometimes, 2 = about half the time, 3 = most of the time, 4 = always). Task importance was rated from 1-5 (1 = not important, 2 = moderately important, 3 = very important, 4 = mission-essential, 5 = vital to survive). After survey completion participants were offered the chance to provide their contact information in a separate survey to win a gift card of $25 (n = 25) or $100 (n = 5).

Statistical Analysis

Data were analyzed with SPSS version 25 (IBM, SPSS, Armonk, NY). Criticality scores were generated for each combat-relevant task using the following formula [$Criticality = (2 * Importance) + Frequency$].[14] Tasks were identified as CTs using criteria from Whetzel & Wheaton[14] using two methods: mean criticality score ≥ 5.00 and mean importance rating ≥ 3.00. Task ratings were reported as the mean and standard deviation for task frequency, task importance, and task criticality.

Results

Two-hundred forty-three surveys were started, and 163 were completed (67% completion). Twenty-six completed surveys were excluded from analysis due to incomplete survey responses (i.e., missing 33% of the JAQ). Table 1 details participant characteristics. Table 2 provides results for task frequency, importance, and criticality scores. Of the 19 tasks, 17 were identified as CTs for criticality and 11 for importance. Both methods identified the top 11 tasks as CTs while six additional tasks were identified for criticality. The six additional CTs identified for criticality, but not importance, had lower frequency and higher importance, which may represent CTs performed during emergency scenarios. CTs regarding tactical proficiencies with a weapon were the top two CTs for criticality and were among the top five for importance.

Table 2.1.

Online Job Analysis Questionnaire Participant Characteristics (N = 163)

Characteristic		N	%	Mean (SD) [a]
Military Branch				
	Air Force	4	2.9	-
	Army	106	77.4	-
	Marines	27	19.7	-
Sex				
	Men	129	94.2	-
	Women	8	5.8	-
Ethnicity				
	Asian	6	4.4	-
	Black/African American	5	3.6	-
	Native American/Alaska Native	1	0.7	-
	Native Hawaiian/Pacific Islander	1	0.7	-
	White/Caucasian	114	83.2	-
	More than one ethnic group	6	4.4	-
	Preferred not to answer	4	2.9	-
Rank at End of Last Deployment				
	E4 and below	59	43.1	-
	E5	39	28.5	-
	E6	17	12.4	-
	E7 or above	8	5.8	-
	O1-O2	1	0.7	-
	O3	10	7.3	-
	O4	1	0.7	-
	O5 or above	2	1.5	-
Number of Combat Deployments				2 (1)
	1	58	42.3	
	2	51	37.2	
	3	18	13.1	
	4	5	3.6	
	5	2	1.5	
	6	0	0	
	≥7	3	2.2	
Frequency of Leaving the Safety of the Forward Operating Base				127 (72)

Data are presented as sample size (N), percent of sample (%), and mean values with the standard deviation (SD) in parentheses.

Table 2.2.

Mean Item Ratings for Task Frequency, Importance, and Criticality (N = 163)

Rank	Task	Frequency M ± SD	Importance M ± SD	Criticality M ± SD
1	Aim, fire, or prepare to fire your weapon in support of operations*†	1.9 ± 1.3	4.7 ± 0.7	11.2 ± 2.0
2	Maintain a tactical position for an extended period of timeǂ*†	2.1 ± 1.2	3.9 ± 1.0	9.9 ± 2.7
3	Control breathing for marksmanship or tactical advantageǂ*†	1.3 ± 1.2	4.1 ± 1.0	9.6 ± 2.5
4	Walk or run on loose or uneven terrainǂ*†	2.4 ± 1.2	3.5 ± 1.2	9.5 ± 2.9
5	Sprint all-out for <30 seconds in a single or repeated boutǂ*†	1.1 ± 1.0	4.2 ± 1.1	9.4 ± 2.7
6	Sprint, jump, or dive under combat load*†	1.0 ± 1.0	4.0 ± 1.2	8.9 ± 2.9
7	Move on foot carrying a load for > 2 hoursǂ*†	1.5 ± 1.3	3.6 ± 1.0	8.7 ± 2.9
8	Move on foot carrying a load for < 2 hoursǂ*†	1.5 ± 1.0	3.5 ± 1.1	8.6 ± 2.5
9	Carry, drag, push, or pull any object weighing >150 lbs for any distance or durationǂ*†	0.8 ± 0.7	3.5 ± 1.2	7.9 ± 2.8
10	Pull yourself up, over, or through a structure (wall, window, fire escape, vehicle, etc.) for > 30 feet*†	1.1 ± 1.0	3.2 ± 1.2	7.5 ± 2.8
11	Manually breach a structureǂ*†	0.7 ± 0.9	3.1 ± 1.0	6.9 ± 2.4
12	Repeatedly lift objects overhead*	1.2 ± 1.0	2.5 ± 1.0	6.3 ± 2.4
13	Jog or run continuously for greater than 10 minutes with loadǂ*	0.7 ± 0.9	2.8 ± 1.2	6.3 ± 2.9
14	Maintain balance while traversing a narrow object or wallǂ*	0.9 ± 1.0	2.6 ± 1.1	6.1 ± 2.6
15	Climb a ladder*	0.9 ± 0.8	2.4 ± 1.1	5.7 ± 2.7
16	Scale boulders or loose rock with or without special equipment*	0.6 ± 0.9	2.4 ± 1.2	5.4 ± 2.8
17	Lose your balance or fall*	1.1 ± 0.9	2.1 ± 1.2	5.3 ± 2.6
18	Crawl under or through an object for > 30 feetǂ	0.3 ± 0.5	2.3 ± 1.1	4.8 ± 2.4
19	Dig or pound with a sledge hammer repeatedly	0.6 ± 0.7	1.9 ± 1.0	4.4 ± 2.3

Notes: Task Frequency (0 = never, 1 = sometimes, 2 = about half the time, 3 = most of the time, 4 = always); Importance (1 = not important, 2 = moderately important, 3 = very important, 4 = mission-essential, 5 = vital to survive); Criticality [Frequency + (2 x Importance)]. Combat-relevant tasks were generated by subject matter experts or modified from a special weapons and tactics job analysis questionnaire (15) (ǂ). Critical Tasks were identified if Task Importance Ratings were ≥ 3.00 (†) or if Task Criticality Ratings were ≥ 5.00 (*)

Discussion

Our investigation aimed to develop a combat-relevant JAQ and identify CTs with a JTA utilizing importance and criticality ratings. We hypothesized that a majority of combat-relevant tasks from the JAQ would meet CT criteria. Our hypothesis was supported with a majority of tasks identified as CTs for criticality and importance, respectively. To our knowledge, this is the first study to conduct a JTA with a combat-relevant JAQ, which identified CTs using importance and criticality ratings.

Since there was no preexisting JAQ at the time of survey development, we modified job tasks from special weapons and tactics personnel given the similarities in their emergency responsibilities.[15] JAQ development based on similar occupations has been conducted for other combat personnel.[16] Ten of the tasks from the SWAT inventory were modified to more accurately reflect the tasks performed by military personnel in a combat-environment. Nine additional combat-relevant tasks were added to the JAQ and validated by the SMEs. Additionally, our survey extended on previous JAQs by asking participants to rate task frequency and importance by creating a frequency scale similar to JAQs in other combatants and emergency personnel.[21-22] This is a crucial aspect of JAQs, especially amongst military personnel, where task frequency can significantly increase in deployed settings.[23] Together, this approach in JAQ development appeared successful since a majority of the combat-relevant tasks were identified as CTs.

Our JTA characterized combat-relevant tasks and identified CTs by importance and criticality. Criticality scores identify CTs that are not frequently occurring yet important; preventing the incidence of false-negatives that may occur in emergency services (i.e., law enforcement, fire fighters).[14] Seventeen and 11 of 19 tasks were CTs based on criticality and importance, respectively. Previously, importance ratings of “very important or higher” have been used as a criterion of agreement between incumbents and SMEs.[24] Our results suggest that most combat-relevant tasks identified by our SMEs were also rated as critical by our survey respondents. However, eight of the combat-relevant tasks did not meet an average importance rating of 3.0 or higher, indicating some disagreement between our SMEs and survey respondents.[15] Some of the disagreement may be due to differences in tasks performed between differing ranks of survey respondents. Yet, an exploratory analysis revealed no effect of rank (junior enlisted [E1-E4] *versus* NCO [E4-E5] *versus* or >E7) on criticality scores.

Our JTA found that tactical proficiencies with a weapon met CT criteria; however, these tasks are usually not carried into physical employment standard development because they do not occur frequently, are not perceived as physically demanding, or may not be easily evaluated.[7,24-25] The identification of CTs that require multiple facets of health- (i.e., cardiorespiratory, muscular) and skill-related (i.e., balance, power) aspects of physical fitness reflects previous findings.[5,7] The combat-environment requires soldiers to be equipped with both tactical proficiencies and a diverse physical fitness profile. A physical demands analysis is required to determine the physical fitness levels required to meet the demands of our CTs.

