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MODERATE PHYSICAL WORK EFFECTS ON PERFORMANCE AND MOOD DURING SUSTAINED OPERATIONS (SUSOPS)

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SUMMARY

Several factors influence the quality of sustained performance when work requirements include both physical and mental components: physical fitness/endurance training, rest quantity, physical and mental intensity, environment, number and duration of sustained work operations, and the interactions (timing and quantity effects) of these factors. The extent to which an individual can endure intensive high tech sustained operations is not fully understood. Additionally what enhancement or prophalactic procedures are effective under these conditions is of interest. This problem required study in order to predict and plan for the human factor in future military engagements.

This study (one of a series) was primarily concerned with mental effectiveness during continuous work with physical demands. In this repeated measures study, eleven pairs (one experimental and one control) of Marines (N=22) experienced one 12-hour baseline and two 20-hour continuous work episodes (CWE). The 20-hour CWEs were separated by five hours which included a 3-hour nap from 0400-0700. Each hour of CWE was split into two half-hour sessions. During the first half-hour, subjects performed alpha-numeric (A-N) visual vigilance tasks. The experimental number of each pair spent this first 30 minutes also walking on a treadmill in full combat gear (25 kg) at 31 percent max $\dot{V}O_2$ heart rate for a total distance of approximately 114 km. The controls performed the A-N task sitting quietly at a video terminal. During the second half-hour, all subjects completed mood and fatigue scales, measured oral temperature, blood pressure and grip strength, and performed a simple reaction time task. Also during this second half-hour, both Marines performed selected combinations of tasks, such as rapid alternating response, logical reasoning, word memory, four-choice serial reaction time, reading, rifle assembly, Naval Anti-Air Warfare task and Educational Testing Service Visual Memory. Continuous heart rate measurements were obtained for both Marines while performing the A-N task. During sleep periods (baseline, nap, and recovery) electroencephalograph, electrocardiograph, and electro-oculograph recordings were obtained on both subjects.

Three-way analysis of variance (groups by days by sessions) with repeated measures (BMDP-79, Dixon and Brown, 1979) were computed for the various performance tasks, mood and physiological measures. To test the nap effect, t-tests were used to compare average performance scores from the first test administration of each continuous work day (1 and 2).

Results indicated: (a) Mood scales showed that subjects expressed significantly more fatigue and expressed more negative affect during the second sustained operation. (b) No significant sleep stage changes were found. (c) Generally, after nap performance (0800) was not significantly different than CW1 ending performance level. (d) The physical workload did not significantly affect performance, but sleep loss and circadian effects produced performance decrements in some tasks. A wide range of individual response was noted and human reliability from one CWE to another was not consistent. Decrements increased as the sustained operation stretched out into the long hours of night and early morning.

We concluded from a comparison of our nap studies that the timing and duration of the nap are important in determining recuperative value. When designing work/rest schedules to maintain high quality performance in recurring CWEs as short as 20 hours, a 3-hour or longer nap during the circadian nadir may be required. Physical workloads greater than 30% max $\dot{V}O_2$ may produce more rapid and significant decreases in performance.

INTRODUCTION

Performance during sustained work conditions may be influenced by several factors including physical fitness/endurance, rest quantity (before, during and between episodes), timing of performance and rest cycles, workload, number of sustained work episodes, and the interrelationships of these factors (Alluisi, et al., 1977; Bandaret, et al., 1981; Radomski and Defayolle, 1981; Naitoh, et al., 1979; Alluisi and Chiles, 1967). The effects of such factors are of particular interest to the military community because intensive sustained operations inherent in modern warfare permit, at best, brief, fragmented sleep between episodes (Naitoh, 1976; Williams, et al., 1975; McHugh, et al., 1974). Sleep during continuous military operations thus is an indeterminant as to duration and time obtained.

The observed limit of effective human performance, when working intensively and without sleep is reported to be three days when the tasks involved are both physical and mental (Haslam, 1982). Repeated bouts of sustained effort are even more debilitating. Stokes, et al. (1978) found performance deteriorated in 5-man Fire Direction Center teams during an initial 38-hour sustained operation and that following 33 hours of rest, performance of the teams deteriorated sooner and to a greater extent in a subsequent 30-hour sustained episode. Physical workloads of infantry type missions, such as preparation for perimeter defense, e.g., wiring, mining and patrolling, can be maintained for longer periods than mental workloads which degrade earlier in sustained operations (Haslam, et al., 1981). Bonnet (1980) reported that physical exertion alone caused decrements of performance on mental tasks to the same degree as that caused by one night of total sleep loss.

The interaction between physical and mental workloads in sustained operations is not fully understood. This problem requires study in order to predict the effects of physical efforts during military operations upon a person's capability for continuous work (CW) and cognitive performance. When an operation is either prolonged (over 40 hours) or is repeated in a short span of time with minimal sleep and rest, human performance may become so erratic and/or sluggish as to pose a serious threat to mission success. Under these circumstances, it would appear that sleep is necessary to regain efficiency, repay physiological debts and permit a return to duty. Schlosberg and Benjamin (1978) have indicated the seriousness of poor sleep logistics. A particularly critical operational question then is the duration and timing of rest periods. Naitoh's study (1981) of naval recruits suggested that a 2-hour nap between 0400-0600 was not recuperative. Task performance decrements remained as great after the nap as when subjects continued to work without sleep. However, a nap taken from 1200-1400 was recuperative. These results indicate that timing of the nap is as critical as duration in determining recuperative effect.

This study, which is one of a series, was concerned with mental effectiveness. Specifically we have been studying continuous and repeated work episodes on cognitive performance. Throughout the various studies we have been manipulating the length and time-of-day for giving naps. The purpose has been to determine the restorative effectiveness of naps after lengthy CWEs wherein subjects also experience sleep loss. This paper represents an overview of the results of a study in which physical work was an added variable. For this study a moderate physical workload vs. no physical workload was selected to test for effects on cognitive performance. Additionally, a 3-hour nap (an increase of one hour over our previous nap study), (Naitoh, 1981) was given midway (0400-0700) between sustained episodes to determine the restorative effects of the nap at that particular time of day.

METHODS

Subjects

Twenty-two physically fit, male Marines from a reconnaissance battalion at Camp Pendleton, CA (mean age 20.5 ± 1.7 years, 18-24) volunteered to participate in this study. Eleven pairs of Marines were studied, each for a five-day period. Their rates were Lance Corporal (7), Corporal (9), and Private First Class (6). They had all experienced field combat training maneuvers, sleep deprivation (mean hours awake 46.9 ± 22.2), and preferred daytime work hours and nighttime sleep hours (Reference Table 1).

Materials

The study was conducted at the Physical Fitness and Ergonomics Laboratories of the Naval Health Research Center. Within the Ergonomics Lab is a sound-reduced, electronically shielded sleep room and an air-conditioned exercise room. Equipment used was a DEC MINC 11 computer with VT 105 and VT 100 video terminals, a Tektronix 4051 computer and a Quinton clinical research treadmill, model 18-60. Other equipment included a polygraph, FM instrumentation tape recorder, four electronic filters and four differential amplifiers. Average ambient temperature (21.1°C) and humidity (50%) were maintained with environmental control equipment.

Measurements

Heart rate and activity were monitored by electrocardiograph (EKG) with electrodes placed in the CM5 (manubrium, V5 and RV4) configuration. To measure brain activity (during sleep only), electroencephalograph (EEG) electrode placements were C3 in reference to linked mastoids (A1 + A2). C4 was used as an alternate. Right and left electro-oculograph (EOG) recordings were also obtained along with EEG during sleep. Vital sign measurements taken were oral temperature (OT), blood pressure (BP) and heart rate (HR). Profile of Mood States (POMS) fatigue subscale and School of Aerospace Medicine (SAM) Subjective Fatigue Checklists were used as measures of fatigue. Mood changes were obtained by the POMS and Naval Health Research Center (NHRC) Mood Scales. Right and left grip strength were taken as measures of changes in physical static strength. The Task of Rapid Alternation Performance (TRAP) and simple reaction time (SRT) were used to measure psychomotor performance (Lisper and Kjellberg, 1972). Additionally two combat-related tasks, rifle disassembly/reassembly and a simulated naval anti-air warfare (AAW) task, the Air Defense Game (Greitzer, Hershman and Kelly, 1981) were utilized. Other performance measures employed included Logical Reasoning, Auditory Word Memory, Four-Choice Serial Reaction Time Task, Educational Testing Service (ETS) Visual Memory test, Miller and Gates Reading Tests, and the NHRC alpha-numeric visual vigilance task. The Subject Fatigue Scale (Kogi, Saito and Mitsuhashi, 1970) was used to determine types and number of complaints. A description of these tasks may be obtained by writing to the authors, also see Naitoh, 1981 and Naitoh, et al., 1982(b).

