The Effectiveness of Caffeine to Maintain Physical and Cognitive Function during Continuous Operations

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ABSTRACT

Background. *If operational requirements prevent or restrict sleep then other intervention strategies may be necessary to prolong the period before cognitive and physical impairments affect the success of the mission. The focus of this research was to examine the effects of caffeine on vigilance, marksmanship and physical performance during field trials with conventional and Special Forces personnel.*

Study 1

Methods. *Thirty soldiers (23.6± 4.5 y, 81.8 ± 10.3 kg) were divided into a placebo (PLAC) and CAF group. After a period of restricted sleep of 3 hours during the first night, a period of sustained wakefulness began that ended at 1100 hours of the third day. PLAC or CAF doses of 100 mg, 200 mg, 100 mg and 200 mg were administered at 2145, 2345, 0145, and 0345 hours, respectively. At 2200 hours of day 2, subjects began 2 cycles of marksmanship, urban operations vigilance and psychomotor vigilance (PVT) testing which ended at 0600 hours of day 3.* ***Results.*** *CAF maintained marksmanship vigilance at 85% throughout the second night as compared to PLAC who significantly declined to 61.4 ± 28.2% overnight. Marksmanship accuracy also decreased significantly in PLAC from 95.1 ± 8.3% to 83.3 ± 19.2% but no change was observed in CAF. Urban operations vigilance decreased for both groups over the night but the decrease was less for CAF (81.2 ± 14.4% to 63.4 ± 24.1%) compared with PLAC (77.6 ± 19.2% to 44.0 ± 30.2%). Reaction time and the number of major and minor lapses with the PVT significantly increased in PLAC but were unaffected in CAF.*

Study 2

Methods. *Thirty-one Special Forces soldiers (29.8 ± 5.4y, 86.4 ± 8.6 kg) were divided into a placebo (PLAC, n = 15) and CAF (n = 16) group. A 6.3 km control run was completed on the morning of Day 1. In the evening of Day 2, soldiers performed a control observation and reconnaissance vigilance task (ORVT) in the field. This 90-min task was repeated twice more between 02:00 and 06:00 on Day 3 during an overnight period of sleep deprivation. Marksmanship was assessed before and after the ORVT. PLAC or 200 mg of CAF*

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gum was administered at 02:00, 04:00, and 06:00 h on Day 3. A final 6.3 km run commenced within 30 minutes of receiving the final dose. ***Results.*** *ORVT was maintained in CAF at control levels of 77 ± 13% during the overnight testing. However, values decreased significantly for PLAC from 77 ± 15% to 54 ± 29% and 51 ± 31% during the first and second overnight testing periods, respectively. CAF had no effect on marksmanship but improved 6.3 km run times by 1.2 ± 1.8 min. Run times slowed for PLAC by 0.9 ± 0.8 min from approximately 35 min during the control run; the changes in performance were significant between groups.*

Conclusion. *It was concluded that CAF was an effective strategy to maintain vigilance, marksmanship and physical performance during military operations involving sleep deprivation.*

1.0 INTRODUCTION

Current military doctrine requires the ability to maintain round the clock operations in order to achieve mission objectives. This is true for both conventional and Special Forces personnel. Sleep loss impairs cognitive performance [for reviews see 2, 8, 16] and physical tasks that involve self-pacing and motivation are also affected [19, 20, 26]. Thus, under conditions where adequate sleep is not an option other strategies should be considered that prevent or minimize the extent of the degradation in cognitive and physical function and, thereby, extend the period of operational effectiveness.

Caffeine is one such strategy that has been studied for its effectiveness in a military context [18, 20, 28, 30]. Caffeine acts as an adenosine receptor antagonist [for review see 9] and a recent extensive review also concluded that the consumption of caffeine in moderate doses is associated with few, if any, adverse effects in young healthy adults [21]. Findings from several studies have demonstrated caffeine's effectiveness for improving physical and cognitive performance in both rested [1, 4, 13, 17] and sleep-deprived subjects [14, 20, 24]. Caffeine also has been reported to have no effect on marksmanship in rested soldiers (10) but has been shown to improve engagement time and vigilance during simulated [28, 30] marksmanship tasks in sleep-deprived soldiers and those fatigued from prior exercise [11].

The present report summarizes findings from two recent field studies that have extended our laboratory observations [20] and tested the efficacy of caffeine with soldiers conducting military activities. To ensure face validity for our findings, our field tests were designed specifically for the soldiers with the assistance of the unit's training staff. We hypothesized that those soldiers who received caffeine during the overnight period of sleep deprivation would maintain their physical and cognitive function closer to control values than those receiving placebo.