To further complicate the demands of a combat-environment, our CTs likely occur in concert with one another. These conditions would require executing tactical proficiencies with a weapon in conjunction with physically demanding tasks.[26] Multiple JTAs support this by developing physical employment standards such as, “reacting to contact” and “breaking contact” simulations which require soldiers to perform repeated-sprint combat rushes and deliver suppressive fire at enemy forces.[21,27] The development of physical employment standards which combine the tactical proficiencies with a weapon and physically demanding tasks into a task simulation likely possesses higher face validity than generic predictive tasks.[11,28] Arguably, not combining these elements is akin to evaluating marksmanship in a biathlete or a law enforcement officer without introducing the physical rigors endured in competition or in response to an emergency, respectively. The combination of tactical and physical abilities in a single evaluation may provide meaningful insight to military leadership. Such an evaluation has reliability, safety, and monetary concerns, but it may mitigate casualties and support mission success.[25]

Strengths of our investigation include the use of international standards for SMEs to develop a combat-relevant JAQ[12], recruitment of soldiers with at least one combat deployment to a location of recent conflict, and utilization of a novel importance scale that assessed job tasks in a combat-relevant manner. However, our study does not go without limitations. First, our sample size was smaller than other research that developed physical employment standards and is likely not representative of the military as a whole.[23] Different participants (or SMEs) may have result in different CTs than we identified. However, military JAQs have strikingly low response rates (<10%) that fail to represent all soldiers' perceptions and our sample size is similar to other JAQs used in other emergency services.[15,16,20,32] Since approximately 30% of the soldiers from Operation Iraqi Freedom and Operation Enduring Freedom have posttraumatic stress disorder, we refrained from using highly-specific wording on the inventory items to avoid triggering undesirable thoughts/emotions .[17,18] Our JAQ also contained a small number of tasks that evaluated lifting and carrying items, which account for approximately 70% of tasks in U.S. Army Personnel. Our SMEs believed that a majority of lifting and carrying tasks were MOS-dependent and may not be distinguished in a combat-environment. The Physical Demands Study reported that some lifting and carrying tasks occurred more frequently in training since some soldiers were deployed with different equipment and some tasks were not identified as CTs.[10,24]

The majority of our respondents were white males and do not represent the full diversity of the U.S. military. Specifically, women occupy over 20% of enlisted personnel in some divisions of the U.S. Military and are of interest with the opening of combat jobs to women, yet only 5.8% of survey participants were women.[9] Future investigations should aim to recruit a more diverse sample. Since the demands encountered in combat-environments are likely mission and deployment-specific, the physical demands required to support mission success and soldier survivability will ebb and flow with the ever-changing technological and environmental aspects of warfare. As such, these findings should be considered preliminary, confirmed with a larger more robust sample, and be continuously re-evaluated.

Conclusion

To our knowledge, this is the first investigation to develop a combat-relevant JAQ and conduct a JTA utilizing importance and criticality ratings of combat-relevant tasks in veterans of the Global War on Terror. We found most of our combat-relevant tasks proposed by our SMEs were CTs. Our JTA identified both tactical proficiencies with a weapon and tasks which likely require multiple facets of physical fitness as CTs. Identification of combat-relevant CTs are prudent in guiding soldier training programs which promote mission success, soldier survivability, and national security; however, CTs should be consistently re-evaluated with the ever-changing technological and environmental aspects of warfare. Development of valid and reliable combat-relevant task simulations is key to conducting a physical demands analysis and may provide key outcomes for understanding the effects of environmental stressors (i.e., heat, sleep deprivation) and ergogenic aids (i.e., nutrition).

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Chapter 3 - Effects of caffeine on exercise duration, critical velocity, and ratings of perceived exertion during repeated-sprint exercise in physically active men

Abstract

Caffeine improves short-to-moderate distance running performance, but its effect on repeated-sprints remains unknown. The objective of this research was to determine if a single dose of caffeine improved exercise tolerance and ratings of perceived exertion (RPE) during repeated-sprint exercise. Ten physically active men (age = 21.5 ± 1.4 years, body mass = 75.2 ± 5.8 kg, VO_{2max} = 56.8 ± 8.9 [range: 47.2 – 75.7] mL/kg/min) ingested caffeine (5 mg/kg) or placebo (crossover design) 60 min prior to an intermittent critical velocity (iCV) test. iCV is a running velocity that distinguishes intermittent running velocities (velocities ≤ iCV) that are sustainable from those resulting in a predictable time to exhaustion (velocities > iCV). The peak velocity and treadmill grade at VO_{2max} were used for iCV testing, and consisted of 3 sets (10 sec running and 10 sec passive rest) at 130, 110 and 120% peak velocity. Each set continued until volitional exhaustion and was separated by 20 min of passive rest. RPE, total distance and duration were recorded to determine exercise tolerance using the iCV model. Caffeine ingestion increased running duration at 110% peak velocity by 98 sec ($p = 0.02$), but not at 120 and 130% peak velocity. RPE and iCV model parameters did not differ between conditions. These results demonstrate that a single dose of caffeine consumed 60 min before repeated-sprints can improve performance at 110% peak velocity, but not at higher velocities.

Introduction

Many team-sport athletes perform repeated maximal or near-maximal effort sprints interspersed with recovery over 1-4 h, known as repeated sprint exercise (RSE) (16). Resistance to fatigue during RSE is known as repeated-sprint ability (RSA) (16), and characterized by a reduction in velocity/power output from a series of short (< 10 sec) sprints with brief recovery intervals (>30 sec) (9,13). RSA provides evidence for the presence of fatigue, but it fails to define a threshold where fatigue increases during RSE (13). A well-known feature of steady-state high-intensity exercise is the curvilinear relationship between running velocity and time to exhaustion, termed critical velocity or critical speed (6). This has been modeled to RSE, and identifies a novel fatigue threshold known as the intermittent critical velocity (iCV) (14,15). iCV is a running velocity that distinguishes intermittent running velocities (velocities ≤ iCV) that are sustainable from those resulting in a predictable time to exhaustion (velocities > iCV). iCV, therefore, represents the boundary of exercise tolerance during intermittent high-intensity running (14,15). The iCV model also describes an intermittent "anaerobic" running capacity (iARC) and critical rest interval (CRI). The iARC represents a finite distance that can be achieved before the accumulation of metabolites associated with fatigue, while CRI is a theoretical rest period that will enable RSE to continue without the onset of fatigue (14,15). These measures are determined from a series of maximal effort bouts interspersed with short rest intervals.

Caffeine is widely used by athletes before competition to improve endurance performance, muscular strength and power, and augment exercise training adaptations (10,11,17,19,34). Up to 89% of competitive athletes consume caffeine, and trained subjects report daily consumption over 300 mg day (10,29). There are several mechanisms that may be responsible for caffeine's ergogenic properties. As an adenosine-receptor antagonist, caffeine reduces perception of pain and exertion (17,24). Caffeine has also been reported to augment blood flow and muscle oxygenation by activation of endothelial nitric oxide synthase (32,38). In addition, caffeine improves muscle function by modifying K^+ and Ca^{2+} kinetics (2,25). The dose that has typically been tested on running performance is 3-10 mg/kg body mass consumed 60 min before the activity (11,17,28). While this dosing strategy appears to be effective when running for 20-45 min, the benefits of caffeine may not extend to longer duration running events (11). This may be due to the pharmacokinetics of caffeine, i.e. peak plasma concentrations are achieved within 45 min of oral ingestion, and the half-life is 3-4 h (21).

There is currently insufficient evidence to determine if caffeine is effective at improving RSE with reports documenting caffeine's ergogenicity and null effects (4, 8, 9, 13, 22, 23, 36). A single dose of caffeine (300 mg) ingested by recreationally active males before iCV testing did not improve RSE (36). Limited by the study design, the caffeine supplement contained other compounds and this may have interfered with caffeine's metabolism (26,36). Specifically, co-ingestion of caffeine and creatine may cause gastrointestinal discomfort, which would likely mask any ergogenic effect of caffeine supplementation (26). Therefore, it remains unknown if caffeine improves iCV model parameters. The objective of this research was to establish if a modest dose of caffeine consumed 60 min before iCV testing improves RSE performance. Our hypothesis was that caffeine would extend running time at VO_{2max} velocities, and improve iCV parameters and decrease ratings of perceived exertion (RPE).

Materials & Methods

Overview

A double-blind, counterbalanced, crossover design was employed to determine the effects of acute caffeine supplementation on exercise tolerance during RSE using the iCV model. The design was chosen to minimize subject recruitment needs while achieving adequate statistical power. Caffeine and placebo (biotin) pills were used based on recommendations from a registered dietitian, and a moderate dose of caffeine (5 mg/kg body mass) was selected based on previous investigations (37). The iCV model was used to evaluate exercise tolerance during RSE because it is reliable and has been previously used in other ergogenic evaluations (15,36). Subjects visited the laboratory three times over two weeks. All testing was scheduled between 8:00 AM and 12:00 PM. Participants were encouraged to continue their normal exercise and dietary habits during the study. Subjects were instructed to refrain from caffeine and alcohol for 12 h, and vigorous physical activity for 24 h before testing. Additionally, subjects refrained from eating 2-3 prior to VO_{2max} testing, and were provided a standardized meal 3 h prior to each iCV test. Subjects were provided the standardized meal (Boost™ meal replacement shakes) 3 h prior to iCV testing, and comprised ~20% of their estimated total energy expenditure (7).