Procedure

Pairs of subjects were divided randomly into experimental or control subjects. Both subjects of each pair performed all the same tasks at the same time throughout the experiment. During the first half-hour of each hour session, the experimental subjects (physical work) walked on the treadmill in full combat gear carrying a pack and rifle while performing a visual monitoring alpha-numeric task. The gear (shoes, rifle and field pack) weighed 27 Kgs. Treadmill speed was determined by heart rate. The experimental subjects' exercise HR was kept as near as possible to the rate determined from their individual exercise test to correspond to an energy expenditure equal to 30 percent of his maximal rate of oxygen uptake ($\dot{V}O_2$ max). The control subject performed the same alpha-numeric task while seated at a video terminal.

During the second half-hour of each hour, both subjects performed the remainder of the series of aforementioned tasks, including completing computer-presented mood checklists and vital sign measures. Most tasks were computer automated and controlled. Oral temperature, blood pressure and grip strength data were manually entered into the computer by the subject as the measures were taken.

Each pair of subjects remained in the lab for five days (Monday-Friday). The protocol is presented in Figure 1. On Monday, subjects were given a graded maximum exercise test at the NHRC Physical Fitness Lab to determine maximal rate of oxygen uptake ($\dot{V}O_2$ max) and HR at 30% $\dot{V}O_2$ max. The remainder of Monday was used for familiarization with the experimental procedure and training for the various tasks and measurements.

The experimental phase started at 0800 Tuesday. This first work segment (Tues. baseline) consisted of 12 one-hour sessions ending at 2115. EEG electrodes were placed on the subjects for the first sleep recordings, and they went to bed around 2300. The experimental group walked a total of six hours on the treadmill this first day (twelve 1/2 hour sessions). On Monday and Tuesday nights subjects slept 8 hours (2300-0700). The first sustained operation (Continuous Work, CW1) began Wednesday at 0800, ending Thursday at 0400 whereupon subjects were given a three-hour nap (0400-0700 Thursday). Subjects were awakened at 0700, allowed to eat, and at 0800 (Thursday) the second 20-hour sustained operation, CW2, began, ending at 0400 Friday. Subjects were allowed to sleep until 1200 that day (see Fig. 1). Sleep records (EEG, EOG, EKG) were obtained during all sleep times except the first adaptation night in the lab (Monday). During baseline, CW1 and CW2, except for short meal breaks and sleep times, subjects were continuously performing tasks. Subjects were encouraged to complete all tasks in the time allotted. They were allowed to interact freely throughout the experiment.

Analysis

Three-way analysis of variance (groups by days by sessions) with repeated measures (BMDP-79, Dixon and Brown, 1979) were computed for the various performance tasks, mood and physiological measures, in order to answer the following questions: (1) Did the physical workload affect performance? (significant group difference); (2) Did sleep loss affect performance? (significant between-day difference); (3) Did performance change as a function of time-of-day? (significant session (each 1-hour of the 24-hour day) differences); (4) What, if any, were the interactions between sleep loss, physical workload and time-of-day variations? (5) Was the 3-hour nap (0400-0700) effective for restoring performance to baseline levels? To test the nap effect, t-tests were used to compare average performance scores from the first test administration of each continuous work day (1 and 2).

We had to contend with two analysis issues. The first concerned the repeated measures design. In order to keep the number of repetitions less than the number of subjects within each group, it was necessary to collapse means for those measurements taken every session. This occurred for the alpha-numeric, SRT, mood and physiological measurements in the following manner: sessions 1-4 between 0800-1200, sessions 5-8 from 1230-1630, sessions 9-12 from 1715-2115, and sessions 13-17 from 2145-0315. Logic, TRAP and four-choice tasks were completed every third session; therefore, means for those sessions could be used directly in the analysis.

The second issue concerned the number of sessions in each of the experimental days. We performed one ANOVA comparing the two groups across the three days over sessions 1-12 (0800-2115). This was accomplished to allow comparison of Tuesday baseline day performance with CW1 and 2. The second ANOVA was done for the two groups across CW1 and 2 for the 17 sessions. Since the results were essentially the same, only those from the second ANOVA are reported. Exceptions are discussed.

The significance level for this study was set at a nominal level (5% or better) for individual tests. Thus data have been presented for any result achieving the 5 percent level. Recognizing the possible violation of homogeneity assumptions with small samples (Winer, 1971), we have included in the tables a conservative Geisser-Greenhouse (1958) adjustment in df (a lower limit probability estimate) for repeated measures where appropriate. Instead of correcting for multiple ANOVA tests (Dunn-Bonferroni, ref. Harris, 1975), the exact probability associated with each F-ratio is provided. The reader may choose to incorporate this information when interpreting results that have not been replicated elsewhere.

RESULTS

Group Differences

Treadmill speeds ranged from 3.2-4.8 Km/h depending upon the physical fitness (as determined by the max stress test) of the subject. Distance covered in the 23 hours (6 hrs Baseline + 8.5 hrs each CW1 & CW2) on the treadmill averaged 92.6 $\pm$ 9.6 Km and ranged from 77.4-121.0 Km.

The effects of physical workload upon performance and mood were tested by determining group differences (Experimental vs. Control) with a 3-way ANOVA. The results of the ANOVA for 3 days (first 12 sessions) revealed only one measure (TRAP 10% slowest* reaction time responses, F=6.35, df=1,19; p<.021) indicating a significant group difference. This result was also found in the 2 (CW1, CW2)-day (17 sessions each) ANOVA. Additionally, 12 out of 30 variables showed trends indicating some influence of workload (p<.20). A further test clarified these findings. A t-test (t=-1.232, df=19) between groups for baseline (Tues) 12-session TRAP performance was not significant. Additionally, no significant results were found by subtracting baseline means from CW1 and CW2 performance means for each group (thus removing their initial differences) and calculating a between-group t-test. With these results for the TRAP measure, which had met the a priori alpha level, it was decided that further t-tests with the variables showing trends was unwarranted.

Two variables showed day x group interactions (3-day ANOVA). Patterns for both Four-Choice Number of Correct Detections (NCD) (F=5.01, df=1,20; p<.037) and Four-Choice Percent Correct Responses (F=4.31, df=1,19; p<.05) were essentially identical. The within group trends across the 3 days were not however significant. The absolute difference (Exp. - Cont. means) at each day over all days was significant for NCD (F=4.39, DF=1,20; p<.05) but not for Percent Correct Responses (F=4.17, df=1,20; p<.06). Both groups were performing nearly the same number of correct responses initially, but that over the two CW segments their patterns diverged. The Control subjects increased by 33 the number of correct responses from Baseline (B) to CW2, whereas, the experimental subjects decreased an average of 40 responses.

Righthand (RH) grip strength (GS) displayed a significant session x group interaction (F=4.79, df=1,18; p<.04). Again, the trends within groups were not significant. Tukey's honestly significant difference (hsd) procedure (Winer, 1971, page 198) was used to identify times of significant group differences. The differences between groups were greatest during

* See Williams, et al., 1959 and Lisper & Kjellberg, 1972. Williams, et al. demonstrated that the 10 longest RTs increased with sleep deprivation, but the 10 shortest were less affected. Lisper & Kjellberg found that even the shorter RTs were affected by sleep deprivation; however, the longest and shortest RTs may occur at different and predictable times of the test segment. RT is sensitive to sleep loss, fatigue and task duration.

the morning hours (4.72 Kgs, $p<.001$), and, least during the afternoon (3.49 Kgs, $P<.01$) and evening (2.63 Kgs, $p<.01$). The decrease in differences (from morning to evening) or convergence of scores (control subjects decreasing and experimental subjects increasing GS performance) was significant by Tukey's hsd at the .05 level.