2.0 METHODS

2.1 Study One

2.1.1 Subjects

Thirty healthy male soldiers, from four separate sections, with mean ± SD values for age of 23.6± 4.5 y, height 181 ± 6 cm and body mass of 81.8 ± 10.3 kg participated in this study. Each section was assigned a number (1-4) and two of the sections were selected to receive CAF (n = 15) and the other two a placebo (PLAC, n = 15) in a double-blind manner. Since all tasks could not be evaluated at the same time for all subjects (see below), one CAF and one PLAC section were grouped together to control for any bias due to the presentation order of the tests. The soldiers were fully informed of the details, discomforts and risks

associated with the experimental protocol during an initial briefing, and written informed consent was obtained. This study was granted approval by the human ethics review committee of Defence R&D Canada, Walter Reed Army Institute of Research and the Therapeutics Protection Directorate of Health Canada.

2.1.2 Baseline Testing

Day 1 was the base line day. Soldiers reported to the drill hall at 08:00 h where they were briefed by the scientific staff about experimental procedures. After the briefing, the soldier's coffee/tea consumption for the morning and daily consumption habits was noted and recorded on a caffeine questionnaire and they were restricted from any caffeine use for the remainder of the study period.

At approximately 09:00 h a baseline 5 km run was conducted. After the run the soldiers underwent training on the psychomotor vigilance task (PVT) as described below. Following lunch, soldiers reported with all personal equipment necessary for a 48-hour operation and completed an 11 km forced march to the target range. They set-up camp for the night and the zeroing of weapons was performed in preparation for the night control shoot. Smoking or chewing of tobacco was not allowed between 18:00 and 23:00 h but otherwise its use was not restricted during day 1.

Sections1 and 3 reported to the target range at 19:00 h where they completed the baseline cycle of PVT and control marksmanship testing (as described below). Two hours later the other sections began their cycle of PVT and marksmanship testing. Once these sections had finished the marksmanship testing a final PVT was performed by all soldiers. Soldiers were kept awake until 02:00 hr of Day 2 at which time they began a three hr sleep period in the range hut.

Soldiers were awakened at 05:00 hr and following breakfast performed a second forced march of five km to the Fighting In Built Up Areas (FIBUA) site. For the remainder of the morning the sections fortified and set-up sandbag defensive positions in and around the building that would be used during the evening's vigilance testing. In the afternoon the soldiers conducted a live-fire simunitions exercise.

2.1.3 Experimental Testing

At 19:30 hr subjects were briefed on the sequence of testing that would occur during the overnight period. Smoking or chewing of tobacco was not allowed between 20:00 hr and 06:30 hr the next morning but its use was not restricted at other times of the day.

The testing was divided into an early (2200 hr of Day 2 to 0200 hr of Day 3) and late session (0200 to 0600 h of Day 3). Within each test session the soldiers completed the PVT and marksmanship task and the FIBUA vigilance task. Sections 1 and 3 completed the PVT and marksmanship task first while sections 2 and 4 completed the FIBUA task first in both the early and late test sessions. Prior to beginning the early phase of testing all soldiers chewed one stick of gum for five minutes. A further two sticks of gum were chewed for five minutes after completing the first task and before switching to begin the other task at approximately midnight of Day 2. Each piece of the gum contained either 100 mg of caffeine or no caffeine. This sequence of testing and caffeine or placebo administration was repeated during the late phase of testing. The total dose of caffeine administered during the night was 600 mg. After the late phase of the testing was completed soldiers were transported to the drill hall where a repeat of the initial five km run was performed starting at 09:00 hr. Prior to beginning this five km run, soldiers chewed on a cotton stick for three minutes to provide a saliva sample that was later analysed for caffeine. After the final five km run, a short debriefing occurred after which soldiers were transported to their place of residence for recovery sleep.

2.1.4 Marksmanship Vigilance and Accuracy

The marksmanship task consisted of two components. The first was a vigilance task lasting 40 minutes. During this time the soldier shot at paper targets 100 meters in front of them. For each soldier a target appeared 4 times randomly sequenced throughout the 40-minute period but they were instructed that anywhere between 2 and 5 targets might appear over this time period. The targets were illuminated from below; otherwise this task was conducted in total darkness. The soldiers were instructed to fire only one shot when their target appeared with each target remaining visible for 4 seconds. A maximum of 2 points was awarded for each target; one for recognizing their target and firing their rifle, and one for hitting the target.

The second component was an accuracy task. This occurred at the end of the vigilance session. The soldiers had 5 minutes to fire the remaining rounds in their clip (they began the vigilance task with 10 rounds) at a new target. Each shot that hit the target was awarded one point since no specific firing instructions were given other than to hit the target. During this part of the marksmanship task paraflares were used to light the target range.