Subjects

Ten physically active men volunteered for the study (Table 3.1). Subjects completed a health-history questionnaire, and were disqualified from study participation if they had cardiovascular, pulmonary, muscular, or metabolic disease; acute or chronic muscle pain or injury; suffered from seizures; were not between 18-25 years old; consumed a diet with less than 3 mg/kg body mass of carbohydrates; had a pacemaker or other internal device; followed a specialized or restricted diet; had unexplained weight loss in the past 6 months; reported food allergies found in the standardized meal; or experienced adverse events after caffeine consumption. All subjects completed a self-reported 7 d caffeine recall, and consumed less caffeine than described in trained subjects (≥ 300 mg/d) (27,29). Dietary intake prior to iCV testing was reported with a 24-h dietary recall using the Automated Self-Administered 24-hrs Dietary Assessment Tool (ASA24) developed by the National Cancer Institute (Bethesda, MD). Total energy and carbohydrate intake were not significantly different between the caffeine (3036 ± 753 kcal; 297 ± 84 g) and placebo sessions (3217 ± 899 kcal; 424 ± 104 g, $p > 0.05$). Each subject was briefed on the procedures and risks associated with study participation before providing written informed consent The study was approved by the Kansas State University Institutional Review Board (#9607).

Table 3.1.

Subject Characteristics (N = 10)

Age (years)	Height (cm)	Body mass (kg)	Body Mass Index (kg/m^2)	Body Fat (%)	VO_{2max} (mL/kg/min)	Caffeine consumption (mg/day)
21.5 ± 1.4	182.3 ± 7.6	75.2 ± 5.8	22.6 ± 0.9	13.5 ± 2.1	56.8 ± 8.9	90.8 ± 91.3

Data are presented as mean ± standard deviation.

Anthropometric Measurements

Height was measured using a stadiometer. Body mass, body mass index, basal metabolic rate, and percent fat were determined using bioelectrical impedance analysis in standard mode (TBF-300A; Tanita, Japan).

VO_{2max} Protocol

Subjects performed a graded exercise test (GXT) to volitional exhaustion on a treadmill to determine VO_{2max} and peak velocity (PV). The GXT consisted of two 3-min warm-up stages at

4-and 5 km/h. Treadmill velocity was set to 6 – 10 km/h and increased by 0.5 km/h every min until 95% of the predicted maximal heart rate (220-age) was achieved. The velocity was then decreased by 1.0 km/h and the grade increased by 1.0% every min until volitional exhaustion. VO_{2max} was confirmed using a validation protocol after 15-20 min of passive recovery (30). Briefly, subjects lowered themselves onto the treadmill set at the highest grade, and 110% of PV achieved during the GXT. VO_{2max} was considered valid if the highest VO_2 obtained on the validation test was less than 0.2 L/min higher than that achieved during the GXT. All subjects performed the validation test and achieved their VO_{2max}.

Supplementation Protocol

Subjects returned to the laboratory for the second visit after a minimum of 48 h. Subjects consumed caffeine (5 mg/kg) or a biotin placebo (300 µg) 60 min before testing. The placebo was indistinguishable from the caffeine pill. After ingesting the supplement and prior to warming-up for the iCV test, subjects completed the dietary recall. Subjects returned to the laboratory after at least a 7 d washout period to repeat exercise testing with the other supplement.

iCV Protocol

The iCV test protocol followed the same procedures used in the reliability study conducted by Fukuda and colleagues (15). In order to minimize learning effects and ensure safety, subjects were familiarized with brief intermittent running bouts, and then completed a 5 min warm-up at a self-selected pace. The treadmill grade was set to the highest level obtained during the GXT for iCV testing. Subjects completed 3 sets at 130-, 110- and 120% PV interspersed by 20 min of passive recovery, each to volitional fatigue. The order of running bouts were not randomized across participants in order to preserve the reliability of the iCV test conducted by Fukuda and colleagues (15). Each set consisted of 10 sec of running followed by

10 sec of passive recovery. Water was available ad libitum during passive rest periods. Subjects mounted and dismounted the treadmill by lowering themselves onto the treadmill belt during running bouts and straddling the treadmill during passive rest.

Subjects repeated 10 sec running bouts during each set until they could no longer maintain the selected velocity or complete the full 10 sec running bout. The total duration (running + rest), running duration only, the number of running bouts (determined by lap counter), and total distance covered were determined for each set. The linear, total distance model (L-TD) (15) was used to determine iCV and iARC:

$$Total\ Distance\ = iARC + iCV\ x\ time$$

Where total distance was (time x velocity) and time was the exercise duration. The iCV represents the slope of the regression line of exercise distance and duration, while iARC represents the y-intercept. CRI was determined with the following equation:

$$CRI = \left(\frac{TD}{\Sigma INT}\right)/iCV_{CRI}$$

where TD, ΣINT and iCV_{CRI} represents the total distance of all sets, the total number of running bouts completed in all sets, and the slope of the linear regression between total distance and the total duration of the exercise bout (exercise + rest), respectively. The L-TD model was also used to establish an alternative iCV to determine the CRI (iCV_{CRI}):

$$iCV_{CRI} = \frac{Total\ Distance\ (m);\Sigma\ (130\%\ +\ 110\%\ +\ 120\%\ PV)}{Total\ Duration\ [exercise + rest](s);\ \Sigma\ (130\%\ +\ 110\%\ +\ 120\%\ PV)}$$

RPE and Adverse Event Measurements

Subjects reported their ratings of perceived exertion (RPE) using the 15-point Borg scale after each set (5). RPE was averaged for each iCV test. Subjects completed a brief questionnaire immediately after the last exercise bout and indicated, “yes” or “no”, if they perceived an effect from the supplement that was provided. An online survey was used to determine if any adverse events occurred in the recent h after testing and the following day. Subjects were asked to complete surveys prior to bed and upon awakening.

Statistical Analysis

Data were analyzed with SPSS version 25.0 (IBM, Armonk, NY, USA). The level of significance was set at $\alpha = 0.05$. Three subjects did not complete the study due to either scheduling conflicts ($n = 1$) or failure to follow-up after testing ($n = 2$). Both a completers analysis and an intention-to-treat analysis with the last observation carried forward were conducted and compared (20). Results from each were similar and the completers analysis is presented below. Normality was determined using a Kolmogorov-Smirnov test. Exercise duration (110, 120, and 130%), RPE, iCV, iARC, and CRI were normally distributed and analyzed using a paired t-test, and reported as means ± SD. Eight subjects were needed based on a large effect size of caffeine supplementation (0.8), at an alpha-level of 0.05 with 80% power (39). iCV and iARC display the highest reliability (ICC = 0.89, SEM = 0.2 m/s, CV = 12.4-15.4%; ICC = 0.80, SEM = 28.6 m, CV = 45.2-49.9%) and CRI displays moderate reliability (ICC = 0.59, SEM = 1.5 s, CV = 8.2-10.7%) (15). Hedge's G was used to indicate effect size (ES) and was classified as "trivial" (< 0.19), "small" (0.20-0.49), "moderate" (0.50-0.79), and "large" (>0.80) (12).

Results

Figure 3.1 shows exercise durations for the 130, 110, and 120% of PV sets between the caffeine and placebo conditions. Significant differences were found during the exercise bout at 110% of PV, where subjects ran for longer durations during the caffeine condition (392 ± 95 sec) compared to the placebo condition (294 ± 29 sec, $t(6) = -3.15$, $p = 0.020$, $g = 1.4$). No significant differences were found between conditions during the 120% exercise bout duration (t(6) = - 0.093, p = 0.929, g = 0.045) or 130% exercise bout for duration (t (6) = -1.7, p = 0.139, g = 0.83).