Between Day Difference

The Marines experienced 21 hrs of CW prior to the nap and a second 21 hr CW episode. Loss of sleep for CW1 and 2 was approximately 5.5 hrs (as opposed to 8 hrs normal sleep time) each episode. Accumulated time awake was 42 hrs separated by the 3-hr nap.

A second factor of the 3-way ANOVA determined significant between-day differences. Table 2 contains the means and standard deviations for the 3 days and the results for those analyzed variables exhibiting significant between-day differences. Most, but not all, variables showed significant between-day differences. Although the results indicated are for the 2-day, combined-group ANOVA, the table provides means and standard deviations for each group separately over 3 days providing a more definitive and meaningful exposition of the data.

Figures 2 through 7 provide graphic representations of the types of changes (quantified in Tables 2 and 3), that were found. Referring to Tables 2 and 3 (Table 3 shows percent of change), one can see that errors of omission increased, correct responses decreased, reaction time increased, positive mood decreased, negative mood increased, vigor and physical strength decreased while fatigue and physical complaints increased (also reference Table 6 for a list of symptoms and reported frequencies). Average body temperature was lower during CW2, however the pattern of this basic biological rhythm remained intact. The highest average body temperature appeared approximately one hour later during CW2 compared to CW1. There was no difference in oral temperatures between groups or during baseline. There was also no measured increase in tension, depression, anger-hostility or confusion as reported by the POMS.

As indicated, not all tasks used in this study showed significant differences between CW1 and CW2. Logical Reasoning, TRAP and Four-Choice Reaction Time, in particular, should be mentioned since they have been found in previous sleep studies to be sensitive to sleep deprivation. In addition, no effects were found for Educational Testing Service shapes, map and objective memory task, the Air Defense Game simulation task, word memory or reading. However, in each case trends toward degraded performance were indicated. Interestingly, there were significant ($F=3.56$, $df=1,20$; $p<.03$) improvements in performance for rifle disassembly/reassembly for these Marines from CW1 to CW2.

Time of-Day Effects

The third effect analyzed by the 3-way ANOVA determined sessions or within-day differences. By dividing a composite day (days combined) into parts and comparing these part-days for significant differences, time-of-day changes in performance could be located. Table 4 presents this information and includes conservative probability values (Winer, 1971, p. 526). The results indicated that almost all variables/measures analyzed exhibited time-of-day changes. Exceptions were Simple Reaction Time 10% slowest (SRT) task and right and lefthand (LH) GS.

Significant Interactions for CW Days and Time-of-Day

The combination of day differences and time-of-day upon performance, are demonstrated in interaction effects. Due to the large number of ANOVAs performed for this study, only those significant interaction effects meeting a conservative p value have been presented.

CW1 - CW2 two-day ANOVA: Four variables indicated significant session x day interactions. This meant that the time-of-day patterns found for CW1 were not uniformly expressed during CW2.

NHRC positive mood ($F=4.53$, $df=1,18$; $p<.05$) showed a linear downward trend ($F=6.22$, $df=1,18$; $p<.021$) over CW1 and a somewhat flattened curvilinear pattern for CW2 ($F=7.53$, $df=1,18$; $p<.013$) (see Figure 6). Overall, mood was less positive during CW2. The ending mood value for CW1 (0220 hours) about equalled the average mood during CW2. By Tukey's "hsd" procedure significant differences were found between CW1 and CW2 late morning ($p<.001$), afternoon ($p<.05$) and evening ($p<.05$) sessions. No difference was found between the two CW segments for mood during the early morning hours. POMS vigor scale ($F=5.49$, $df=1,18$; $p<.03$) indicated patterns similar to the NHRC Positive Mood Scale for day and session differences. The Marines reported less vigor during CW2.

The session x day interaction patterns for RH ($F=7.36$, $df=1,20$; $p<.01$) and LH ($F=4.78$, $df=1,20$; $p<.04$) grip strength were essentially the same. Grip strength moved slightly downward over CW1, and although remaining lower moved in an upward pattern over CW2, (refer to Figure 4). Morning ($p<.001$) and afternoon ($p<.05$) RH GS was significantly less during CW2 than CW1. This was true of the morning sessions only for LH GS. No real session changes were found during CW1 for either RH or LH GS. A significant difference was found however between the day and night GS during CW2 (Tukey hsd $p<.01$). Both RH and LH GS showed improvement during the night (and early morning).

<u>Baseline-CW1-CW2 3-day ANOVA:</u> Two variables revealed session x day interactions for the 3 day ANOVA (includes baseline day). Again, this meant that session patterns were not duplicated over the three days. TRAP 10% slowest responses ($F=6.04$, $df=1,19$; $p<.02$) showed basically somewhat flat patterns for both baseline and CW1. There were no significant trends however. CW2 starting performance was much slower than the comparable CW1 sessions ($p<.05$), picking up over the day in a linear fashion (Tukey's hsd, $p<.01$). By the end of CW1, TRAP performance (average slowest response) was faster than the previous two days, suggesting an ending effect.

Physical complaints (Kogi checklist) increased over the day in linear patterns for both baseline and CW1 ($F=6.22$, $df=1,17$; $p<.02$). There was a higher number of complaints in the morning and afternoon of CW2 than either Baseline or CW1 comparable sessions (Tukey hsd, $p<.01$), however, complaints decreased steadily the remainder of the episode. No significant differences were found between any of the three days for evening sessions.

<u>Nap Effects:</u>

The student t-test was used to examine the effects of a between-episode (CW1/CW2), 3-hr early morning (0400-0700) nap upon performance. The purpose of this analysis was to test the quality of performance contiguous to sleep periods, not the long-term effects of the nap. Since no group differences were found, the experimental and control groups were combined for this analysis, presented in Table 5. Performance outcomes of the first CW1 session (0800-0900) were compared to the first CW2 session. Performance, mood and vital signs measurement values were taken approximately 1-1/2 hours after awakening from either 8 hours (CW1) or 3 hours of sleep (CW2). The results indicated that the first CW2 session overall task performance and mood were significantly degraded when compared to the first CW1 performance. Since average CW2 performance was significantly less than that observed during CW1 (refer to Table 2 and Figure 2), the next logical Post Hoc analysis question concerned performance levels just before nap compared to after nap. We computed t-tests for the series of variables, listed in Table 4, to test (1) group differences during CW1 last session, (2) group differences during CW2 first session, (3) combined groups CW1 last session vs. CW2 first session, and (4) each group separately comparing CW1 last session with CW2 first session. The elapsed time between CW1 last session (before nap) and CW2 first session (after nap) was 5 hours, the period also coincident with the range of biological and psychological circadian trough. Only two t-ratios were significant. For TRAP 10% slowest responses ($t=2.812$, $df=20$, $p<.02$), our results indicated that the experimental (physical work) group demonstrated significantly more degraded performance than the control group at 0220 of CW1 just before the nap. RH grip strength ($t=4.244$, $df=21$, $p<.001$) was significantly less after nap than before for combined groups.

Additional Information Related to the Findings.

The detailed results of HR, sleep EEG and sleep characteristics during baseline, nap and recovery sleep may be found in Naitoh, et al., (1982(a)). Table 1 contains basic physical and physiological characteristics of the subjects and physiologic parameters during the experiment. The target 30% max $\dot{V}O_2$ HR was 87.6 ± 13.5 for the E-group. The average E-group HR during the treadmill walks was 89.2 ± 6.5 bpm. Even though the E and C groups were chosen randomly, three significant differences were found to exist between them. The C-group smoked significantly more cigarettes (12.9 ± 7.6 vs. 3.7 ± 8.1) per day ($t=2.75$, $df=21$; $p<.01$), weighed significantly more (80.4 ± 8.3 vs. 71.8 ± 10.8 kgs) ($t=2.10$, $df=21$; $p<.05$) and had significantly greater percentage of body fat (13.7 ± 2.5 vs. 10.9 ± 2.4) than the experimental group. Body fat percent was estimated from neck and abdominal circumferences using the equation of Wright et al. (1981) developed for Marine Corps personnel. Although the average control subject max $\dot{V}O_2$ was lower than the average experimental subject, the values were not significantly different.