2.1.5 Fighting in Built-Up Area (FIBUA)

At the FIBUA site each soldier was assigned an observation position in a window or doorway and directed to observe and record any actions (time, location, event) occurring in and around a building on the opposite side of the street (~15 M). The soldiers were to record the where, when and what of any activity that occurred in and around this building. The nature of the activities (such as a person opening and closing shutters, coming out of a door, a pen light being turned on to simulate reading a map, or someone walking from a corner of the building to enter the building) and the time that they appeared throughout the 90 min observation period were randomized such that one activity occurred randomly within each ten-minute block for a total of nine activities over the 90-minute period. Prior to the start of this activity soldiers synchronized their watches and were given a flashlight, clipboard and pen to record their observations. Each activity was awarded a maximum of three points; one for recording the appropriate time of the activity, one point for describing the whole activity accurately and a third point for stating accurately where the activity happened. Thus, the total number of points awarded for this activity was 27 and scores were expressed as a percentage.

2.1.6 Psychomotor Vigilance Task (PVT)

The PVT is a computerized vigilance test with a reaction time component that is administered on a hand held palm pilot [29]. Subjects press a button each time a bull's-eye appears on the screen. Test presentation occurs with 1-5 sec interstimulus interval and the test is five min in duration. The data collected included reaction time (RT, speed), minor lapses (RT > 500 msec) and major lapses (RT > 3000 msec).

2.1.7 5 km Run

Four soldiers at a time, one from each section, started together. The next four runners followed the initial group by 5 minutes. This timing cycle was repeated until all groups of 4 soldiers had commenced and completed the run that was an out and back course. Split times and finish times were recorded. The soldiers performed this run dressed in combat clothing and running shoes.

2.1.8 Measurements

Saliva samples were assayed for caffeine concentration using gas chromatograph-mass spectrometry electron impact single ion monitoring (model MSD 5970a Hewlett Packard, Palo Alto, Ca).

2.1.9 Statistics

An analysis of variance with one repeated factor (time) and one grouping factor (drug) was used to determine differences between and within groups. When a significant group and time interaction occurred, a Newman-Keuls post-hoc analysis was performed to isolate differences among treatment means. For all analyses, an alpha level of ≤ 0.05 was used for statistical significance.

2.2 Study Two

2.2.1 Subjects

The study was granted approval by the human ethics review committee of Defence R&D Canada – Toronto, Walter Reed Army Institute of Research USA, and the New Zealand Defence Force. Thirty-one male Special Forces personnel with mean ± SD values for age of 29.9 ± 5.3 y, height 179.6 ± 5.3 cm and body mass of 86.4 ± 8.6 kg participated in this study. An initial briefing was provided where the soldiers were fully informed of the details, discomforts and risks associated with the experimental protocol, and written informed consent was obtained. During the briefing the soldiers were separated according to their primary role as shooters or non-shooters and were divided into groups of 4 identified with letters from A through H. Two soldiers in each of these groups were designated to receive CAF (n = 16) and the other two received placebo (PLAC, n = 15) in a double-blind manner. The soldiers were informed that no coffee or caffeine containing products were to be consumed for 12 hours prior to the performance of the 6.3 km control run on day 1 of the study, and following their morning breakfast on day 2 until after the study was completed on the morning of day 3.

2.2.2 Baseline Testing

Between 08:00 and 10:00 of Day 1, the soldiers performed their control 6.3 km run consisting of 3 laps around the inside of a fenced area. The soldiers wore their combat clothing and boots, and carried approximately 11 kg of additional weight with their rifle, tactical assault vest and canteens of water. Fluid replenishment was not permitted throughout the run. Start times were staggered by 10 minutes for each group. During the run the soldiers were told to give their best effort. Lap times and total time were recorded to the nearest second. Normal training activities were conducted for the remainder of this day.

Soldiers reported at 06:00 following an eight-hour sleep period and performed their normal training on Day 2. However, at 19:00 hours they reported for a briefing that described the sequence of activities throughout the night. At 19:45 hours they were transported from their base camp to the range. A PVT was performed by all subjects in the range shack after which they walked approximately 300 m to the range to begin the observation and reconnaissance vigilance task (ORVT) that is described below. This ORVT, which represented the control session, lasted 90 minutes. The soldiers then walked back to the range shack, performed another PVT and were then transported back to their base camp. From 22:30 until 24:00 of Day 2 control marksmanship testing was performed. Soldiers performed the shooting task in their groups.