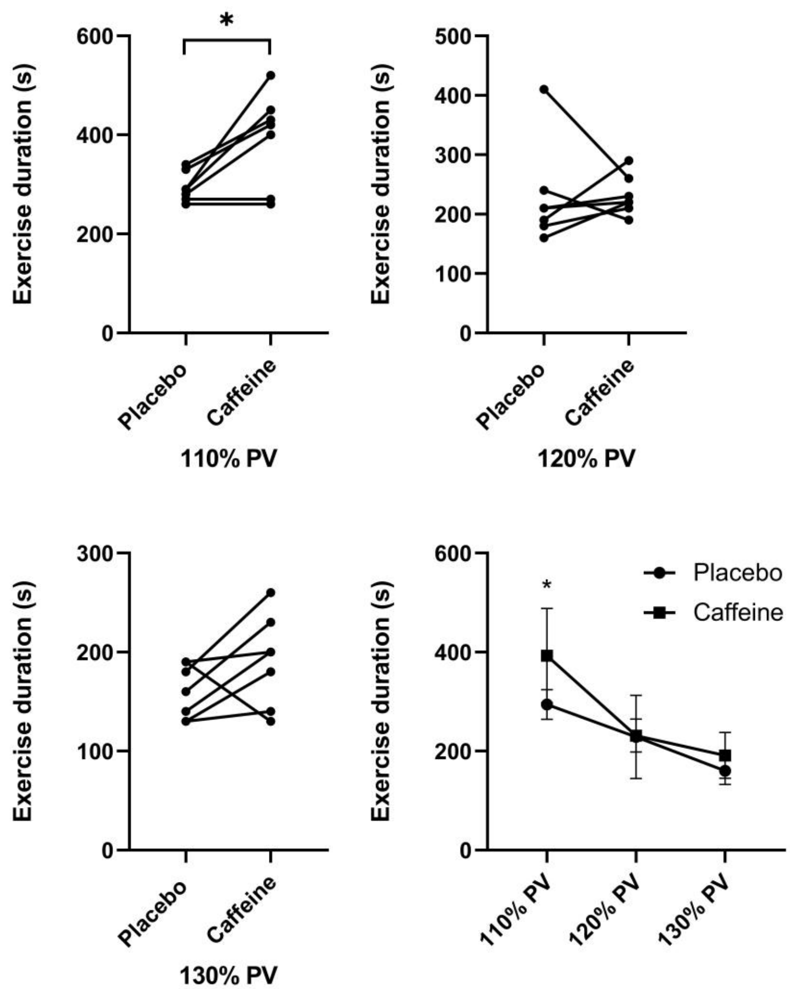

Figure 3.1. Differences in exercise duration during the iCV test between placebo and caffeine conditions (N = 7). (Top left) Exercise duration during 110% of PV bout. (Top right) Exercise duration during 120% of PV bout. (Bottom left) Exercise duration during 130% of PV bout. (Bottom right) Exercise duration at all running velocities. Data are presented as means ± SD. * Denotes significant differences (p < 0.05) between the caffeine and placebo condition.

As shown in Figure 3.2, there were no significant differences in iCV, iARC, CRI or RPE between conditions. Subjects reported a perceived effect (88.9% vs. 37.5%), increased activeness (40% vs. 10%) and gastrointestinal problems (20% vs. 10%) with caffeine compared to placebo. The morning after iCV testing, subjects reported shakiness (10% vs. 0) and indigestion (10% vs. 10%) with caffeine compared to placebo.

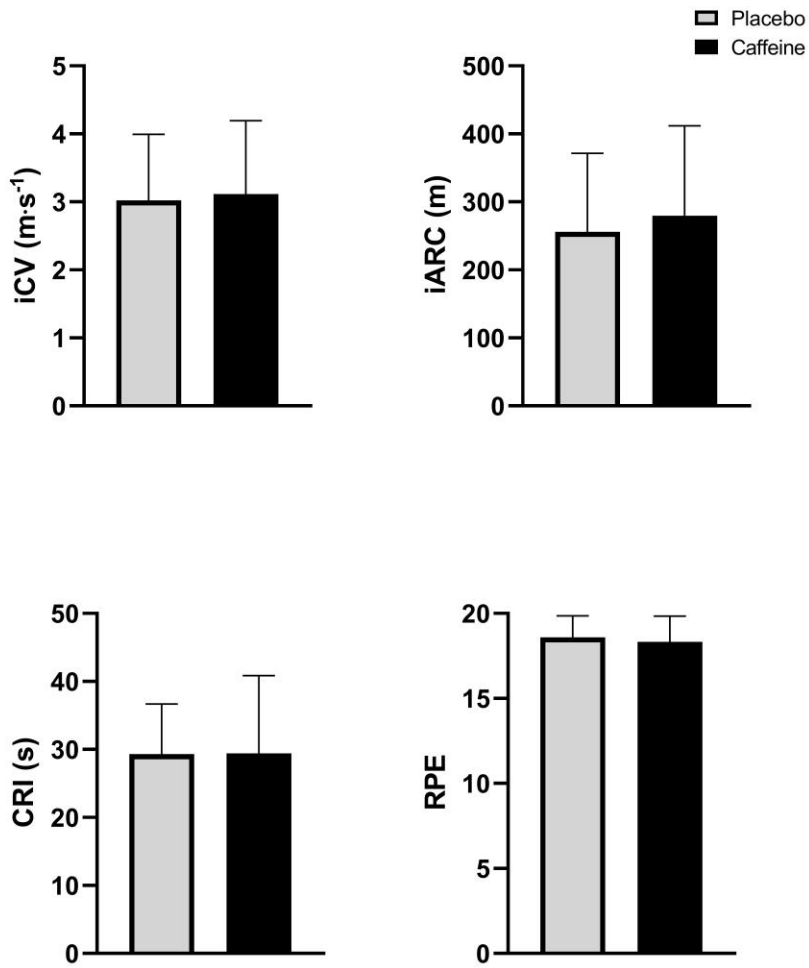

Figure 3.2. iCV parameters and ratings of perceived exertion between placebo and caffeine conditions (N = 7). (Top left) Intermittent critical velocity. (Top right) Intermittent Anaerobic Running Capacity. (Bottom left) Critical rest interval. (Bottom right) Ratings of perceived exertion. Data are presented as means ± SD. No significant differences were found between conditions.

Discussion

The purpose of our investigation was to determine the effect of acute caffeine supplementation on exercise tolerance during RSE in physically active males utilizing the iCV model. The ability to resist fatigue during RSE is a key attribute to many sporting disciplines, where athletes are reported to use ergogenic aids (10,16). Improvements in iCV and CRI reflect resilience to fatigue and rapid recovery during RSE, respectively (14). In this study, we determined that ingesting 5 mg/kg of caffeine 60 min before iCV testing increased running duration at 110% of PV, but not at 120- or 130%, or in any parameter of exercise tolerance, or RPE during RSE.

Caffeine supplementation may improve some, but not all sprints during RSE (4,8,22,23). Our investigation found that caffeine improved exercise duration at 110% of PV (set 2), but not at 120- or 130% PV. Prolonging the duration of high-intensity running, in turn, increases the distance covered by an athlete. Interestingly, Del Coso and colleagues (8) reported that caffeine significantly improved the distance covered at the end of the first half of a simulated soccer match. They also reported a significant improvement in the duration spent at some, but not all, intensities (8). Thus, it may be that caffeine improves RSE in a time and intensity dependent manner. Interestingly, the highest running velocity used in Spradley and colleagues (36) during the iCV was at 110% of PV, which was the intensity for which our study found caffeine to be ergogenic. Caffeine extends exercise duration between 75-85% of PV during continuous exercise; however, it was unknown if caffeine improved RSE at exercise intensities below 110% of PV (11). The investigation by Spradley and colleagues reported that a multi-ingredient pre-workout supplement containing an absolute dose of 300 mg of caffeine (< 4 mg/kg) did not improve iCV or iARC (36). It is possible that the dose of caffeine used by Spradley and the current investigation was insufficient to cause an increase in exercise tolerance to RSE. Investigators have reported that ergogenic doses of caffeine range from 3-10 $mg \cdot kg^{-1}$ body mass (11,17,28), but for RSA the dose found to be ergogenic was 6 mg/kg body mass (22,23). Due to previous work in our laboratory (37) we used a dose of 5 mg/kg body mass, which may have been insufficient. Higher doses of caffeine may be necessary to offset the perturbations to the muscle milieu during RSE by increasing calcium release from the sarcoplasmic reticulum and retaining potassium ions (2,16,25).

Moderate-doses of caffeine act on multiple target tissues to antagonize adenosine receptors (A1 and A2A receptors), which decrease RPE (24). Our study found no significant difference in RPE after acute caffeine supplementation, similar to other reports (3,37). In some investigations, caffeine results in an increase in performance with no changes in RPE (3,35). This suggests that caffeine is ergogenic by maintaining RPE at higher workloads, which is reported to enhance exercise training adaptations when caffeine-containing products are consumed prior to training sessions (34).

The current investigation employed a robust study design with subjects serving as their own controls, provided standardized meals prior to iCV testing, and was the first study to determine the effects of acute caffeine supplementation on exercise tolerance during RSE using the iCV model; all of which, contributed to the study's strengths. However, by only recruiting young, physically active men, our results cannot be generalized to women, middle-age adults, or subjects with lower physical activity levels. Additionally, a large effect size was used to determine the recruitment needs for statistical analysis; however, other studies have found limited effects of caffeine on RSE (39). A larger sample size would better determine whether caffeine only exerts a small effect during RSE as we found in the current investigation. Caffeine metabolism is prolonged by estrogen and oral contraceptives, however, improvements in performance have been reported to be similar between sexes (35). Although our study lacked invasive measures to determine plasma caffeine concentration and caffeine metabolism, the likelihood that caffeine supplementation from caffeinated pills increases plasma caffeine concentration has substantial support given that it is used as a standard when comparing caffeinated products (21). Interestingly, caffeine is likely ergogenic in the absence of elevated plasma caffeine concentrations, as suggested by caffeine's ergogenic properties when mouth rinsing caffeinated fluids (4). However, caffeine may not be ergogenic for all athletes, which may be in part associated with genetic influences from the CYP1A2 and ADORA2A polymorphisms (31,40). The CYP1A2 gene encodes cytochrome P450 1A2, an enzyme responsible for 95% of caffeine metabolism and determines the pharmacokinetic response of caffeine metabolism (18). Carriers of the C allele (slow metabolizers) in the CYP1A2 gene have been characterized as “non-responders” after caffeine supplementation, although these findings are preliminary with conflicting reports (18,31). We were not able to characterize the genetic differences among our subjects, which presents an avenue for future investigations.

