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The Effects of Exercise Versus Napping on Alertness and Mood in Sleep-Deprived Aviators (Reprint)

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Aircrew Health and Performance Division

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THE EFFECTS OF EXERCISE VERSUS NAPPING ON ALERTNESS AND MOOD IN SLEEP-DEPRIVED AVIATORS

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SUMMARY

A quasi-experimental approach assessed the comparability of exercise versus napping for maintaining alertness in aviators deprived of sleep. Subjective and objective data from two sleep-deprivation studies were pooled. Thirty aviators were included, 18 who were given zolpidem induced naps during the deprivation period and 12 who exercised during 40 hours of continuous wakefulness. Performance on Repeated Tests of Sustained Wakefulness, Profile of Mood State questionnaires, and Visual Analogue Scales was assessed. Zolpidem-induced naps were superior to rest in sustaining mood, and alertness on both a subjective and objective test. Napping was also clearly better than exercise for attenuating changes in mood and subjective alertness typically produced by sleep loss.

INTRODUCTION

Tasks that place heavy demands on working memory, that call for sustained attention, or require creativity even for short durations are affected by sleep deprivation. In general, tasks that require sustained concentration and vigilance such as monitoring radar screens and control panels are the most susceptible to the influences of sleep deprivation (SD). Sleep deprivation produces periods of slow performance and periods of non-performance or lapses. As the duration of sleep loss increases, the lapses increase in frequency and duration. Williams et al.² found that on a 10 minute monotonous vigilance-test which is typically performed without difficulty, after one night of sleep loss, performance began to degrade within 7 minutes. On this same task, after 2 nights without sleep, the degradation began after 2 minutes. Hockey^{3,4} has shown that sleep deprivation produces slower reaction times on tracking tasks and that subjects become more easily distracted and have difficulty concentrating on sustained attention tasks such as card sorting.

There is considerable evidence which shows that napping can be used as an effective countermeasure to the effects of sleep deprivation. In a study conducted by Bonnet,⁵ some subjects napped before a 52-hour continuous performance period while others remained awake. The nap was beneficial in keeping performance and alertness from decreasing for up to 24 hours of

sleep loss as compared to the no-nap condition. In a study by Naitoh and colleagues,⁶ subjects were given a 3-hour nap after being awake for approximately 24 hours. After the nap, they were required to stay awake an additional 20 hours. Results indicated that this 3-hour nap reduced the decline in performance during the additional work period. Other studies have found similar results using 24 hours of sleep deprivation.⁷⁻¹⁰ In each case, naps taken prior to extended periods of sleep loss, "prophylactic naps," considerably attenuated the decrease in performance.

Naps are especially effective when they are properly planned in relation to the timing of work requirements, and placed at times that are most conducive to natural sleep.¹¹⁻¹⁹ A nap is most beneficial if taken before significant sleep loss occurs, a prophylactic nap,^{7,8} and sleep occurs most readily and performance is sustained most effectively when naps are placed in the circadian troughs (although post-nap grogginess may be exacerbated at that time).^{8,21} Unfortunately, in real world scenarios, it is often difficult to place naps at times when optimal results will be achieved. For instance, while personnel may have opportunities for prophylactic naps prior to sustained wakefulness, operational constraints may prevent the scheduling of naps when people are most able to initiate and maintain sleep. In these situations, it may be necessary to use a short acting hypnotic such as zolpidem tartrate to promote restful and restorative sleep.

Low doses of zolpidem (10 mg or less), have been shown to effectively promote sleep without inducing long-term hangover effects, alterations in sleep architecture, or severe performance impairments.^{22,26} Additionally, it has been shown to improve the benefits of prophylactic napping during periods of significant sleep loss. Caldwell and Caldwell²⁷ reported that while both placebo and zolpidem-induced naps were beneficial in terms of sustaining mood, alertness, and performance throughout the final 24 hours of 38-hour periods of sustained operations, zolpidem maximized these effects. Subjects were able to go to sleep faster, maintain sleep longer, and sleep more soundly following zolpidem administration when compared to placebo-induced naps. While postnap grogginess was seen for about 3 hours after awakening, it was present following both placebo and zolpidem administration. The benefits from napping, which

were seen toward the middle and end of the deprivation period, however, appeared to outweigh the early postnap inertia.