2.2.3 Experimental Testing

At 01:00 of Day 3 the soldiers were again transported back to the range and at 01:40 another PVT was performed in the range shack. At 01:45 two sticks of caffeine or placebo gum were administered and chewed for 5 minutes and a PVT immediately followed. The soldiers then walked to the range and began their first ORVT at 02:00. At 03:30 the soldiers returned to the range shack and performed another PVT at 03:40. This entire cycle was then repeated with the chewing of 2 additional sticks of gum beginning at 03:45 and ending at 05:45 when soldiers were transported back to the base camp. At 06:15 the marksmanship testing commenced.

After each group of soldiers completed their marksmanship testing they reported to the base gym to perform the 6.3 km run. Because only 4 soldiers at a time could be tested for marksmanship the timing of the last dose of gum varied somewhat among the groups. However, the amount of time that elapsed between the chewing of the gum and the testing of the marksmanship and the subsequent performance of the run was consistent for all soldiers. A final briefing to all participants was made at 11:00 hours after which they were released.

2.2.4 Observation and Reconnaissance Vigilance Task (ORVT)

Prior to the start of this task, all subjects synchronized their watches and made sure that they had a flashlight, notebook and pen to record their remarks. Soldiers assumed a seated or prone position 4-5 m apart with half of the group at 175 m and the others 200 m away from a building façade that was lit with interior and exterior lights. The width of the range precluded all of the soldiers from being positioned the same distance from the façade, however, the smaller groupings of 4 soldiers were used to ensure that there was no bias in the number of CAF or PLAC participants positioned at either 175 or 200 m. The soldiers were required to record the where, when and what of any activity that occurred around this building over a 90-min observational period. Within each 15-min block, one activity was randomly presented. Each activity was awarded a maximum of 3 points; one for recording the appropriate time of the activity, one point for describing the activity accurately, and a third point if they stated accurately where the activity happened. Thus, the total possible points awarded for this activity was 18 and scores were expressed as a percentage of this total possible score.

2.2.5 Marksmanship Task

The marksmanship task evaluated both accuracy and target engagement and response time for four soldiers at a time. All soldiers were tested with a pistol and those designated as shooters were also tested using a standard military assault weapon. For the accuracy component, the individual stood 10 meters from 2 vertically aligned (one for each weapon) paper targets that presented an approximate 25x20 cm head and torso outline of a terrorist. Ten rounds were fired at the designated target for that weapon with scoring shots represented by any hit within the outline of the target. The lights in the indoor range remained on throughout this phase of the testing.

The second component was a target engagement and response time task. Again soldiers stood 10 meters from targets that were presented in three rows of three, randomly numbered 1 through 9. A target number was identified as the lights in the room were turned off. The soldiers were instructed that when the lights were turned back on they were to shoot twice at the identified target. The lights would come on for 4 seconds and then turned off again as another target number was identified. This procedure was repeated until five different targets were engaged, thus representing a maximum possible score of 10. The time that the room remained dark between target engagements varied from 5 to 30 seconds. The target numbers that were to be engaged and the time that the room remained dark between target engagements were randomized for each group of shooters. The scoring for the accuracy and reaction time components was expressed as a percentage of the maximum score.

2.2.6 Statistics

Similar statistical procedures as were used in Study one were performed for this study.

3.0 RESULTS

3.1 Study One

3.1.1 Daily Caffeine Consumption

Two soldiers in the CAF group and 4 in PLAC were nonusers of caffeine. For the remaining soldiers, caffeine consumption varied considerably from a low of 42 to a high of 1823 mg/day. Daily caffeine consumption was not different between the CAF (698.4 ± 493.1 mg/day) and PLAC (400.9 ± 456.4 mg/day) groups.

3.1.2 Caffeine Concentration

One saliva sample was lost for a soldier in the PLA group but for the remaining soldiers in this group there was no measurable trace of caffeine in their saliva. In contrast, saliva concentrations of caffeine measured 9.9 ± 6.0 μM for the CAF group.

3.1.3 Marksmanship

There was no significant decline in marksmanship vigilance during the early test session on Day 2 in either the placebo or caffeine groups. However, in the late session there was a significant decrease in vigilance in PLA while vigilance was maintained in CAF (See Figure 1). There was no significant difference between PLA and CAF in any test session.

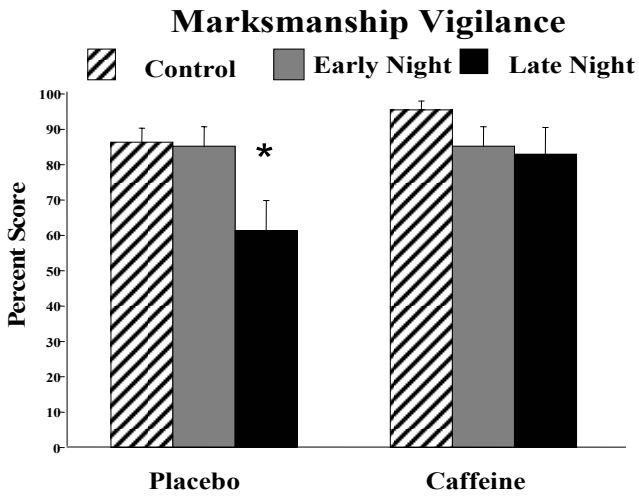

Figure 1: Effect of caffeine on marksmanship vigilance. * = significant difference compared to control.