Almost 90% of subjects indicated a perceived effect from the supplement during the caffeine condition which may indicate poor blinding to the treatment conditions. Despite reports of increased effect from subjects correctly identifying a supplement with an active ingredient, we failed to confirm these findings via their RSE performance (33). Lastly, our iCV protocol replicated Fukuda and colleagues (15). While the authors did not provide rationale for the 130%, 110%, and 120% PV testing order, the results may differ if the running sets were randomized (15).

RSA is a key attribute among many team sport athletes and remains a priority for strength and conditioning specialists and coaches. Our findings suggest that an acute dose of caffeine provides significant improvements in tolerance to RSE in physically active men at 110% of PV, but not at higher PV’s, nor did caffeine have any effect on RPE. Our RSA protocol utilized exhaustive RSE, which may replicate prolonged gameplay (i.e., overtime) or some high-intensity interval training sessions.

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Disclosure Statement

The authors report no conflicts of interest.

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Chapter 4 - Caffeine gum selectively improves susceptibility to enemy fire during tactical combat movement simulation

Abstract

Military personnel supplement caffeine as a countermeasure during unavoidable sustained wakefulness; however, it's utility in combat-relevant tasks is unknown. This study examined the effects of caffeinated gum on performance in a tactical combat movement simulation. Healthy men (n = 30) and women (n = 9) (age = 25.3 ± 6.8 years, mass 75.1 ± 13.1 kg) completed a marksmanship with a cognitive workload (CWL) assessment and a fire-and-move simulation (16 6-m bounds) in experimental conditions (placebo *versus* caffeinated gum, 4 mg/kg). Susceptibility to enemy fire was modeled on bound duration during the fire-and-move simulation. Across both conditions, bound duration and susceptibility to enemy fire increased by 9.3% and 7.8% during the fire-and-move simulation, respectively ($p = 0.001$). Cognitive performance decreased after the fire-and-move simulation across both conditions ($p < 0.05$). However, bound duration, susceptibility to enemy fire, marksmanship and cognitive performance did not differ between the caffeine and placebo conditions. These data do not support a benefit of using caffeinated gum to improve simulated tactical combat movements.

Introduction

In combat, warfighters are involved in direct-fire engagements that are responsible for nearly half of all casualties (64). Performance during direct-fire engagements is critical and requires soldiers to perform repeated high-intensity sprints and deliver suppressive fire to protect friendly units advancing on hostile forces during recovery periods (2,19,32,46,55,58,62). Multiple stressors act on warfighters that deteriorate physical and cognitive performance; which, in turn, decreases combat effectiveness (6,28,36,56). Countermeasures to restore warfighter performance in austere conditions have included pharmacological substances such as caffeine (33,42,43,45).

Caffeine is an ergogenic aid that improves both physical (24,25,57,66,67) and cognitive performance (8,43). Emerging evidence suggests that caffeine may improve repeated-sprint performance, which deteriorates during direct-fire engagements (4,6,10,30,49). However, caffeine's ability to improve repeated-sprint exercise are preliminary and has not been supported by other investigations (1,9,13,16,17,23,40,49). Caffeine also improves muscular strength and power, which may help soldiers tolerate heavy personal protective equipment worn during direct-fire engagements (3,25,46). Lastly, caffeine improves marksmanship accuracy and reaction time, which depreciate in stressful environments (31,33,41,42,50,56,59). While caffeine represents a viable ergogenic target to support soldiers, it is unclear if caffeine can increase soldier survivability during direct-fire engagements.

Blount and colleagues developed a model to predict susceptibility to enemy fire during tactical combat movements such as direct-fire engagements (7). The susceptibility to enemy fire model was predicated on a soldier's bound duration and exposure to enemy fire (e.g., longer bound duration, longer exposure, and increased susceptibility to enemy fire) (7). Yet, the onset of physical fatigue is rapid during repeated high-intensity sprints, and exposure time progressively increases during direct-fire engagements (6,22,30). However, caffeine may mitigate performance decrements during direct-fire engagements by sustaining bound durations.

To the best of our knowledge, the effects of caffeine supplementation on marksmanship and susceptibility to enemy fire during a tactical combat movement simulating a direct-fire engagement remain unknown. We hypothesized that performance would deteriorate during a tactical combat movement simulation resulting in significant decrements in marksmanship, cognition, and susceptibility to enemy fire. Additionally, we hypothesized that caffeine supplementation would significantly attenuate performance decrements in marksmanship, cognition, and susceptibility to enemy fire during the tactical combat movement simulation.

Methods

Design

The study was approved by the Kansas State University Institutional Review Board (#9821). Subjects attended four laboratory visits. Subjects were informed of the study procedures, provided written consent, completed baseline measures, and were familiarized with the tactical combat movement simulation during the first laboratory visit. Subjects were randomized in a double-blind, counterbalanced, crossover design to determine the effects of caffeine on performance during the tactical combat movement simulation. The second laboratory visit served as a baseline control (BL) with no supplement provided to the subject before completing the tactical combat movement simulation. The effects of caffeine (CAF) *versus* placebo (PLA) were evaluated on the third and fourth laboratory visits. Laboratory visits 1, 2, and 3 were separated by at least 48 h. Laboratory visits 3 and 4 were separated by at least 96 h for a washout period. All trials occurred indoors in temperature-controlled conditions set to 22°C as previously described (58). Subjects were asked to maintain their physical activity and dietary habits throughout the study. Additionally, subjects were asked to abstain from vigorous physical activity 24 h before testing, avoid caffeine and alcohol 12 h before testing, and avoid eating a heavy meal 2-3 h before testing.

Subjects

Subjects completed a screening questionnaire to ensure that they were in good health, non-tobacco-users, did not possess a condition that would be worsened by physical activity, and were regular caffeine users (≥ 50 mg/d of caffeine) (5). Daily caffeine consumption was evaluated using a 7-day caffeine recall (47). A Snellen Visual Acuity Test was used to verify that subjects had at least 20/30 vision (31). Corrective lenses were allowed during the visual acuity test and required for all testing. Laboratory personnel verified that inclusion and exclusion criteria were satisfied before experimentation. Thirty-nine subjects qualified for the study (age 25.3 ± 6.8 years; height 177.1 ± 21.6 cm; mass 75.1 ± 13.1 kg; body fat percent 20.8 ±8.2 %; fat-mass 15.8 ± 7.2 kg; fat-free mass 59.3 ± 10.7 kg; men n = 30). Height was measured using a stadiometer. Body mass, body fat percent, fat-mass, and fat free mass were determined using bioelectrical impedance analysis in standard mode (TBF-300A; Tanita, Japan). Subjects demonstrated proficiency with marksmanship by either providing evidence of a military rifle qualification in the last 12 months (n = 8), or by successfully engaging 12 targets with at least 75% accuracy using a modified M4 device (n = 31).

Supplementation Protocol

Subjects chewed approximately 4 mg/kg body mass of caffeinated (Military Energy Gum, Market Right Inc., Plano, IL) or placebo gum during sessions 3 and 4. The mode of delivery and dose was selected based on reported military use and the previous work of others (35,43). Each piece of gum contained 100 mg of caffeine. Pieces of gum were cut in half to achieve approximately a 4mg/kg body mass dose to the closest 50 mg increment. The placebo gum was provided by the manufacturer to replicate the color, taste, size, and texture of the caffeinated gum. Subjects chewed in two boluses of gum similar to Lane and colleagues (39). Each bolus of gum was chewed for at least 10 min based on the buccal absorption of caffeine (34). Subjects initiated a standardized warm-up 10 min after the second bolus of gum, followed by the tactical combat movement simulation. Subjects returned after a minimum of 96-h and performed the tactical combat movement simulation with the opposite gum (4,48,49).

