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MINUTEMAN MISSILE CREW FATIGUE AND 24-HOUR ALERTS

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A battery of psychobiological measures was used to evaluate the degree of fatigue experienced by missile crews performing 24-hour continuous duty alert tours at Minuteman launch control centers. Operationally significant findings relative to the duty schedule occurred for subjective fatigue scores, hours slept per day, and urinary outputs of 17-OHCS, sodium, and potassium. The moderate postalert fatigue and physiologic cost present at the end of the 24-hour alerts were ameliorated by one night of undisturbed sleep. Values indicative of severe crew fatigue or stress were never attained for any of the measures. A buildup

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20. ABSTRACT (Continued)

of cumulative fatigue over several alerts could be avoided by scheduling a minimum of two consecutive nights sleep at home between alerts. The impact of the duty schedule on contingency and emergency situations was also considered.

MINUTEMAN MISSILE CREW FATIGUE AND 24-HOUR ALERTS

INTRODUCTION

As part of the RIVET SAVE modification program, SAC is implementing 24-hour continuous duty alert tours at Minuteman launch control centers. Under the previous 36- to 40-hour discontinuous alert tours, one two-man Minuteman crew was on alert in the launch control center while another rested in the above-ground support facility. About one-third of a crew's duty tour was spent in a nonalert status. Under the new system, a crew will spend an entire 24-hour tour in the launch control center, with the two crewmen being permitted to sleep, one at a time, during periods of low workload. The crew will be relieved by a fresh crew reporting directly from the main base. Thus, the 24-hour schedule results in a considerable manpower savings. To insure that the 24-hour alert procedure had no adverse effect on operational effectiveness, SAC/DOMV requested that personnel of the Crew Technology Division at the USAF School of Aerospace Medicine (SAM/VN) study and evaluate the impact of the new schedule on missile crew fatigue and ground safety.

METHOD

Twelve crews at Malmstrom AFB, MT were selected for participation in the SAM study. Six of the crews were from the A-M ("Mod") system and six were from the B ("Deuce") system. The two systems are, for the most part, very similar, but do differ in the physical layout of the control centers and in some specific pieces of hardware. The crews represented a cross section in terms of experience and age. The missile launch centers involved in the study included Alternate and Squadron Command Posts. Eleven different A-M sites and three different B sites were manned during various alerts by crews participating in the study.

A typical 24-hour alert tour schedule is presented in Table 1. Depending on the driving conditions and the driving distance between the base and the site, the changeover between crews usually occurred between 0900 and 1200 hours. Assuming the authorized maximum speed of 50 mph, one-way driving time to the sites involved in the study ranged from less than 1 hour to 3.5 hours. Thus, a complete duty cycle usually encompassed a 28- to 30-hour interval.

A battery of psychobiological measures was used to evaluate crew fatigue. The measures consisted of self ratings of subjective fatigue, sleep surveys, and biochemical indices derived from analysis of urine samples. An extensive data base has been developed on these measures in past studies on a wide range of Air Force operations (1, 4, 5). The subjective fatigue questionnaire (Fig. 1) yielded a score from 0-20, with lower scores indicating feelings of greater fatigue (6). The sleep survey (Fig. 2) documented the total hours slept during each 24-hour period. The urinary determinations were 17-hydroxycorticosteroids (17-OHCS), an index of adrenocortical activity; and sodium and potassium, both indices of mineral metabolism. In addition, the ratio of sodium to potassium was calculated as an index of metabolic balance (homeostasis). Environmental factors, as well as intrinsic factors, induce increases in the output of some or all of these selected physiologic variables (1, 4). Each urinary measure was adjusted to a quantity per 100 mg creatinine. The use of the creatinine-based ratio corrects for variations in the timing of urine collections, as well as variations in subject body size and age (2, 3).

TABLE 1. TYPICAL ALERT TOUR CYCLE

0745	Arrive squadron
0800	Pre-departure briefing
0810	Depart base
0945	Arrive launch control center
1000	Changeover with off-going crew
1030	Perform inspections
1030 - 1000 Next Day	Monitor weapon system status
1000	Changeover with oncoming crew
1030	Depart launch control center
1200	Arrive base

Data were collected from each crewman for a period of 10 consecutive days. During this sequence, days 3-4 and days 7-8 were alert tour intervals; the remaining days were nonalert days during which time other squadron duties and days off were scheduled. Subjective fatigue ratings and urine samples were collected at about 0800, 1200, 1600, and 2000 hours each day. The urine samples were mixed immediately with dilute HCl acid and frozen within 24 hours for later biochemical analyses. Sleep surveys were completed only at 0800 each day.