Both groups showed a decrease in marksmanship accuracy during the second testing session of the overnight period but the 9% decrease was not significant for the CAF group whereas the 12% change for PLAC was significantly different than the other testing sessions.

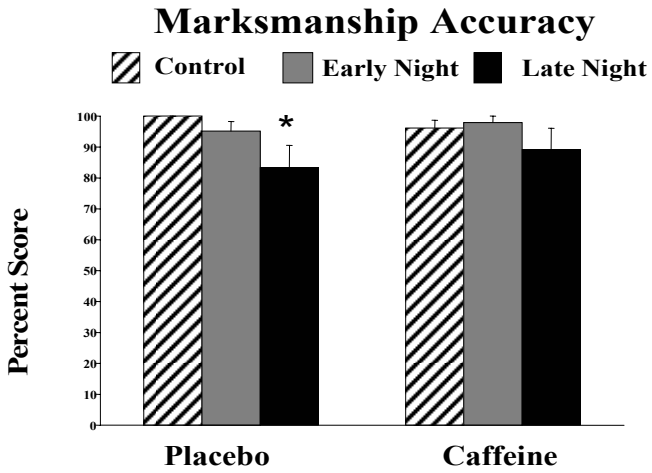

Figure 2: Effect of caffeine on marksmanship accuracy at three different time points. * = significantly different from control and early night.

3.1.4 FIBUA

Performance on the FIBUA task was significantly impaired in PLA between the early and late test sessions (82 to 44%) while performance was maintained in CAF (See Figure 3.). In addition, in the late test session (0200-0400 hr) performance in PLA was significantly impaired relative to CAF.

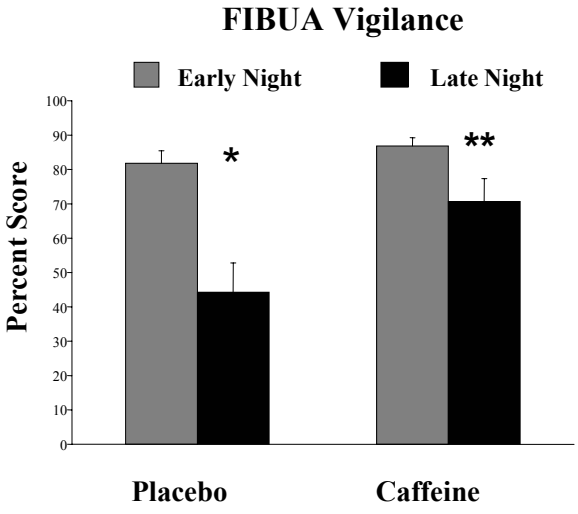

Figure 3: Effect of caffeine on performance in the FIBUA vigilance task. * = significant difference between early and late. ** = significant difference between PLA and CAF.

3.1.5 PVT

Figure 4 presents the changes in reaction time throughout the study when the PVT was administered at a similar time for both groups. Reaction time was significantly slower for PLAC compared with CAF from 0200 through until 0600 on Day 3. The use of caffeine maintained reaction time at baseline levels for the CAF group.

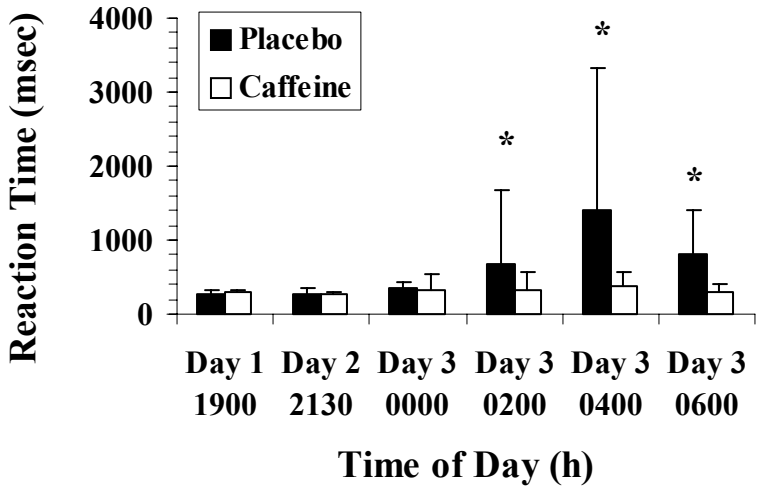

Figure 4: Reaction time measured throughout the study using the psychomotor vigilance task for the placebo and caffeine groups. * Significant difference between groups.