Despite these promising results, hypnotics such as zolpidem can produce adverse central and peripheral nervous system reactions such as headache, drowsiness, dizziness, lethargy, and a drugged feeling. The most common gastrointestinal reactions are nausea, dyspepsia, and diarrhea.^{28,29} For these reasons, some aviators may be unable or unwilling to use hypnotics during periods of sustained operations despite sleep loss. Even if personnel are willing to take advantage of this medication, the opportunity to expose each individual to a test dose to check for possible idiosyncratic reactions prior to deployment may not exist. Thus, it is important to find non-pharmacological interventions which can be used in cases where hypnotics are contraindicated.

Studies which examine arousers such as noise on SD performance, typically find that decrements in performance are to some degree ameliorated. Wilkinson³⁰ has reported that 100db of white noise reduced the error rate produced by 32 hours of SD on a serial reaction task. Similarly, 75db of pink noise improved speed of response at 0500, the lowest point of the circadian dip, on a spatial memory test in subjects subjected to partial sleep deprivation.³¹

While exercise is considered an arousing activity, little is known about the effects of exercise on alertness in SD subjects. To date, most sleep deprivation studies have employed exercise as an additional stressor.³²⁻³⁵ The most commonly used schedules of exercise are bouts of 30 continuous minutes/hour or 1 continuous hour/3 hours, throughout the duration of sleep deprivation. Despite the strenuous exercise schedules used in the above mentioned studies, cognitive and physiological performance decrements in sleep deprived subjects were not compounded by exercise. In the case of Englund et al.³⁴ vigilance decrements may have been delayed by as much as 8 hours when compared to nonexercising controls.

In spite of the extreme levels and durations of exercise typically used, there are some hints throughout the literature that exercise may be used in a practical manner, outside of the laboratory, as an effective method to increase alertness/arousal during periods of sleep deprivation. It has been shown that short bouts of submaximal exercise can improve cognitive performance in nonsleep deprived subjects.^{36,37} Davey³⁷ examined the function of various amounts of exercise on a continuous attention task. Exercise had an inverted U-shaped effect on performance. Low intensity exercise had little or no effect, moderate submaximal exercise enhanced performance and exhaustive exercise produced decrements in performance. These and other studies provide supporting evidence that moderate levels of exercise can affect cognitive performance by raising arousal levels. While evidence does exist for the arousing properties of acute

submaximal exercise, few studies have been done which examine exercise induced arousal on cognitive performance in sleep deprived subjects.

The only study to date which directly examined the arousing effects of short bouts of submaximal exercise in sleep deprived/restricted subjects was conducted by Horne & Foster.³⁸ These researchers examined the effects of 10 minutes of exercise, at four different levels 0%, 20%, 40%, and 70% VO₂max, on performance of sleep restricted people. Subjects were restricted to 4 hours of sleep on the previous night and subsequently tested between 14:00-16:00. These authors used the Wilkinson Auditory Vigilance Test (purported to be extremely sensitive to changes in sleepiness/alertness). The 30-minute test was given prior to exercise and re-administered following 10 minutes of exercise and 5 minutes of rest. Exercise at all levels (20, 40, & 70%) produced some improvement in vigilance. The only significant change, however, was seen in subjects who exercised at the highest level (70%). Postexercise vigilance measures were significantly better in the high exercise group. Self-rated alertness was improved in all exercise groups but the effects were short lived, lasting only 10-15 min in the low (20%) and middle conditions (40%). In the high exercise condition (70%), this effect was extended to 30 minutes. As self-rated measures of sleepiness and exertion are more highly correlated with performance than physiological measures,^{32,35,39} it may be possible to capitalize on the alerting effects of short bouts of submaximal exercise in sleep deprived aviators

In cases where subjects are required to perform sustained attention tasks such as monitoring radios and radar screens or routine tasks such as preflighting aircraft, short bouts of submaximal exercise may prove to be a useful cognitive arouser. The literature shows that exercise produces improvements or can reduce or delay the onset of decrements in auditory and visual vigilance tasks in sleep deprived subjects.^{34,36,37} However, of these studies, none have been aviation-related. When operational or medical constraints prevent the use of pharmacological countermeasures (hypnotic-induced naps) for the alleviation of aircrew fatigue, behavioral strategies such as short bouts of exercise may provide a safe alternative for maintaining aviator performance.