Three crews from each of the two weapon system types (A-M vs. B) started the 10-day sequence of data collection at 0800 on 12 July 1977.

NAME AND GRADE			TIME/DATE
INSTRUCTIONS: Make one and only one (✓) for each of the ten items. Think carefully about how you feel RIGHT NOW.			
STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7. PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

PREVIOUS EDITION WILL BE USED

SAM FORM SEP 76 136 SUBJECTIVE FATIGUE CHECKCARD

Figure 1. SAM Form 136. A Subjective Fatigue Checkcard was completed at 0800, 1200, 1600, and 2000 hours each day of the study.

SLEEP SURVEY

NAME (Last, First, MI)	GRADE	DATE/TIME

1. On the chart below, mark an **X** in each half hour interval you slept yesterday and today.

YESTERDAY

MID-NIGHT 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 MID-NIGHT

TODAY

MID-NIGHT 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 MID-NIGHT

2. HOW MUCH TROUBLE DID YOU HAVE GOING TO SLEEP LAST NIGHT?

☐ NONE ☐ SLIGHT ☐ MODERATE ☐ CONSIDERABLE

3. HOW RESTED DO YOU FEEL?

☐ WELL RESTED ☐ MODERATELY RESTED ☐ SLIGHTLY RESTED ☐ NOT AT ALL

4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP?

☐ YES ☐ NO

SAM FORM SEP 78 154 PREVIOUS EDITION WILL BE USED REMARKS ON REVERSE

Figure 2. SAM Form 154. A Sleep Survey was completed at 0800 hours each day of the study.

The remaining crews from each of the two systems started data collection at 0800 one day later on 13 July. After being given proper instruction, the study procedures were easily self administered by each crewman, and could be completed in less than 5 minutes at his residence, squadron, or duty site. Completed materials were turned in and new ones issued each time the crewmen reported for pre- and postalert briefings. This procedure permitted adequate interaction between the study director and the crewmen without overly disrupting normal duties and personal activities during the 10-day study period.

RESULTS

For purposes of analysis, the subjective fatigue and biochemical data were grouped into intervals which corresponded with the 28-30 hours of duty typically experienced by the launch crews. By grouping each pair of successive study days, five functional intervals were formed consisting of three nonalert intervals separated by two alert tour intervals. Within each of these 2-day intervals, data from 1200, 1600, and 2000 on the first day and 0800, 1200, and 1600 on the second day were statistically analyzed. The sleep data were analyzed for the total time slept during each 24-hour interval (1200-1200) over the 10-day study. Because of missing data, it was necessary to omit one A-M crew and one B crew from all of the analyses. Another A-M crew was included in the sleep analysis, but excluded from the subjective fatigue and biochemical analyses.

Analysis of variance of the fatigue ratings, hours spent sleeping, and biochemical measures revealed no systematic differences related to missile system type (A-M vs. B) or to crew position (commander vs. deputy). Therefore, these data were combined for the analyses of effects relating to the schedule over the 10-day study period. Typical within-day (circadian) changes were found for all of the measures. Operationally significant findings relating to the duty schedule occurred for subjective fatigue scores, hours slept/day, and the urinary outputs of 17-OHCS, sodium, and potassium. The sodium/potassium ratio was not significantly modified by the 24-hour alerts. Mean absolute values indicative of severe crew fatigue or stress were never attained for any of the measures. However, the patterns of change over time were meaningful operationally, and levels of moderate fatigue and biochemical activity occurred which could become significant in contingency or emergency situations.

The crewmen slept an average of 8.1 hours on nonalert nights which neither preceded nor immediately followed an alert tour (Table 2). A slight reduction to an average of 7.2 hours occurred on the nights immediately preceding alert tours. During alert tours, the crewmen averaged 5.9 hours of sleep. An average of 9.7 hours of sleep occurred during the 24 hours following an alert. Whereas sleep was typically acquired in one continuous block during nonalert nights, that acquired during alert tours was usually in two or three discontinuous blocks, lasting 2-4 hours and sometimes occurring during normal hours of wakefulness.