Figure 5 shows that the number of minor lapses (response times greater than 0.5 s but less than 3 s) increased significantly for PLAC reaching values around 20 during the latter part of the morning on Day 3. These increases were significantly greater than the changes observed for CAF, which did not change significantly throughout the course of the study. The number of major lapses (response times greater than 3 s) increased significantly for PLAC from values close to 0 during baseline testing to a high of 4.3 ± 4.8 at 0400 of Day 3. The number of major lapses did not increase throughout the study for CAF.

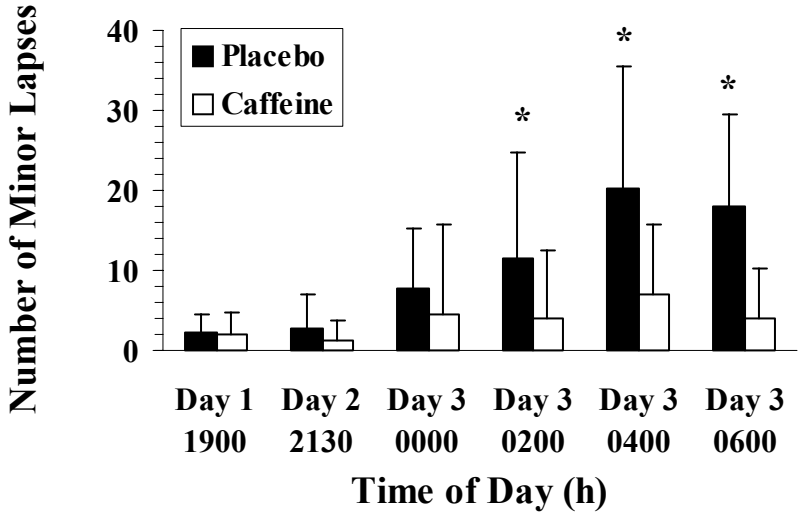

Figure 5: The number of minor lapses measured throughout the study using the psychomotor vigilance task for the placebo and caffeine groups. * Significant difference between groups.

3.1.6 5 km Run

Run times slowed equally for both groups. Times increased 15.5% ± 13.7 for PLAC and 13.6% ± 8.9 for CAF from their respective baseline times on day 1 of 27.9 ± 3.1 and 26.0 ± 1.6 min.

3.2 Study Two

3.2.1 Daily Caffeine Consumption

One soldier in CAF and 3 in PLAC were nonusers of caffeine. For the remaining soldiers, caffeine consumption varied considerably from a low of 10 to a high of 700 mg/day. Average daily caffeine consumption was not different between the CAF (230.0 ± 133.7 mg/day) and PLAC (273.8 ± 232.9 mg/day) groups.

3.2.2 ORVT

The performance for the ORVT is depicted in Figure 6. The significant decrement in performance for PLAC from their control trial to the first and second early morning sessions was 22.8 and 26.7%, respectively. CAF showed no decrement in performance from their control level and values were significantly greater than PLAC during the morning sessions.