The average C-group HRs (see Table 1, this paper) while sitting and working were 65.6(B), 65.2(CW1) and 65.3(CW2). Since the relationship between HR and oxygen uptake is linear (see Figures 6.20, p. 165 and Figure 11.3, p. 352, also discussion, p. 352 in Åstrand and Rodahl, 1970), it is estimated that the C-group worked at approximately 13% of their max $\dot{V}O_2$. The average HRs for the E-group while on the treadmill were 90.3(B), 89.7(CW1) and 87.7(CW2). Their overall average HR was 89.2 bpm during treadmill walking. This HR translates to approximately 31.1% of the E-group max $\dot{V}O_2$. Given that the E-group spent only one-half of their time at this rate, it is estimated that their overall average workload for the experimental phase was between 17-20% of their max $\dot{V}O_2$.

DISCUSSION

Group Differences

A series of Franco-Canadian joint experiments was conducted to examine the relationships between stress and military performance during prolonged military operations. The energy expenditure reported for day time marching in Operation Fastball was 31% of $\dot{V}O_2$ max (Myles, et al, p. A-8 in Radomski and Defayolle, 1981). This figure was extrapolated from measures of HR and compares favorably with the 31.1% estimated in similar fashion for our study. The repetitive marching was reported to have had no effect on grip strength, but decrements were produced by the exercise upon Four-Choice correct responses, vigilance and mood. An earlier study at NHRC by Lubin, et al. (1976), reported that exercise as opposed to bedrest during sleep deprivation increased performance decrements. This finding was quite different from that previously reported by Webb and Agnew (1973). Differences in study design was one explanation given for the two outcomes. Webb indicated (see Lubin, et al., p. 338, 1976) that their subjects found the moderate exercise level to be energizing while sleep deprived. All of these (including ours) studies compared generally in terms of energy expenditure of a moderate nature. The manner of expenditure (bicycle ergometer vs. walking) and amount of sleep (full night, partial, or none) were points of departure. Although we found that the physical work treatment did not differentiate between groups there were important differences between them. The experimental group's mental performance was degraded more than the control group on at least one task. This effect was seen to be more predominate in the morning hours (e.g., RH grip strength). These measures were taken after the exercise session. Performance differences during exercise (although not significant) indicate that the activity may have kept the E-group more alert. Comparisons of average alpha-numeric vigilance performance showed that the E-group had fewer omissions and more correct responses than the C-group, though they took longer to make responses. Within a larger group of subjects, these statistical comparisons may well have been different. Light physical work has been observed to enhance performance, however moderate physical workloads produce wide individual variations (Davey, 1973) as observed in this study. From this observation it is possible to speculate that physical workloads greater than the moderate 20-30% of max $\dot{V}O_2$ range for periodic CW may show more rapid and significant decreases in performance. Our E-group reported slightly more fatigue than the C-group at the end of CW1.

Day Differences, Nap, and Time-of-Day Effects

Although the effects of the physical work were minimal, the accumulation of fatigue and possibly the decrease in sleep hours had a great effect upon both the sedentary and active subjects. Similar results were reported in a recent study in Canada (Myles, et al., 1982). Morgan, et al. (1974) determined that after 18 hours of continuous work, performance efficiency was 82% of baseline. By the 44th hour of the 48 hr CW study performance was 67% of baseline. They reported an interaction of circadian, CW and sleep loss effects when the larger decrements of either CW day occurred during the early morning hours. The second CW day produces the poorer performance (Morgan, et al., 1974; Stokes, et al., 1978). All of these findings were confirmed in our study. The largest drop occurred during the first 21 hours of CW. Performance and mood almost never exceeded CW1 levels after that. Exceptions were rifle assembly and grip strength which exhibited some improvement, perhaps due to a modest adaptation to the regimen (Breithampt, et al., in press). These findings are even more relevant in terms of the short duration of each task in our study. Short duration tasks may not exhibit circadian or sleep loss effects due to the nature of performing the task (a single burst of energy for each moment of performing) (Alluisi and Chiles, 1967).

We have determined that time-of-day patterns were not consistent over both CW days. Most of the changes began early in CW2 after the nap. We conclude that the morning performance of CW2 was unlike the comparable CW1 timeframe due to fatigue and sleep inertia. The remainder of CW2 showed either slight improvement or stayed at a CW1 low point.

It was evident that our findings were also task specific. Increases in errors, omissions, response time, negative mood, fatigue and complaints are all typical in sleep deprivation studies (Naitoh and Townsend, 1970). Atypical was that we found no degradation in reasoning, decision making, map reading and memory, auditory memory, reading abilities, and performance at an air defense game. These latter tasks were also rated some of the most interesting by the subjects. It has been suggested that different tests are not equally affected by the arousal attributed to a given workload (Wojtczak-Jaraszowa, 1978).

Performance differences between CW1 and CW2 were most notable 1-1/2 hours after the nap, more than likely due to sleep inertia (Wilkinson and Stretton, 1971; Taub, 1979). Significant differences were found between the two 0800 morning performance sessions. The 3-hour nap did very little, however, to contribute to any performance changes by comparison to our earlier 2-hour nap study (Naitoh, 1981). When the CW1 ending session performance was compared to the CW2 starting performance, no differences were found, except to indicate an increase in response time (in several tasks) and a decrease in grip strength. It was concluded that performance had changed little during the 5-hour interval (0300-0800) spanning the nadir of the circadian cycle. The nap was apparently of insufficient length (for this time of day) to restore performance to the non-fatigued, beginning level of CW1. The nap may have had a slight detrimental effect (depending upon the task or variable measured). Overall it would appear that the nap maintained most of the abilities of the subjects over this time period, although a non-nap study is required for confirmation.

Types of changes in performance patterns were (1) slowing down (either from fatigue or becoming accustomed to the work routine/requirements, thus invoking a more relaxed strategy); (2) a change in time of best performance; (3) a leveling out or improvement in performance; and (4) inconsistencies from one CW episode to another. Significant between-day effects had been assumed due to sleep loss and the resultant fatigue associated with continuous work. The between-day difference may be due to (1) sleep loss/sleep inertia, (2) constantly improving or degrading task performance (as in the Rifle Assembly Task), (3) boredom/constant decreasing willingness to work hard (Wilkinson, 1961), and (4) physical adaptation.

CONCLUSIONS

This study has indicated that healthy, physically fit and trained individuals can successfully carry out a moderate continuous workload (as described in our experiment) with sleep loss although there is a cost. The physical workload appeared to cause no significant decrements in performance. Performance decrements found between the initial phase of CW1 and the end of CW2 were due to sleep loss and the circadian cycle. Performance decrements (depending upon the task or measure) ranged from 9-55%. Simple reaction time decreased by 10% in the fastest responses to 33% change in the slowest responses. Vigilance ability dropped nearly 10% by the second phase of the operation. There was over 50% increase in negative mood, physical complaints, and errors committed, and significant increases in reported fatigue

The results indicated a wide range of individual variation as previously demonstrated by Davey (1973). Some of the Marines found the workload taxing, whereas others thought it not difficult. This may be an expression of individual fitness and preparation. Noting the performance patterns change from one CW episode to another, perhaps human reliability changes as a function of time under the conditions of continuous work regimen. Selection of personnel on the basis of susceptibility to sleep loss or other such mission parameters (i.e., workload) may improve overall unit performance for specialized forces in the military. From this and previous SUSOPS studies significant decreases in performance, fatigue, and mood can be expected and predicted.

Sleep records showed no group differences. Subjective mood and fatigue measures indicated that the Marines felt better during the day than night and were showing cumulative effects of the mission by late CW1 and most notably early in CW2. This cumulative effect was observed in increases in response time, somatic complaints, and deteriorated performance posture. Post-nap performance was no better than pre-nap performance. The 3-hour nap, taken at 0400, appeared to sustain effectiveness rather than improve or degrade performance. Generally, however, by comparison to the same time period of the previous day, the tasks were performed less well 1 to 1-1/2 hours after the nap. Sleep inertia probably accounts for this phenomenon. Three hours of sleep at this time of day is not adequate to improve or restore performance or mood, or decreased fatigue after an extended work segment combined with sleep loss.