Tactical Combat Movement Simulation

The tactical combat movement simulation required subjects to engage a series of targets with a modified M4 under physical and cognitive workloads. Subjects wore a 25-kg weight vest during the tactical combat movement simulation to replicate a combat load (6). Subjects wore exercise attire during the familiarization period. Subjects wore a military issued combat uniform and boots during all other sessions. The tactical combat movement simulation initiated with a marksmanship and cognitive workload protocol. An M4 was modified with a shot indicating resetting trigger automatic rifle bolt (SIRT-AR Bolt, Next Level Training, Ferndale, WA), so trigger squeezing emitted a laser from the M4. Laser Activated Shot Reporter software (L.A.S.R, Shooter Technology Group, Lincoln, NE) was used to acquire marksmanship data. The marksmanship with cognitive workload protocol was modified from the Army Research Laboratory to reflect simulated shooting (54). Four targets were mounted to the wall to simulate distances of 18-, 100-, 150-, and 200-meters. All targets were E-type target silhouettes and had colored backgrounds of yellow, red, green, or blue. The L.A.S.R. software randomly called out a target color every 4-s until 12 targets were announced by an external speaker. Subjects were asked to aim the modified M4 and engage the targets by squeezing the trigger as quickly and accurately as possible. The modified M4 had an iron sight aiming platform that subjects used for accuracy. All subjects confirmed the iron sight's accuracy before each simulation. Subjects were allowed one trigger squeeze per target call out. The number of correctly engaged targets (i.e., marksmanship accuracy) was scored by the L.A.S.R. software. The L.A.S.R. software also reported the time series data for target engagement. The duration between the first target call out and the first target engagement was the first shot reaction time. The average duration between all target call outs and target engagements was the marksmanship reaction time. Four target configurations were generated, randomly assigned, and counterbalanced across sessions.

Cognitive workload (CWL) was induced with a mathematical problem-solving task similar to the Army Research Laboratory (54). An auditory message was presented to the subjects through the external speaker. The auditory message was delivered in between target callouts and contained mathematical problems that were moderate in difficulty and consisted of addition and subtraction of single and double-digit numbers. Subjects verbally answered the mathematical problems before engaging the next target callout. Twelve auditory messages were presented to the subject. The number of correctly answered mathematical problems was used as an index of cognitive performance. Four sets of mathematical problems were generated, randomly assigned, and counterbalanced across sessions.

After answering the last mathematical problem, subjects transitioned to a fire-and-move simulation to induce a combat-relevant physical workload. The fire-and-move simulation protocol was modified from Silk and Billing (55), which is used in the Australian Army Combat Arms Physical Employment Standards Assessment (68). Subjects performed 16 x 6-meter bounds on a 20-s cycle. Subjects carried a separate modified M4 to ensure the modified M4 used for marksmanship maintained calibration. An auditory message was used to instruct subjects to initiate each bound. All bounds started from the prone position and terminated in the kneeling position. Subjects readopted the prone position before initiating the subsequent bound. The duration of each bound was determined with an infrared timing gate system (Position Fitness, Boston, MA). The infrared timing gates that indicated bound completion were placed at shoulder height (48), and initiated by the investigators (38). The average bound duration and fastest bound duration were determined for each condition. Subjects returned to the marksmanship with CWL after the final bound was completed. Subjects were again presented with 12 target callouts every 4-s that were interspersed with 12 mathematical problems.

Modeling Susceptibility to Enemy Fire

The model developed by Blount and colleagues (7) was used to determine susceptibility to enemy fire. The average bound duration from the fire-and-move simulation was used to determine exposure time to enemy fire using the following equation with the reaction time of enemy forces set to 1-s.

$$Exposure\ Time = Bound\ duration - Reaction\ Time\ of\ Enemy\ Forces$$

The number of shots from enemy forces was determined using the following equation with shooting cadence set to 1.3 shots/s.

$$Shots = Exposure\ Time\ x\ Shooting\ Cadence$$

Susceptibility to enemy fire was determined using the following equation with the accuracy of enemy forces set to 10%.

$$Susceptibility\ to\ Enemy\ Fire = 1 - (1 - Accuracy)^{Shots}$$

Assessment of Treatment Blinding

Subjects were sent an electronic survey (Qualtrics Labs Inc., Provo, UT) after the third and fourth visits to determine if they perceived an effect from the supplement they were provided ("yes"/"no"/"not sure").

Statistical Analysis

An a priori power analysis determined a minimum of 39 subjects were required to achieve 80% power, $\alpha < 0.05$, and a moderate effect size (52). Complete data were acquired from 31 subjects. Incomplete data were available from eight subjects due to: injury not associated with the study (n = 1), failure to comply with the testing timeframe (n = 1), scheduling conflicts (n = 1), failure to follow-up (n = 2), loss of student housing due to COVID-19 outbreak (n = 2), and COVID-19 illness (n =1). Data were analyzed with subjects with complete data (26). Data were analyzed with SPSS version 25.0 (IBM, Armonk, NY, USA). All descriptive and dependent variables were assessed for normality using a Kolmogorov-Smirnov test and boxplot analysis. All analyses were conducted with and without outliers. Two-way repeated-measures ANOVAs were used to determine the main effects of condition (PLA *versus* CAF) and time (pre-/post-fire-and-move simulation) for marksmanship accuracy, first shot reaction time, marksmanship reaction time, and cognitive performance. Two-way repeated-measures ANOVAs were also used to determine main effects of condition (PLA *versus* CAF) and time (first three/last three bounds of the fire-and-move simulation) for the bound duration, exposure time, shots, and susceptibility to enemy fire. A paired samples t-test was used to determine the effect of condition (PLA *versus* CAF) on the fastest bound duration. Significant main effects were followed by posthoc pairwise comparisons (Bonferroni). Posthoc values were reported as estimated marginal means ± standard error of means. Statistical significance was set at $\alpha < 0.05$. Eta squared (η^2) was used to indicate effect size.

Results

Marksmanship

Figure 1 shows marksmanship accuracy, first shot reaction time, and reaction time pre- and post- fire-and-move simulation between conditions. No main effect was found for condition ($p = 0.960$) or time ($p = 0.127$) on marksmanship accuracy. No main effect was found for condition on first shot reaction time ($p = 0.601$) or time ($p = 0.350$). No main effect was found for condition ($p = 0.592$) or time ($p = 0.424$) on marksmanship reaction time.

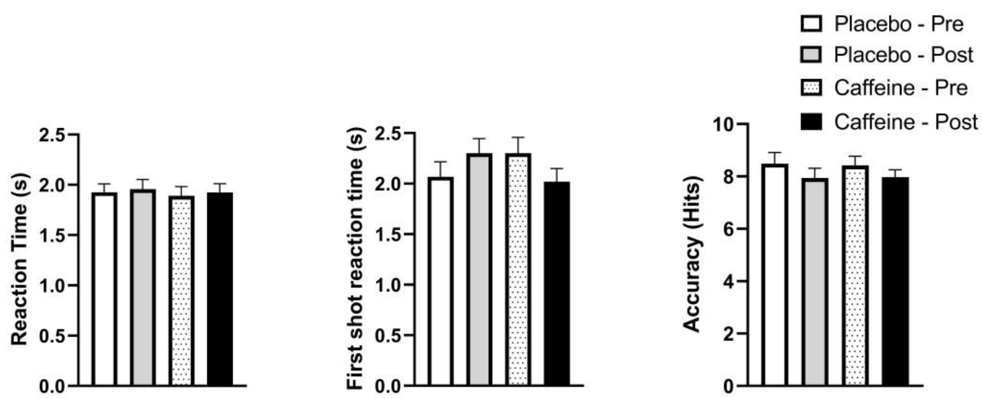

Figure 4.1. Differences in marksmanship parameters pre-/post- fire-and-move simulation between conditions (N = 31). (Left) Marksmanship reaction time between pre-/post-fire-and-move simulation. (Middle) First shot reaction time between pre-/post-fire-and-move simulation. (Right) Marksmanship accuracy between pre-/post-fire-and-move simulation. Data are presented as means ± SEM. No significant differences were found for condition or time.

Cognitive Performance

No main effect was found for condition ($p = 0.280$) on cognitive performance. A significant main effect was found for time [$F = (1,29) = 4.678$, $p < 0.05$, $\eta^2 = 0.13$) on cognitive performance. The total number of correct answers to math problems was lower (9.0 ± 0.4) after the fire-and-move simulations compared to before the fire-and-move simulation (9.6 ± 0.4).

Modeling Susceptibility to Enemy Fire

Figure 2 shows the parameters from modeling susceptibility to enemy fire for the first three and last three bounds of the fire-and-move simulation across conditions. A significant main effect was found for time [$F (1, 30) = 20.2$, $p < 0.001$, $\eta^2 = 0.403$], but not condition on bound duration ($p = 0.795$). Bound duration was significantly longer in the last 3 bound of the fire-and-move-simulation compared to the first 3 bounds (4.62 ± 0.25-s *versus* 4.17 ± 0.17-s, $p < 0.001$). A significant main effect was found for time [$F (1, 30) = 20.23$, $p < 0.001$, $\eta^2 = 0.403$] on exposure time to enemy fire, but not condition ($p = 0.795$). Exposure time to enemy fire was significantly longer in the last 3 bounds of the fire-and-move simulation compared to the first 3 bounds (3.62 ± 0.25-s *versus* 3.17 ± 0.17-s, $p < 0.001$). Caffeine did not improve the fastest bound duration [$t (30) = 0.642$, $p = 0.526$].