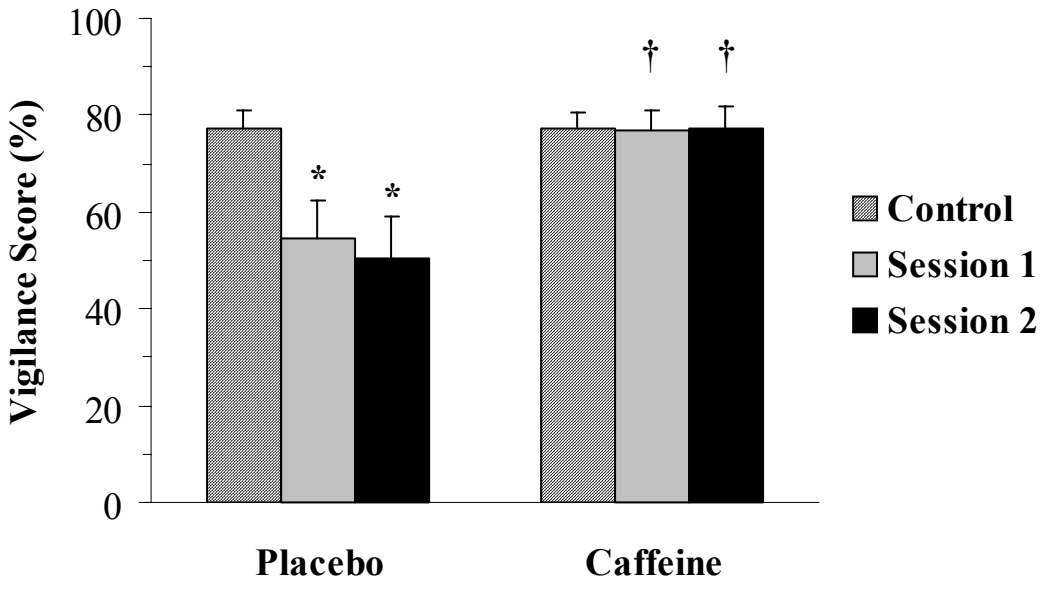

Figure 6: Observation and reconnaissance vigilance scores expressed as a percentage (%) of the total possible score of 18. The asterisk indicates a significant difference from the control placebo score whereas the cross indicates significant difference between the caffeine and placebo groups.

3.2.3 PVT

Baseline values for both reaction time and lapses were not different between groups recorded during the evening of day 2. Reaction time during the PVT conducted before and after the ORVT slowed throughout the early morning of day 3 for the placebo group whereas values slowed for the caffeine group only during the testing conducted at 05:30 on day 3 of the trial (Figure 7). Values between groups were significantly different beginning with the testing conducted at 03:30 of day 3. There was a main effect of group for lapses recorded during the night. The caffeine group had significantly fewer lapses (1.8 ± 2.1) compared with the placebo group (3.6 ± 3.1).

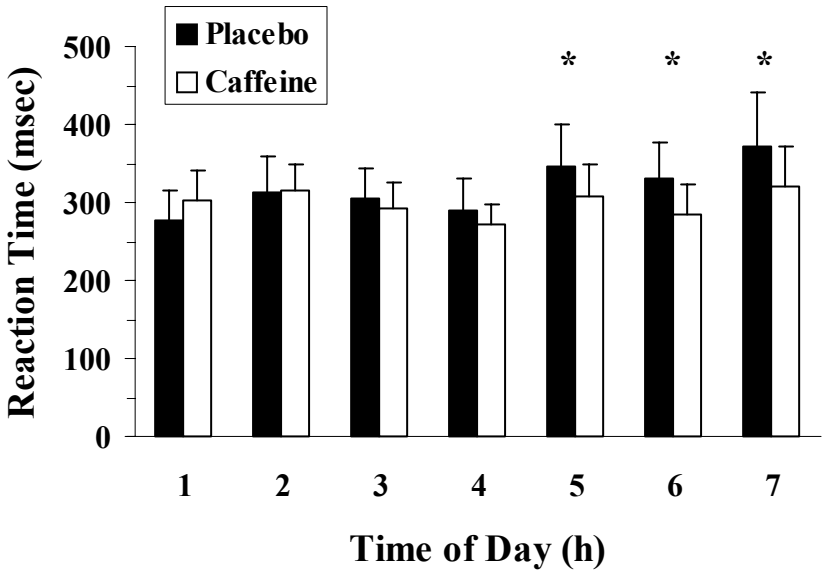

Figure 7: Reaction time scores during the PVT performed before or after ORVT conducted during the evening of the day 2 and the early morning of the day 3. The asterisk indicates a significant difference between the placebo and caffeine groups.

3.2.4 Marksmanship

CAF did not affect the accuracy or target engagement and response time scores for either the pistol or the assault weapon. There was, however, an over night decrement in performance in the pistol target engagement and response time performance in both groups from approximately 90 to 75%.

3.2.5 6.3 km Run

The time to complete the 6.3 km distance was significantly slower for CAF compared with PLAC for the control run (Table 1). However, following the overnight period of sleep deprivation 6.3 km run times were not different between groups. The change in run time expressed as a percentage of the control value was significantly different between groups. Whereas a slowing of 2.6 ± 2.4% was observed for PLAC, those soldiers receiving CAF improved by 2.5 ± 4.7%. The completion of the second and third laps during the run was also significantly faster for CAF following the overnight period of sleep deprivation (Table 1).

Table 1: Lap times and total 6.3 km run times in minutes for the caffeine and placebo groups. The asterisk indicates a significant difference between the caffeine and placebo groups whereas the cross indicates a significant difference from the control test.