The daily fluctuations in performance, mood and fatigue due to the circadian cycle or perhaps some adaptive process were actually in some cases more substantial than those day-to-day changes resulting from the work or sleep loss. Consistent time-of-day patterns over the days were not found in the variables studied. Recovery in patterns for blood pressure, fatigue and grip strength was observed in CW2. Although oral temperature was generally lower during CW2, this basic biological rhythm remained stable.

Our results indicate that physical workloads of 30% max $\dot{V}O_2$ or less, interspersed with frequent sedentary work sessions will not adversely affect cognitive performance even when the shifts run as long as 20 hours. However, the largest decrements will occur during the latter part of continuous operations. There are indications of wide individual responses to this work regimen. Performance, fatigue and mood will degrade over successive shifts when the between shift sleep period is too short. Most, but not all, cognitive and psychomotor tasks will show decrements. The changes shown in this study were due primarily to sleep loss/inertia, the continuous nature of the work regimen, and circadian rhythms. Repeated bouts of continuous work increase decrements in mood, fatigue and performance; however, the profiles either level off or show a slight adaptive improvement. A 3-hour nap between 20-hours continuous work episodes at the circadian nadir did not effect changes from the ending values of the first CW episode.

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Table 1

Demographic, Physical and Physiological Characteristics of Subjects (N=22)

Variable	Group	Mean	S.D.
Age	E	20.6	1.7
	C	20.5	1.9
Reading Grade Level	E	10.7	2.6
	C	11.7	2.3
Chronotype	E	60.1 x	8.1
	C	54.2 x	7.6
Previous Sleep Loss (hrs)	E	51.5	27.4
	C	42.4	17.0
Height (cm)	E	177.3	9.0
	C	180.6	6.1
Body Weight (Ks)	E	71.8 +	10.8
	C	80.4	8.3
% Body Fat	E	10.9 +	2.4
	C	13.7	2.5
$\dot{V}O_2$ Max	E	55.5	7.2
	C	51.6	4.6
HR at $\dot{V}O_2$ Max	E	191.1	9.0
	C	196.2	11.3
HR at 30% Max $\dot{V}O_2$ (target HR)	E	87.6	13.5
	C	92.5	6.6
Resting HR (bpm)	E	62.5	12.1
	C	64.3	8.1
Baseline HR * (12 hr workday)	E	90.3	6.1
	C	65.6	6.8
CW1 HR * (20 hr workday)	E	89.7	6.4
	C	65.2	6.8
CW2 HR * (20 hr workday)	E	87.7	7.1
	C	65.3	7.8
Overall working HR (3 workdays)	E	89.2	6.5
	C	65.4	7.1
Resting Systolic BP (mm Hg)	E	116.0	5.9
	C	116.9	8.4
Resting Diastolic BP	E	75.2	5.4
	C	72.0	7.7
Baseline Systolic BP	E	117.1	13.3
	C	114.4	8.7
Baseline Diastolic BP	E	64.7	10.7
	C	64.8	7.8
CW1 Systolic BP	E	112.7	10.1
	C	114.0	12.2
CW1 Diastolic BP	E	64.2	9.6
	C	65.6	9.8
CW2 Systolic BP	E	113.7	11.7
	C	116.0	13.0
CW2 Diastolic BP	E	66.0	11.2
	C	66.6	8.7

*NOTE: Values given for the groups during the alpha-numeric task. E-group was walking on the treadmill during this task. C = Control group; E = Experimental group. Continuous Work (CW).

x = Morning chronotype (Horne and Ostberg, 1976)

+ = E and C groups significantly different ($p<.05$).

Table 2

Summary of ANOVA for Significant Day Differences

Tasks/Measure	Groups	12 Hr Workday Baseline Mean	$\pm$ S.D.	20 Hr Workdays CW1 Mean	$\pm$ S.D.	20 Hr Workdays CW2 Mean	$\pm$ S.D.	N	F-Ratio[1]	p[2]	df
Alpha-Numeric Omissions	E	3.36	3.17	3.45	3.97	4.72	3.89	11	11.13	.003	1,19
	C	2.35	2.06	3.57	3.42	6.83	4.43	10			
Alpha-Numeric No. Corr.	E	16.2	3.91	16.1	4.07	14.5	5.54	10	9.21	.008	1,16
	C	17.0	3.38	15.7	4.47	13.7	6.00	8			
Alpha-Numeric MRT (1/100 sec)	E	1.30	.37	1.67	.53	2.23	1.06	11	9.37	.006	1,19
	C	1.56	.83	1.61	.91	1.87	.94	10			
SRT 10% fast (1/100 sec)	E	.176	.040	.195	.051	.220	.070	11	15.51	.0008	1,20
	C	.181	.036	.195	.039	.208	.042	11			
SRT 10% slow (1/100 sec)	E	.448	.212	.697	.552	.964	.697	11	12.62	.002	1,20
	C	.510	.379	.510	.217	.631	.331	11			
SRT TRRT (1/100 sec)	E	.279	.114	.343	.170	.437	.231	11	20.25	.0002	1,20
	C	.266	.055	.301	.074	.341	.100	11			
NHRC Positive Mood	E	40.3	13.6	36.0	11.6	30.5	13.0	10	18.02	.0005	1,18
	C	33.6	10.2	29.6	12.7	25.1	13.9	10			
NHRC Negative Mood	E	2.91	4.09	4.29	4.93	6.75	7.20	10	11.11	.004	1,18
	C	2.49	2.32	3.31	3.13	5.53	4.73	10			
POMS Vigor	E	17.0	6.88	15.2	6.52	11.1	6.65	10	16.79	.001	1,18
	C	15.1	4.54	12.8	5.29	10.3	6.23	10			
POMS Fatigue	E	1.72	3.01	2.47	3.17	4.22	5.13	10	8.64	.009	1,18
	C	1.18	1.68	1.52	2.38	3.49	3.82	10			
SAM Fatigue	E	4.79	4.16	7.54	4.44	9.21	4.94	10	11.11	.004	1,18
	C	5.72	3.17	6.38	4.30	9.08	5.17	10			
Kogi Phy. Symp.	E	2.09	2.26	4.21	4.73	5.42	5.89	10	8.75	.008	1,18
	C	2.40	1.71	2.59	2.73	4.99	5.31	10			
PH Grip Strength (Kg)	E	49.8	6.15	48.7	5.63	48.1	6.50	11	5.38	.031	1,20
	C	53.6	7.46	54.1	8.10	52.2	7.77	11			
LH Grip Strength (Kg)	E	46.8	7.17	44.9	6.46	44.1	7.07	11	6.87	.016	1,20
	C	49.4	8.21	48.5	7.90	47.4	8.30	11			
Oral Temp. °F	E	97.6	0.95	97.4	1.01	97.3	1.14	10	4.94	.039	1,18
	C	97.6	0.77	97.7	0.76	97.5	0.84	10			

[1] The F-ratios reflect a combined Group ANOVA between CW1 and CW2. Means and S.D.'s have been provided for E and C Groups separately for baseline, CW1 and CW2.

[2] Conservative P-value

Table 3

Summary of Actual, Percentage, Direction and Time of Change Due to Continuous Work and Sleep Loss for Variables Indicating Significant Day Differences

Task/Measure	CW1-CW2 Actual Change	% of CW1 Mean Value	Direction of Change	Time of Day When Change Occurred *
Alpha-Numeric				
Omissions	-1.96	55.0	More omissions CW2	Early morn-late eve
No. correct	1.5	9.0	Fewer correct CW2	Early morn-late eve
MRT	- .41 secs	25.1	Slower RT CW2	Early morn-afternoon
SRT				
10% Fast	- .02 secs	10.4	Slower CW2	Mid morn-early eve
10% Slow	- .20 secs	32.7	Slower CW2	Early evening
MRT	- .07 secs	21.9	Slower CW2	Early morn-late eve
Positive Mood	5.15	15.2	Less pos. mood CW2	Mid morn-early eve
Negative Mood	-2.46	59.5	More neg. mood CW2	Mid morn-afternoon
POMS Vigor	3.38	23.9	Less vigor CW2	Mid morn-early eve
POMS Fatigue	-1.93	92.6	More fatigue CW2	Mid morn-afternoon
SAM Fatigue	-2.40	59.5	More fatigue CW2	Early morn-late eve
Physical Symptoms	-1.89	54.0	More symptoms CW2	Early morn-afternoon
RH Strength	1.43 kg	2.7	Weaker CW2	NS
LH Strength	1.15	2.5	Weaker CW2	Early morn
Oral Temperature	- .18	6.2	Lower temp CW1	Early morn-afternoon

* Statistically significant quadrant differences (CW1 vs. CW2); $p<.05$.