TABLE 2. AVERAGE HOURS SLEPT/DAY

Immediate prealert days	7.2 hours/continuous
Alert days	5.9 hours/discontinuous
Immediate postalert days	9.7 hours/continuous
Other nonalert days	8.1 hours/continuous

Time trends within each interval for the subjective fatigue, 17-OHCS, sodium, and potassium data are presented in Figures 3 and 4. Figure 3 demonstrates the consistency of the changes within each of the three nonalert intervals versus the different but also consistent changes within the two alert intervals. By combining similar types of intervals, Figure 4 describes the overall differences between nonalert and alert intervals. Graphically, the difference in pattern between nonalert and alert intervals is most apparent for the subjective fatigue data. During the nonalert intervals, the changes over time followed established circadian patterns. The crewmen were fresh and alert during the midday (1200 and 1600), relatively tired and less alert in the evening (2000), somewhat rested and recovered after a night of sleep (0800), and returned to peak alertness at midday. The pattern was considerably different during the alert intervals, resulting in a significant ($P = .003$) interval x time interaction. As during the nonalert intervals, a general increase in fatigue (decreasing scores) occurred during the initial part of the alert interval (1200-2000). However, low subjective fatigue scores were still reported at 0800 the next morning, with no improvement and, perhaps, even further deterioration through the end of the alert interval.

Although not as conspicuous, changes in the urinary measures provided support for the subjective fatigue differences found between nonalert and alert intervals. As in the fatigue data, circadian variations occurred during the nonalert intervals for 17-OHCS, sodium, and potassium. During the alert intervals, the circadian patterns were generally maintained, but with modest elevations in urinary output occurring throughout most of the alert tour for sodium and during the late morning hours for 17-OHCS and potassium. These interval x time reactions were also statistically significant: sodium, $P = .002$; 17-OHCS, $P < .001$; potassium, $P = .012$.

DISCUSSION

The moderate fatigue experienced by the crews during the latter portion of the alert tours resulted from a busy schedule of activities during the first half of the alert, combined with a reduction in the quantity and the quality of sleep acquired while in the launch control center. The quality of sleep was reduced by the inherent requirement for short periods of sleep, the poor sleeping environment (noise, light, vibration), and the salubrious inability of the crewmen to completely relax while responsible for the status of a complex weapon system. The increased urinary output of 17-OHCS, sodium, and potassium during the alerts reflects increased metabolic activity in response to the demands being made on the organism. The increased metabolic activity is an adaptive process permitting the organism, at some physiologic cost, to maintain itself while under the demands of the alert tour. The nonsignificant effect of the alert schedule on the sodium/potassium ratio is further evidence of the maintenance of physiologic homeostasis.

Thus, the moderate crew fatigue and physiologic cost resulting from the alert tours were ameliorated by a good night's sleep. The recuperative value of an uninterrupted night of sleep has been well documented (1, 4, 5). In Figure 3, the absolute levels of all the measures were relatively constant for the three nonalert intervals, indicating (1) recovery after a slightly extended (9.7 hours) night of sleep at home, and (2) the absence of a cumulative buildup in fatigue or physiologic cost over the duration of the study. The fact that the crewmen had two nights of sleep at home between the two alerts was also significant in preventing any cumulative fatigue effects. These are important findings, and support current scheduling procedures as being realistic and within the capabilities of the crewmen.

The crew fatigue reported at the end of an alert dictates the need for caution and vigilance during the return drives to the main base. An advantage of the 24-hour alert tours over the 36- to 40-hour alert tours is that most road travel involving the missile crews will occur during daylight hours, a positive factor in maximizing automobile safety. As is current practice, the vehicle operator should be the crewman who slept last or longest. For extreme distances, trading off operator responsibilities between crewmen once or twice during the drive may aid alertness. When able to sleep very little or not at all during an alert, crewmen should be encouraged to sleep in the support facility for a few hours before returning to the main base. It is important that both crewmen be qualified to drive the shuttle vehicles.