	Caffeine (n = 14)				Placebo (n = 8)			
	Lap 1	**Lap 2**	**Lap 3**	**Total**	**Lap 1**	**Lap 2**	**Lap 3**	**Total**
Control	10.64	12.15	12.53	35.32 *	10.38	11.67	11.77	33.82
	± 0.87	± 1.59	± 1.77	± 4.16	± 0.84	± 1.39	± 1.37	± 3.54
Post	10.72	11.73 †	11.88 †	34.32	10.71	11.91	12.07	34.69
	± 0.79	± 1.10	± 1.00	± 2.81	± 1.02	± 1.33	± 1.47	± 3.70

4.0 DISCUSSION

The results from these studies have shown that the use of caffeine is an effective strategy to extend the period of operational effectiveness for both conventional and Special Forces personnel during an overnight period of sustained wakefulness. The use of 600 mg of caffeine throughout the night maintained alertness and vigilance during our field observational tasks while performance decreased for those receiving placebo, enhanced run performance during study two and either maintained marksmanship vigilance and accuracy in study one or had no effect on marksmanship accuracy in study two. These findings, therefore, are consistent with a previous laboratory study [20, 30] that tested the efficacy of a similar dose of caffeine on cognitive and physical performance and marksmanship during a period of sustained wakefulness with conventional forces personnel.

4.1 Cognitive Function

The impact of caffeine on cognitive function is well documented for both rested [1, 17] and sleep-deprived [3, 14, 23, 31, 32] individuals during controlled laboratory studies. Typically, effects have been assessed using computer-based tasks to measure reaction time, vigilance and alertness [3, 14, 32]. In one of the few studies to examine performance in a field environment, Lieberman et al. [18] determined the effectiveness of caffeine on cognitive function during a stressful military training exercise. Following 72 hours of sleep restriction either caffeine (100-300 mg doses) or placebo was administered and cognitive function was assessed 1 and 8 hours later. Improvements in vigilance, reaction time, attention, mood and sleepiness were reported and the degree of improvement was related to the dose of caffeine administered. However, none of this information could be used on its own to conclusively state that the performance of military tasks would be compromised by sleep deprivation and subsequently restored with the ingestion of caffeine. The findings from the present studies, therefore, are of paramount importance in assisting with the transfer of information from these laboratory-based tests to the more generalized performance of military activities. The construct of the FIBUA and ORVT produced both consistent and sensitive findings that showed the impact of sleep deprivation and beneficial effects of caffeine.

4.2 Physical Function

Physical performance is more resistant to sleep deprivation [25, 27] but nonetheless those physical tasks that involve self-pacing and motivational efforts to continue are impacted by sleep deprivation [19, 20, 26]. Caffeine has ergogenic properties for rested individuals when it is ingested prior to or during exhausting exercise [5, 7, 12, 15] and it appears to respond in a threshold-dependent manner [6, 13, 22] with lower threshold values being necessary to observe effects in non-users compared with users of the drug [4]. Caffeine's ergogenic effect on sleep-deprived individuals is less consistent. A previous laboratory study revealed that 600 mg of caffeine provided throughout an overnight period of sleep deprivation restored running performance to levels consistent with a rested state [20]. These findings are similar to the benefits observed in study two but contrast the lack of effect noted in study one where the last dose of caffeine was given about 5 hours before the final 5 km run. Clearly, the timings and dose of caffeine that are administered during the overnight are important considerations if heavy or potentially exhaustive exercise is part of the military scenario.

4.3 Marksmanship

Previous studies have used firearms training simulators to assess the impact of caffeine on marksmanship in rested [10], physically fatigued [11] and sleep-deprived soldiers [28, 30]. Caffeine had no effect in the rested state [10] but decreased target engagement time and increased the number of shots fired at foe targets in either the physically fatigued [11] or sleep-deprived state [28, 30]. In study one, caffeine maintained the vigilance of target recognition at control levels during an overnight period of sleep deprivation compared with the significant decline that was observed under placebo conditions. In study two, we did not have access to a firearm training simulator and were not able to assess marksmanship vigilance on a live-fire range as was done in study one. Thus, we assessed live-fire marksmanship accuracy and constructed a marksmanship task to determine the impact of caffeine on the accuracy of target engagements. Regardless of whether the assault weapon or pistol was used, caffeine had no affect on our measures of marksmanship during the overnight period of sleep deprivation. It should also be emphasised that caffeine had no negative effects on marksmanship in the present study, a finding that is consistent in all of the previous reports [10,11,28,30].

5.0 CONCLUSION

In summary, the present studies have conclusively shown the benefits of caffeine for maintaining vigilance and reaction time during an overnight period of sleep deprivation. Given also that a) there is the potential for an ergogenic effect from the drug if it is administered within 3 hours of the physical effort [4] and b) there is either no change or a positive impact on marksmanship, our findings support the recommendation that during periods of unavoidable sleep loss the use of caffeine can extend the period of operational effectiveness during the conduct of military operations.

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