Sessions 1-4(1024) = Mid-morn; Sessions 5-8(1435) = Afternoon;
Sessions 9-12(1950) = Early evening; Sessions 13-17(0020) = Late eve-early morn.

Table 4

Summary of ANOVA Time-of-Day Effects for Composite Day (CW1 + CW2) for Combined Groups

Session Number	1	4	7	10	13	16	17	F Ratio	df	P Value	df Cons	P Cons
Midpoint Time	0850	1150	1520	1920	2250	0150	0250					
TRAP 10% Fast	.273	.238	.252	.234	.241	.249	.250	2.56	6,114	.023	1,20	.13
	(.10)	(.12)	(.11)	(.06)	(.09)	(.13)	(.11)					
10% Slow	.75	.65	.65	.68	.65	.71	.62	2.53	6,120	.024	1,20	.13
	(.19)	(.18)	(.30)	(.23)	(.18)	(.29)	(.26)					
Total Responses	995	1119	1106	1129	1158	1033	1074	5.58	6,120	.0000	1,20	.028
	(184)	(257)	(287)	(229)	(230)	(293)	(242)					
Logic # Attempted	33.6	38.2	36.7	38.3	(3-Day Analysis)			5.45	3,60	.002	1,20	.030
	(6.7)	(10.6)	(10.7)	(10.2)								
% Correct Resp.	79.2	81.3	79.8	82.6	78.7	75.8	78.1	2.97	6,120	.010	1,20	.10
	(17.3)	(14.4)	(14.9)	(16.0)	(14.4)	(14.8)	(16.9)					
Session Number	**2**	**5**	**8**	**11**	**14**	**17**						
Midpoint Time	**0945**	**1315**	**1615**	**2015**	**2345**	**0245**						
Four Choice 10% Slow	1.30	1.32	1.26	1.26	1.22	1.32		4.65	5,100	.0007	1,20	.043
	(.18)	(.18)	(.20)	(.18)	(.23)	(.18)						
% Correct	87.6	85.2	85.2	86.6	87.5	79.4						
	(7.3)	(5.7)	(2.8)	(5.7)	(7.0)	(3.7)		3.65	5,100	.0045	1,20	.071
Mean IR	.79	.83	.77	.75	.75	.84		3.09	5,100	.012	1,20	.090
	(.075)	(.071)	(.082)	(.067)	(.073)	(.093)						
No. Correct	477	466	490	507	505	448		4.94	5,100	.0004	1,20	.028
	(95)	(96)	(111)	(102)	(109)	(108)						
Session Number	**1-4**	**5-8**	**9-12**	**13-17**								
Midpoint Time	**1025**	**1435**	**1950**	**0020**								
Alpha-Numeric Mean RT	1.81	1.85	1.82	1.90	(3-Day Analysis)			4.27	2,40	.021	1,20	.052
	(.77)	(.81)	(.74)	(.80)								
SRT 10% Fast	.203	.199	.203	.210				2.76	3,60	.050	1,20	.11
	(.052)	(.049)	(.050)	(.045)								
RH Grip Str. (kg)	50.4	50.3	50.8	51.5				2.39	3,60	.078	1,20	.138
	(6.5)	(6.4)	(6.9)	(6.0)								
LH Grip Str. (kg)	45.4	46.1	46.5	46.6				2.40	3,60	.077	1,20	.100
	(6.5)	(6.8)	(7.4)	(6.6)								
Session Number	**1-4**	**5-8**	**9-12**	**13-17**								
Midpoint Time	**1025**	**1435**	**1950**	**0020**								
POMS Vigor	14.8	13.2	12.1	10.7				8.56	3,54	.0000	1,18	.009
	(4.7)	(4.6)	(4.3)	(5.6)								
POMS Fatigue	2.4	2.7	3.1	3.9				4.17	3,54	.010	1,18	.056
	(2.3)	(2.5)	(2.8)	(3.8)								
SAM Fatigue	4.4	5.1	5.2	6.3				5.34	3,54	.003	1,18	.033
	(3.0)	(3.5)	(3.7)	(4.4)								
NHRC Pos. Mood	33.1	32.3	31.3	28.3				4.63	3,54	.006	1,18	.050
	(9.9)	(9.8)	(9.8)	(11.1)								
NHRC Neg. Mood	4.4	5.1	5.2	6.3				5.34	3,54	.003	1,18	.033
	(3.2)	(3.8)	(4.6)	(4.3)								
Systolic BP	115.0	117.0	116.1	109.8				12.69	3,60	.0000	1,20	.002
	(5.8)	(8.0)	(8.2)	(7.7)								
Diastolic BP	66.9	67.6	63.4	64.4				10.53	3,60	.0000	1,20	.004
	(7.6)	(7.5)	(6.0)	(5.5)								
Kogi Phys. Symp.	4.2	4.0	3.4	6.1				6.98	3,54	.0005	1,17	.017
	(2.4)	(2.8)	(2.5)	(4.2)								
Oral Temp. °C	35.8	36.0	36.3	36.0				31.60	3,54	.0000	1,18	.000
	(.4)	(.4)	(.3)	(.7)								

Table 5

0800-0900 Performance/Mood/Temperature
Before and After 3-hr Nap
(Subjects were awakened at 0700)

Measure/End of Task Time	CW1 Mean	CW1 S.D.	CW2 Mean	CW2 S.D.	t-ratio (2-tailed)	P Value+	df
SRT (0840)							
Mean R.T. (secs)	.27	.10	.36	.13	-4.71	.00015	19
10% fastest resp. (secs)	.18	.05	.22	.06	-4.73	.00015	19
10% slowest resp. (secs)	.44	.21	.62	.25	-4.91	.0001	19
TRAP (0845)							
Total presses	1046.6	272.1	926.1	199.1	2.42	.025	21
10% slowest resp. (secs)	.67	.27	.85	.27	-2.28	.033	21
Word Memory (0855)							
% Correct	64.1	14.5	49.5	20.9	2.78	.012	20
Alpha-Numeric (0830)							
% Correct	85.7	12.2	71.2	29.5	2.66	.018	15
POMS*							
Vigor	16.6	6.15	10.4	7.6	4.52	.0002	19
Fatigue	5.1	3.7	9.5	4.3	-3.70	.0015	19
NHRC Mood							
Positive	37.5	13.9	26.6	13.0	4.46	.00026	19
Grip Strength (Kg)							
Right Hand	53.0	8.7	47.2	8.2	3.13	.005	21
Left Hand	46.7	7.5	43.1	7.9	2.77	.011	21
Oral Temp. °F	97.24	1.02	96.57	1.21	3.31	.003	21

* Moods, etc. complete 0835

\+ Dunn-Bonferroni conservative p value for 13 t-tests = .0038

Table 6

Frequency of Physical Complaints from KOGI Checklist

Item	Physical Symptom	Frequency CW1	Frequency CW2	Difference
1	Head feeling heavy	23	53	30
2	Whole body getting tired	74	115	41
3	Legs feel heavy	37	64	27
4	Yawning	125	145	20
5	Muddled brain	32	53	21
6	Becoming drowsy	67	116	49
7	Eye strain	84	127	43
8	Rigid or clumsy in motion	15	25	10
9	Unsteady in standing	20	26	6
10	Want to lie down	77	132	55
11	Difficulty in thinking	17	41	24
12	Weary of talking	11	20	9
13	Becoming irritable	40	54	14
14	Unable to concentrate/attend	27	45	18
15	Unable to have interest	14	56	42
16	Apt to forget things	41	78	37
17	Apt to make mistakes	67	97	30
18	Uneasy about things	5	14	9
19	Unable to straighten posture	28	34	6
20	No energy	15	28	13
21	Headache	12	19	7
22	Stiffness in shoulders	121	120	-1
23	Low back pain	49	43	-6
24	Breathing oppressed	15	30	15
25	Thirsty	94	93	-1
26	Husky voice	39	50	11
27	Dizziness	6	10	4
28	Eyelids twitching	14	37	23
29	Tremor in limbs	3	13	10
30	Feel unwell	21	21	0