A significant main effect was found for time [$F (1, 30) = 20.23$, $p < 0.001$, $\eta^2 = 0.403$], but not condition ($p = 0.795$) on the number of shots from enemy forces. The number of shots were significantly higher in the last 3 bounds of the fire-and-move simulation compared to the first 3 bounds (4.7 ± 0.32 shots *versus* 4.1 ± 0.22 shots, $p < 0.001$).

A significant main effect was found for time [$F (1, 30) = 25.4$, $p < 0.001$, $\eta^2 = 0.459$], but not condition ($p = 0.820$) on susceptibility to enemy fire. Susceptibility to enemy fire was significantly higher in the last 3 bounds of the fire-and-move simulation compared to the first 3 bounds (38.1 ± 1.8 % *versus* 34.7 ± 1.4 %, $p < 0.001$).

Assessment of Treatment Blinding

The blinding questionnaire had an 83.8% response rate. Twenty-five percent ($n = 6$) and 53.6% ($n = 15$) of subjects perceived an effect of the supplement during the placebo and caffeine conditions, respectively. Over 45% ($n = 11$) and 17.9% ($n = 5$) of subjects did not perceive an effect of the supplement during the placebo and caffeine conditions, respectively. Over 29% (n = 7) and 28.6% (n = 8) were unsure of any effects from the supplement during the placebo and caffeine conditions, respectfully.

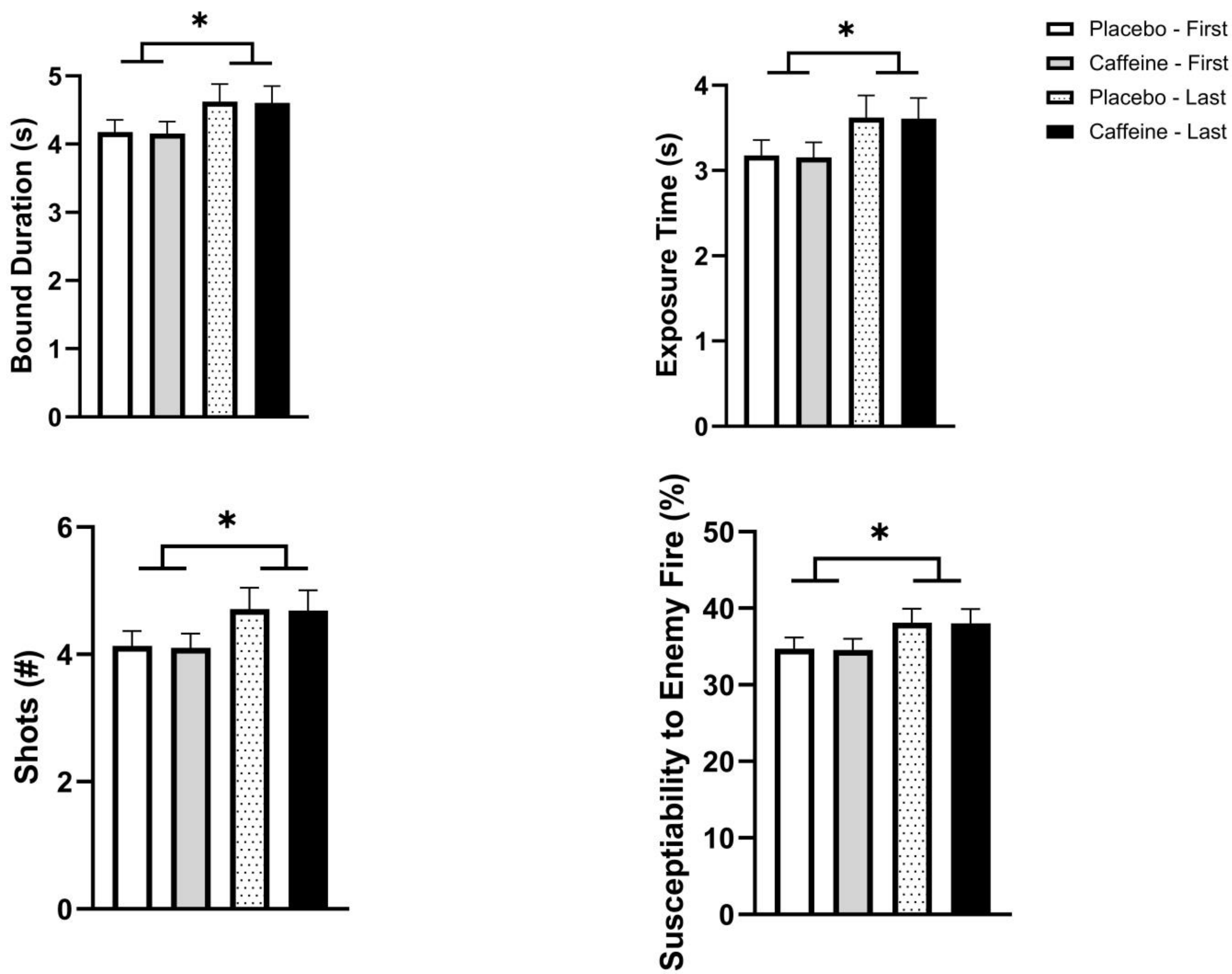

Figure 4.2. Differences in Susceptibility to enemy fire parameters for the first/last 3 bounds of the fire-and-move simulation between conditions (N = 31). (Top left) Bound duration between conditions. (Top right) Exposure time between conditions. (Bottom left) Shots between conditions. (Bottom right) Susceptibility to enemy fire between conditions. Data are presented as mean ± SEM. *Denotes significant differences ($p < 0.05$) in first and last 3 bounds of the fire and move simulation.

Discussion

The purpose of our investigation was to determine the ergogenic properties of caffeine on marksmanship, cognition, and susceptibility to enemy fire during a tactical combat movement simulation. We hypothesized that performance would deteriorate during a tactical combat movement simulation resulting in significant decrements in marksmanship, cognition, and susceptibility to enemy fire. We found that susceptibility to enemy fire and cognitive performance deteriorated from the tactical combat movement simulation, but marksmanship did not. Additionally, we hypothesized that caffeine supplementation would significantly attenuate performance decrements in marksmanship, cognition, and susceptibility to enemy fire during the tactical combat movement simulation. Caffeine did not improve bound duration, marksmanship, cognitive performance or susceptibility to enemy fire during the tactical combat movement simulation.

Deterioration of sprint-ability is a common feature during repeated-sprint running (10,23,48) and tactical combat movement simulations (6,30). Our findings support the importance of repeated-sprint ability in soldiering tasks and the presence of physical fatigue highlighted by Hunt and colleagues during tactical combat movement simulations (30). Fatigue during tactical combat movement simulations is exacerbated by increasing combat loads and exposure time by 1.1% for each kilogram increase (6). The combat load used in our investigation was similar to other investigators (6,30); however, heavier loads may continue to exacerbate fatigue during tactical combat movements and increase susceptibility to enemy fire (6). Load carriage increases the work of respiratory muscles (18), which decreases blood flow to working locomotor muscles causing reductions in exercise tolerance (27). Some investigations have documented that caffeine may increase blood flow and muscle tissue saturation that may increase lower-body muscle function (51,63,65). We found no significant effect of caffeine on fire-and-move simulation performance (i.e., repeated-sprints), corroborating the results of others (1,9,13,16,17,23,40,49). It is possible that providing subjects with a substance that potentially had an active-ingredient elicited an ergogenic response (53). However, this explanation is unlikely since nearly half of the subjects reported no perceived effect from the placebo supplement.

Stressful environments are reported to cause decrements to aspects of lower cognitive function and decision-making (28,36,56). The fire-and-move simulation deteriorated cognition performance, but not marksmanship perhaps because it did not provide enough stress to deteriorate marksmanship (15,37). Stress-induced cognitive decline, such as sleep-deprivation, is often mitigated with caffeine supplementation in soldiers (8). Caffeine also improves complex soldier tasks such as marksmanship reaction time; however, caffeine's effects on marksmanship accuracy are not well-documented (61).

Our analysis revealed that cognitive performance, marksmanship reaction time, or marksmanship accuracy were not different between placebo and caffeine. Our results confirm previous reports documenting no improvements in marksmanship accuracy after caffeine supplementation when protocols elicit a stressful environment without sleep deprivation (12,14,20,21,50). Additionally, this is the first study to document the effects of caffeine supplementation on marksmanship reaction time during a fire-and-move simulation without sleep deprivation. Our findings suggest that caffeine supplementation does not improve marksmanship reaction time; however, caffeine's ergogenic properties on marksmanship reaction time become apparent when subjects are sleep deprived in stressful environments (44,59,60). Another potential explanation for no improvements in marksmanship reaction time may be due to the CWL which increases target exposure time and the number of friendly engagements (i.e., decreased marksmanship accuracy) (54).