The present study did not deal with contingency or emergency situations, such as bad weather, when a crew may be required to remain on alert for an extended period. Using the work/rest data base accumulated over prior studies (7), the current findings may be extrapolated for extended alerts of 48-72 hours total duration. For the systems evaluated in this study, operational effectiveness could be maintained for 72 hours providing the crewmen continued to acquire 5-6 hours of sleep each 24 hours. Of course, the physiologic cost will be substantial and a crew will require extra crew rest upon completion of an extended alert. If no sleep is acquired during a typical 24-hour alert and an extension of the alert is required without sleep, performance impairments are likely to occur at 36-48 hours, with the hours 0200-0600 being the most sensitive to lack of sleep.

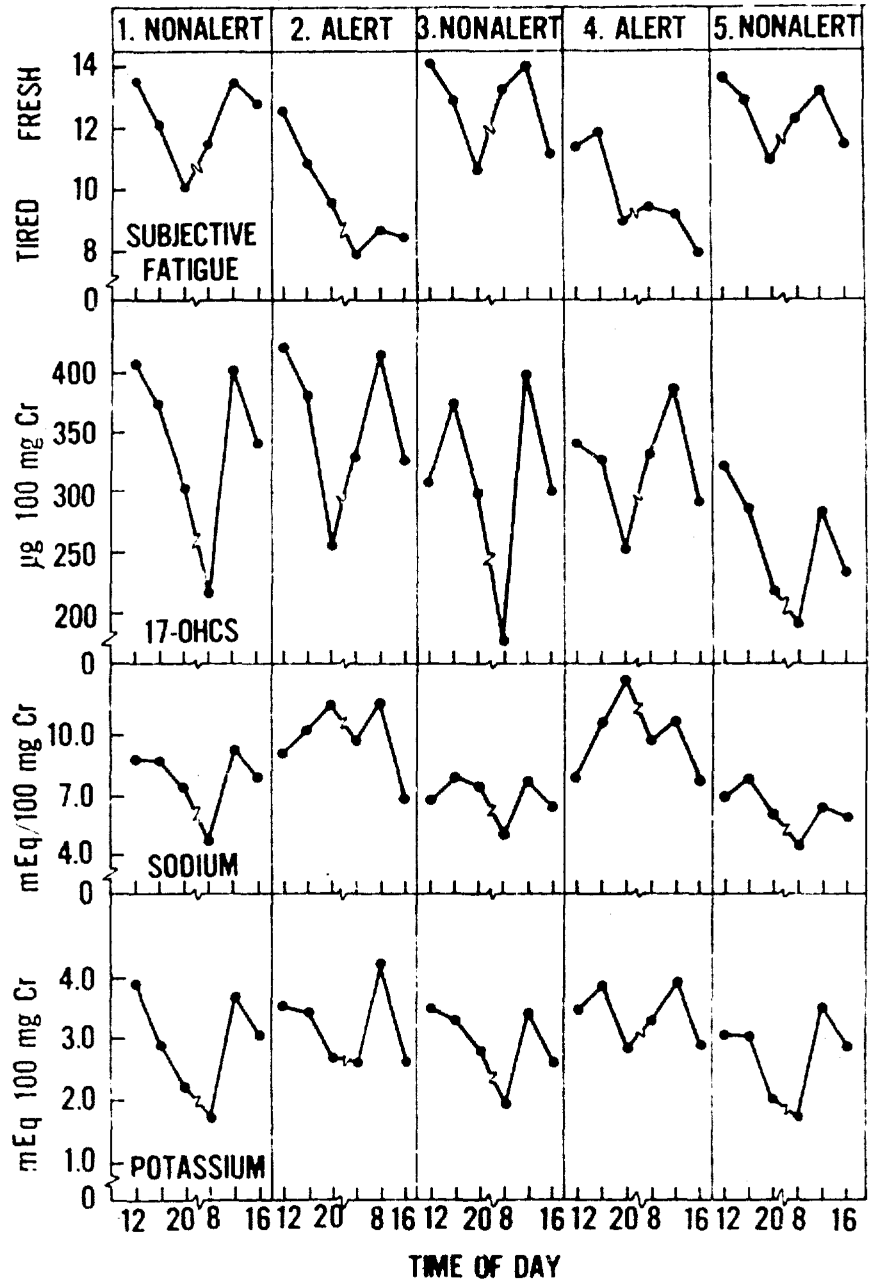

Figure 3. Mean values at 1200, 1600, and 2000 hours for the first day and 0800, 1200, and 1600 hours for the second day of each nonalert and alert interval.