	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY	
EXPT'L PHASE	Training		Baseline		CW1		CW2		Recovery	
TIME	WA	WB	WA	WB	WA	WB	WA	WB	WA	WB
00 - 01							15A	15B	15A	15B
01 - 02							16A	16B	16A	16B
02 - 03							17A	17B	17A	17B
03 - 04			SLEEP Ø		SLEEP 1					
04 - 05										
05 - 06							SLEEP 2		SLEEP 3	
06 - 07										
07 - 08			----- BREAKFAST* -----							
08 - 09			1A	1B	1A	1B	1A	1B		
09 - 10			2A	2B	2A	2B	2A	2B		
10 - 11			3A	3B	3A	3B	3A	3B		
11 - 12			4A	4B	4A	4B	4A	4B		
12 - 13			----- LUNCH ----- 5A		5A		5A		LUNCH	
13 - 14			6A	5B	6A	5B	6A	5B		
14 - 15			7A	6B	7A	6B	7A	6B		
15 - 16			8A	7B	8A	7B	8A	7B		
16 - 17			----- SUPPER -----	8B		8B		8B		
17 - 18			9A	9B	9A	9B	9A	9B		
18 - 19			10A	10B	10A	10B	10A	10B		
19 - 20			11A	11B	11A	11B	11A	11B		
20 - 21			12A	12B	12A	12B	12A	12B		
21 - 22			----- SNACK** -----		13A		13A			
22 - 23					14A	13B	14A	13B		
23 - 24	SLEEP Ø		SLEEP 1		15A	14B	15A	14B		

CW = Continuous Work

*Includes time for attachment of ECG electrodes and rifle assembly task.

**Includes time for rifle assembly task.

Figure 1 - Protocol for Sustained Operations Experiment - Phase 1

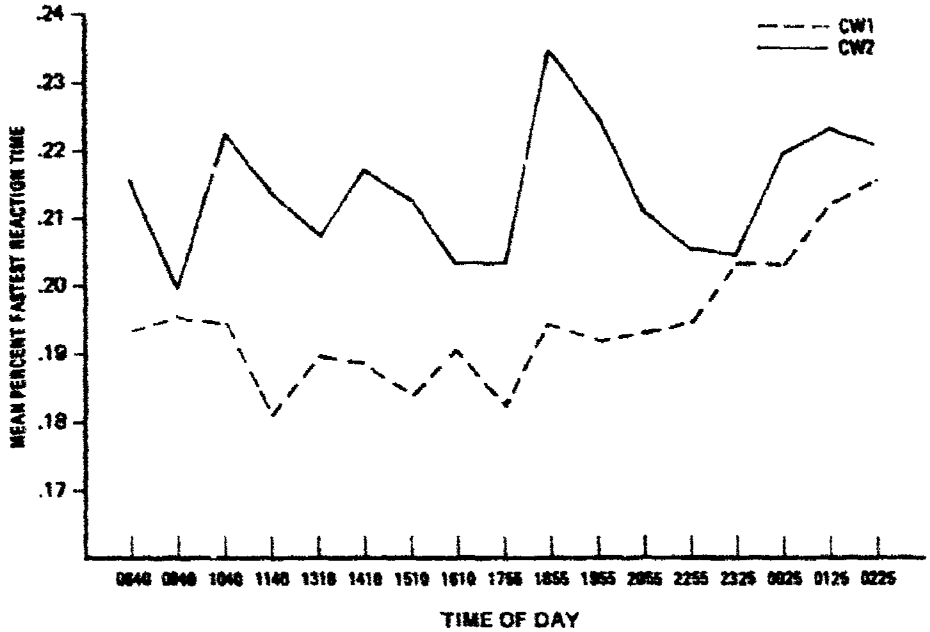

Figure 2 - CW1 and CW2 Performance, Mean 10% Fastest Reaction Time (Secs): Mean Scores of Combined Groups Plotted by Time-of-Day (N=22)

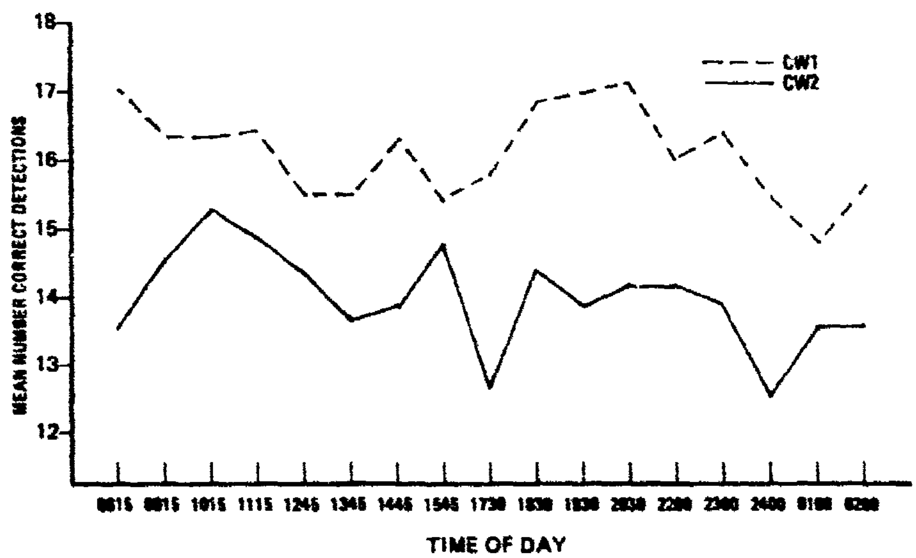

Figure 3 - Alpha-numeric Visual Vigilance Task, Mean Number of Correct Detections

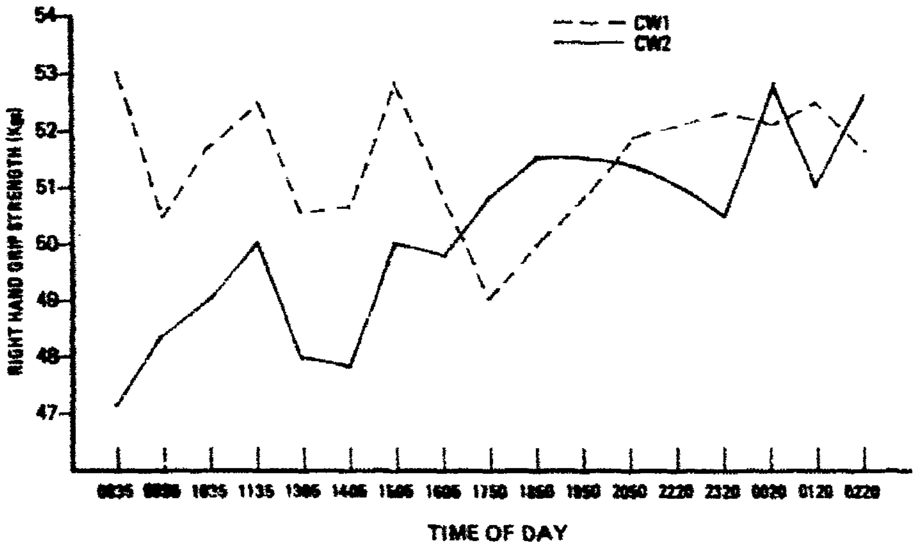

Figure 4 - Right Hand Grip Strength (Kgs)