The current investigation was strengthened by a robust study design with subjects serving as their own controls in a double-blind, counterbalanced, crossover design that determined the effects of caffeinated gum using a combat-relevant protocol inducing both physical and cognitive stressors. Yet, our study does not go without limitations. We were unable to only recruit active duty military personnel who had a rifle qualification. Our subjects, however, exceeded the U.S Army standards by successfully engaging at least 75% of targets. Also, since there is no difference in combat simulations between civilians and this military (29), we do not feel that this influenced our outcomes or interpretations. Our study did not include invasive measures of plasma caffeine concentration, which limits our ability to confirm that caffeine levels significantly increased after chewing the caffeinated gum. However, ingestion of caffeine may not be necessary to elicit an ergogenic response as evidenced by rinsing caffeinated fluids (4). Eight subjects did not complete the study; which, in part, was due to the COVID-19 outbreak. Thus, a fully powered study may have provided different results. Lastly, tactical combat movements are conducted with multiple soldiers and units; thus, our findings may not translate when multiple soldiers work together during direct-fire engagements (62).

Conclusion

Our investigation determined the effects of caffeinated gum on marksmanship, cognition, bound duration, and susceptibility to enemy fire during a tactical combat movement simulation. We found that susceptibility to enemy fire increased and cognitive performance decreased during the tactical combat movement simulation, but caffeine did not change marksmanship, cognition, bound duration, or susceptibility to enemy fire. Significant fatigue on bound duration indicates that susceptibility to enemy fire increased during the repeated bounds; which, in turn, may decrease soldier survivability. While caffeine was not effective at maintaining bound duration or changing marksmanship or cognitive performance, we cannot discount the possibility of improvements during sleep deprivation.

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Declaration of Interest Statement

The authors declare no conflicts of interest.

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Chapter 5 - Conclusions

This dissertation added essential information to the literature for warfighters. After identifying critical tasks (CTs) performed in modern combat-environments, the overall hypothesis of this work is that caffeine supplementation – a common ergogenic aid used amongst military personnel – enhanced CT performance. The first study addressed criticisms of military personnel and echoed by investigators that previous military evaluations of soldiers' skills and abilities lacked application in the combat-environment. Today's warfighters need to prepare themselves for the "anaerobic battlefield", which has evolved from increases in technology (i.e., load carriage, small unit ground vehicles). The combat-environment is austere and unpredictable forcing soldiers to operate at the boundaries of the abilities when executing CTs. Thus, we took a "ground up" approach in determining these CTs. The top CTs executed in modern combat-environments were tasks that likely demand high-levels of muscular strength, endurance, and power. We also found that CTs likely require aerobic fitness, balance and coordination, and marksmanship skills (Chapter 2). Besides addressing previous criticisms, these findings confirmed soldiers' anecdotal perceptions regarding the need for the fundamental skills and abilities taught during basic combat training such as, "shoot and move".

Caffeine is a potent ergogenic aid used by military personnel during sustained operations; however, it was unknown whether caffeine improved performance of the CTs we identified in study 1. In study 2, we aimed to determine the effects of a moderate caffeine dose (5 mg/kg) on the boundaries of exercise tolerance during repeated-sprint exercise. Acute caffeine supplementation improved exercise duration at 110% of peak velocity achieved during a graded exercise test during repeated-sprint exercise (10-s running; 10-s passive rest), but not at 120% or 130% of peak velocity. Additionally, the moderate dose of caffeine did not improve intermittent critical velocity or critical rest interval (Chapter 3). These findings suggested that caffeine was not ergogenic during repeated-sprint exercise at intensities beyond 110% of peak velocity. The protocol reflected the CT of “sprint all-out in a single or repeated bout < 30-s,” but soldiers frequently perform CTs concurrently during enemy engagements. By combining the CTs “sprint, jump, or dive under combat load” and “aim, fire, and prepare a weapon in support of operations.” In study 3, we were able to evaluate the effects of caffeine on the combined CTs during a tactical combat movement simulation. Our findings revealed that caffeine was not effective in improving bound duration, susceptibility to enemy fire, marksmanship, or cognitive performance (Chapter 4).

In conclusion, these investigations further the information on CTs executed in modern combat-environments and caffeine’s effects on select CTs. The modern combat environment requires soldiers to be equipped with both tactical proficiencies and a diverse physical fitness profile to execute CTs. Additionally, caffeine’s ergogenic effects on CTs were constrained to specific exercise-intensities, but not ergogenic when CTs are performed in concert with one another. Therefore, caffeine represents a potential ergogenic aid for select CTs. The prevalence of dietary supplement use among military personnel remains unprecedented and persists as an ecologically valid countermeasure for enhancing CT performance in warfighters. Dietary supplement use also increases during combat deployment; yet, it is unclear whether the current dietary supplements consumed by soldiers during combat deployments are ergogenic during CTs and presents an avenue for future investigations.

Appendix A - Job Analysis Questionnaire

1. What is your sex?
   - ☐ Male
   - ☐ Female
2. What year were you born? _______________
3. Are you Hispanic or Latino ancestry?
   - ☐ Yes
   - ☐ No
4. What is your ethnicity? (select one or more)
   - ☐ Asian
   - ☐ Black/African American
   - ☐ Native American/Alaska Native
   - ☐ Native Hawaiian/Pacific Islander
   - ☐ White/Caucasian
   - ☐ Prefer not to Answer
5. State your most recent military branch: ______________
6. Choose the answer that best describes your current status:
   - ☐ Active Duty
   - ☐ Active Reserve/Guard
   - ☐ Reserve/Guard
   - ☐ Veteran (of any status) with service since 9/11/2001
7. What was your rank at the end of your last deployment?
   - ☐ E4 and below
   - ☐ E5
   - ☐ E6
   - ☐ E7 or above
   - ☐ O1-O2
   - ☐ O3
   - ☐ O5 or above

8. State your number of combat deployments to Iraq/Afghanistan. (If you deployed more than 7 times, choose 7).

1 2 3 4 5 6 7

9. Counting all your deployments, how many times did you leave the safety of your Forward Operating Base? ____________________

10. During any of your deployments, how many times did you have to do any of the following tasks while "outside the wire"? _________________

Table A.1.

Combat-relevant task evaluation for frequency

How many times did you do any of the following tasks while 'outside the wire?'

	Never	Sometimes	About half the time	Most of the time	Always
Jog or run continuously for greater than 10 minutes with load					
Sprint all-out for less than 30 seconds a single or repeated bout					
Crawl under or through an object for more than 30 feet					
Physically pull yourself up, over or through a structure over 6 feet					
Climb a ladder					
Carry, drag, push, or pull any object that weight more than 150 lbs for any distance or duration					
Lose your balance or fall					
Maintain balance while traversing a narrow object or wall					
Walk on loose or uneven terrain					
Move on foot carrying a load for LESS than 2 hours					
Move on foot carrying a load for MORE than 2 hours					
Aim, fire, or prepare to fire your weapon in support of operations					
Maintain a tactical position for an extended period					
Control breathing for marksmanship or tactical advantage					
Manually breach a structure					
Sprint, jump, or dive under combat load					

Repeatedly lift objects overhead
Dig or pound with a sledge hammer repeatedly
Scale boulders or loose rock with or without special equipment

Table A.2.

Combat-relevant task evaluation for importance

Please assign an **importance** to these same tasks

	Not Important	Moderately Important	Very Important	Mission Essential	Vital to Survive
Jog or run continuously for greater than 10 minutes with load					
Sprint all-out for less than 30 seconds a single or repeated bout					
Crawl under or through an object for more than 30 feet					
Physically pull yourself up, over or through a structure over 6 feet					
Climb a ladder					
Carry, drag, push, or pull any object that weight more than 150 lbs for any distance or duration					
Lose your balance or fall					
Maintain balance while traversing a narrow object or wall					
Walk on loose or uneven terrain					
Move on foot carrying a load for LESS than 2 hours					
Move on foot carrying a load for MORE than 2 hours					
Aim, fire, or prepare to fire your weapon in support of operations					
Maintain a tactical position for an extended period					
Control breathing for marksmanship or tactical advantage					
Manually breach a structure					
Sprint, jump, or dive under combat load					

Repeatedly lift objects overhead
Dig or pound with a sledge hammer repeatedly
Scale boulders or loose rock with or without special equipment

Table A.3.

Combat-relevant task evaluation for difficulty

Please assign a **difficulty** rating to these same tasks

	Not Applicable	Easy	Moderately Difficult	Difficulty	Extremely Difficult
Jog or run continuously for greater than 10 minutes with load					
Sprint all-out for less than 30 seconds in a single or repeated bout					
Crawl under or through an object for more than 30 feet					
Physically pull yourself up, over or through a structure over 6 feet					
Climb a ladder					
Carry, drag, push, or pull any object that weight more than 150 lbs for any distance or duration					
Lose your balance or fall					
Maintain balance while traversing a narrow object or wall					
Walk on loose or uneven terrain					
Move on foot carrying a load for LESS than 2 hours					
Move on foot carrying a load for MORE than 2 hours					
Aim, fire, or prepare to fire your weapon in support of operations					
Maintain a tactical position for an extended period					
Control breathing for marksmanship or tactical advantage					
Manually breach a structure					
Sprint, jump, or dive under combat load					

Repeatedly lift objects overhead
Dig or pound with a sledge hammer repeatedly
Scale boulders or loose rock with or without special equipment