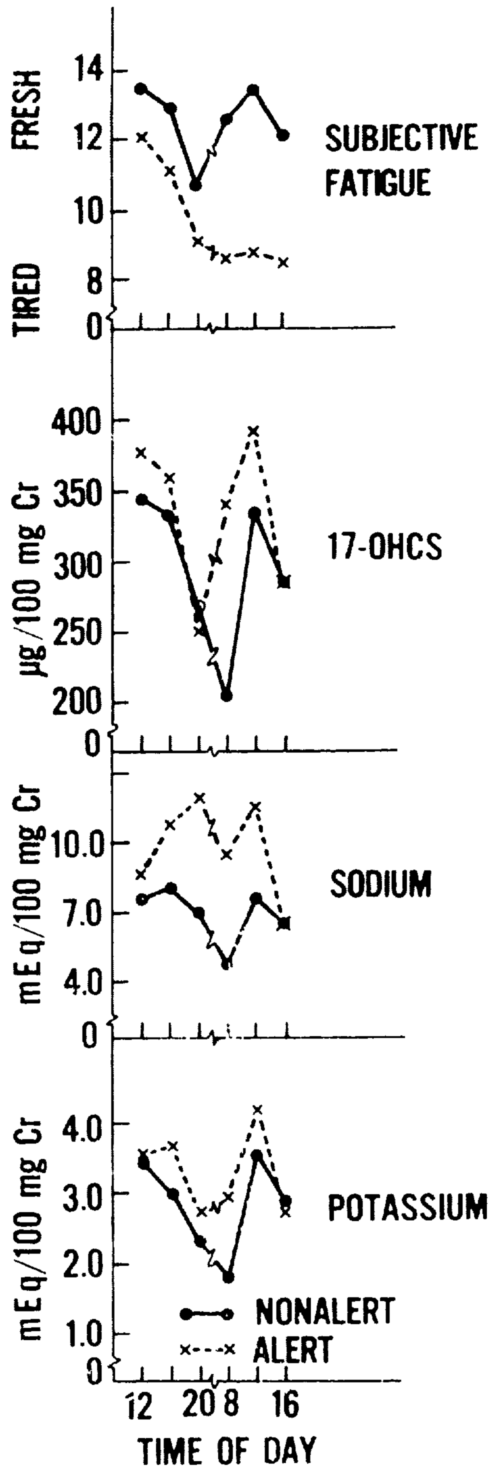

Figure 4. Average nonalert and average alert intervals.

Additional information was collected from the crewmen during interviews. While all the crews followed the same schedule during the study, during the preceding two weeks some of the crews had no alerts while others were assigned three and, in one case, four. Informal analysis indicated no relationship between the number of alerts prior to the study and subjective fatigue responses during the study, providing further evidence that cumulative fatigue is not occurring under current scheduling procedures. Another comparison indicated no differences between the subjective fatigue responses reported during alerts at command posts versus standard launch control centers. A majority (75%) of the crewmen participating in the study preferred the 24-hour alerts to the longer discontinuous alerts. The reasons cited for their preference included more time with their families and less disruption of normal sleep schedules. The crewmen who preferred the 36- to 40-hour alerts cited job-related factors such as more time to accomplish duties and studies and, in their opinion, better crew effectiveness when both crewmen are awake.

CONCLUSIONS

The following conclusions support current 24-hour alert scheduling procedures as being realistic and within the capabilities of the launch crews.

1. Moderate crew fatigue and physiologic cost are present at the end of a 24-hour alert. The fatigue is not so great as to indicate a decrement in crew effectiveness.

2. The postalert fatigue and physiologic cost are ameliorated by one night of undisturbed sleep in the home sleeping environment.

3. Scheduling a minimum of 2 consecutive nights sleep at home between alerts is important for avoiding cumulative fatigue effects over several alerts.

4. If necessary, a crew could effectively manage a control center for 2 or 3 days, providing they received 5 to 6 hours sleep every 24 hours. Without sleep, performance decrements will occur at 36-48 hours.

5. Upon completion of a typical 24-hour alert, crews are capable of returning safely to the main base using the shuttle vehicles. However, because of the fatigue, the need for caution and vigilance must be emphasized.

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