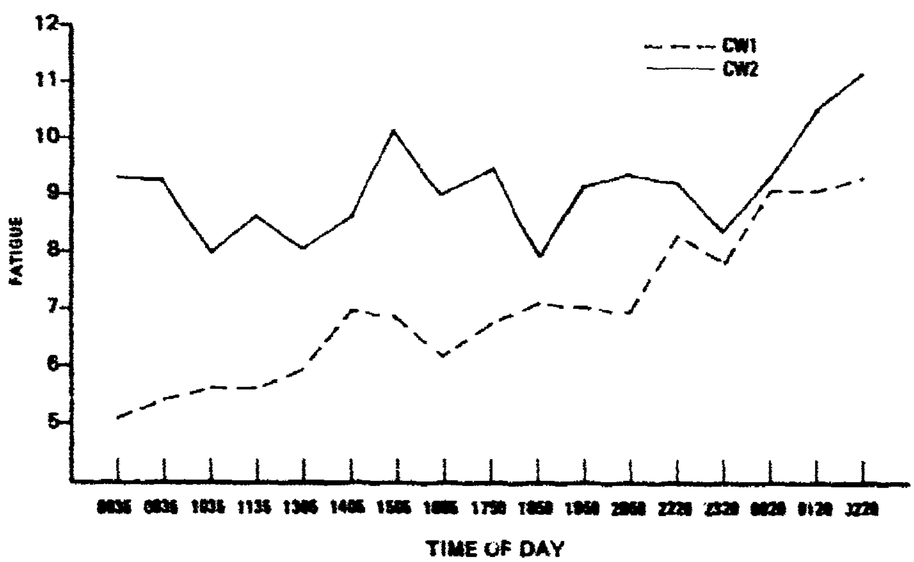

Figure 5 - School of Aerospace Medicine Subjective Fatigue Checklist

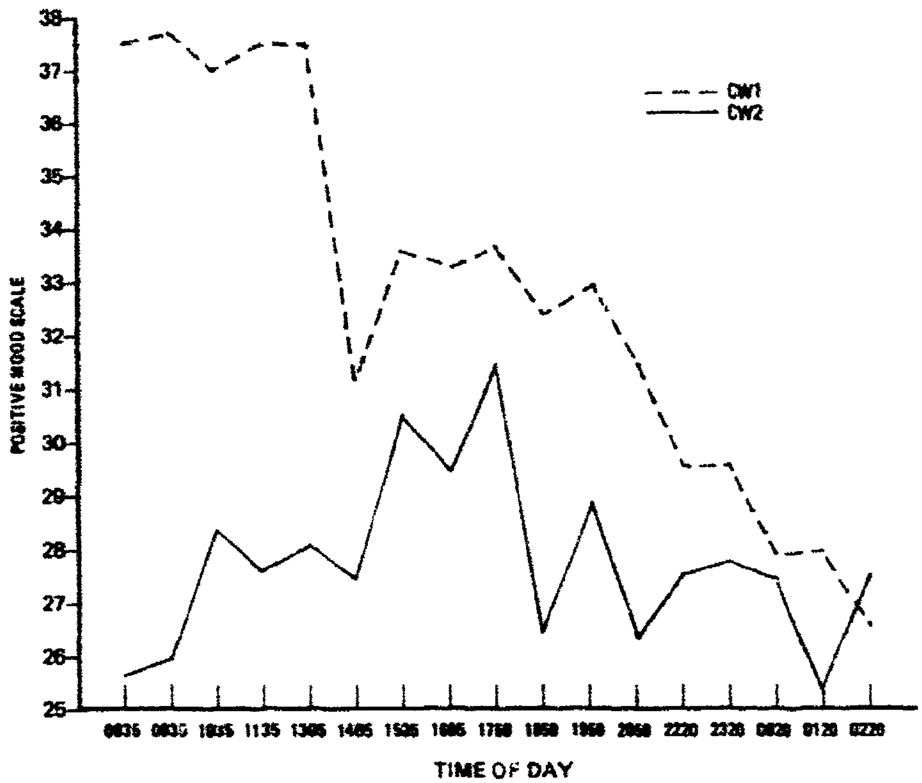

Figure 6 - Naval Health Research Center Mood Scale (Positive Mood)

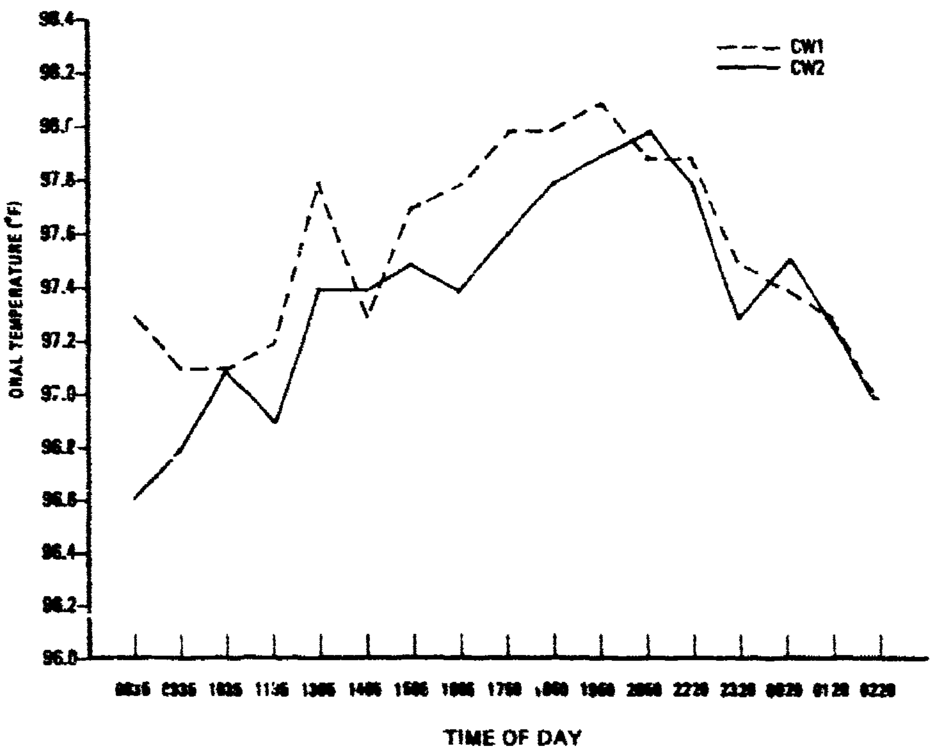

Figure 7 - Oral Temperature (degrees Fahrenheit)

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REPORT DOCUMENTATION PAGE

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Circadian Rhythm	Mood	Military Tasks
Continuous Work	Cognitive Performance	Multivariate Design
Sustained Operations	Nap	Repeated Measures
Fatigue	Vigilance	Human Factor
Physical Work	Sleep	Electrophysiology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During times of emergency, e.g., military operations, humans must often work continuously for long hours at physically demanding tasks while remaining mentally alert. In this repeated measures study eleven pairs (one experimental and one control) of Marines (N=22) experienced one 12-hour baseline and two 20-hour continuous work episodes (CWE). The 20-hour CWEs were separated by five hours which included a 3-hour nap from 0400-0700. Each hour of CWE was split into two half-hour sessions. During the first half-hour (over)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) subjects performed alpha-numeric (A-N) visual vigilance tasks. The experimental member of each pair spent this first 30 minutes also walking on a treadmill in full combat gear (25 kg) at approximately 31 percent max VO_2 heart rate for a total distance of approximately 114 km. The controls performed the A-N task sitting quietly at a video terminal. During the second half-hour, all subjects completed mood and fatigue scales and performed selected combinations of tasks. Biomedical and electrophysiological sleep recordings were obtained on both subjects.

Results indicated: (a) Mood scales showed that subjects expressed significantly more fatigue and expressed more negative affect during the second sustained operation. (b) No significant sleep stage changes were found. (c) Generally, after nap performance (0800) was not significantly different than CW1 ending performance level. (d) The physical workload did not affect performance, but sleep loss and circadian effects produced performance decrements in some tasks. We concluded from a comparison with our previous nap studies that the timing and duration of the nap are important in determining recuperative value. When designing work/rest schedules to maintain high quality performance in recurring CWEs as short as 20 hours, a 3-hour or longer nap during the circadian nadir may be required.