This paper attempts to address these issues by comparing data collected during two studies, one on the effects of zolpidem-induced naps, and the second on the effects of exercise for maintaining alertness in sleep-deprived pilots. The first was a study by Caldwell et al.,⁴⁰ in which 18 aviators were kept awake for 12 hours, given a 2 hour nap or 2 hours of rest, followed by an additional 24 hours of wakefulness. During the period of sustained wakefulness, subjects completed mood, cognitive, and alertness evaluations. The second was a study by LeDuc et al.,⁴¹ in which 12 aviators were kept awake for 40 continuous

hours. Subjects were awake for 18 hours prior to the beginning of the intervention. Subjects exercised (treadmill running at 70% VO_2max) or rested for 10 minutes, every 2 hours, during the next 18 hours of sustained wakefulness. During this period, subjects completed cognitive, mood, and alertness evaluations. Data from the two studies were combined for the present set of analyses.

METHODS

Subjects

Two groups of subjects were compared. Thirty subjects between the ages of 22 and 35 (mean=26.6) were recruited from Fort Rucker and other Army installations. Twenty-nine subjects were males and one was female. Fifteen of the subjects were flight students, and 15 were rated helicopter pilots. All subjects gave informed consent and were medically evaluated prior to testing. Subjects were healthy, used only small amounts of caffeine (no more than three 8-ounce cups caffeinated coffee or five 12-ounce caffeinated soft drinks per day) and reported no problems sleeping. Subjects remained inside of the U.S. Army Aeromedical Research Laboratory at Fort Rucker, Alabama, for the duration of testing. Groups consisted of 18 volunteers who participated in a zolpidem-induced napping study and 12 volunteers who participated in a study examining the effects of exercise on alertness in sleep deprived aviators.

Apparatus

Mood evaluation. The Profile of Mood States (POMS) was used to assess subjective reports of mood at various times throughout the day.⁴² This paper-and-pencil questionnaire consisted of 65 items which measured affect on 6 scales: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. The answers were scored by hand with scoring templates.

Sleepiness evaluations. Subjective sleepiness was measured via the Visual Analog Scale (VAS) which consisted of eight 100 mm lines centered over the adjectives "alert/able to concentrate," "anxious," "energetic," "feel confident," "irritable," "jittery/nervous," "sleepy," and "talkative". At the extremes of each line, "not at all" and "extremely" were printed, respectively.⁴³ Scores consisted of the distance of the subject's mark from the left end of the line (in mm).

Objective sleepiness/alertness was measured using the Repeated Test of Sustained Wakefulness (RTSW) in which the subject's electroencephalogram (EEG) was recorded for up to 20 minutes using a Nihon Kohden electroencephalograph (Model No. EEG-4321 P) during the test to objectively determine whether or not he/she successfully remained awake (subjects were awakened and removed from the room immediately if they fell

asleep). Records were scored in terms of the number of minutes from lights out until sleep onset, up to 20 minutes.⁴⁴

Procedure

Both groups of subjects completed assessments of flight performance, cognitive performance, mood, and sleepiness during the 40-hour periods of sleep deprivation. Flight performance and cognitive performance were assessed at different times (more than 2 hours apart) during these studies and thus were deemed not comparable. However, mood and sleepiness evaluations from the two studies were given within +/- 20 minutes of each other.

Mood evaluation. For the zolpidem group, the POMS was administered every 2 hours beginning at 0900 on training and control days and at 0100 on sleep deprivation days. The last administration occurred at 1900 each day. For the exercise group, the POMS was administered every 2 hours beginning at 0920 on training and control days and at 0120 on sleep deprivation days. The last administration occurred at 1920 each day. The test was administered using the standard POMS answer sheet on which subjects indicated how well each of 65 adjectives described the way they were feeling at the time. The test took approximately 5 minutes.

Sleepiness evaluations. For the zolpidem group, the VAS was administered every 2 hours from 0905 to 1905 on training and control days, and from 0105 to 1905 on test days. For the exercise group, the VAS was administered every 2 hours beginning at 0925 on training and control days and at 0125 on sleep deprivation days. The last administration occurred at 1925 each day. Each subject was given a test sheet containing a series of 100 mm lines drawn horizontally over the adjectives described earlier. At the extremes of each line, "not at all" and "extremely" were printed, respectively. The subject placed a mark on the line to indicate his present feelings.

The RTSW occurred every 4 hours, immediately following the VAS. Subjects were required to lie on a bed in a quiet, darkened room after being instructed as follows: "lie as still as possible with your eyes closed and do your best to remain awake." During the RTSW, EEG data were recorded from electrode sites C3, C4, O1, and O2, referenced to the contralateral mastoid. The subject was allowed to remain in bed either until 20 minutes had elapsed or until he/she entered stage 2 sleep (the first K complex or sleep spindle). The elapsed time from lights out until sleep onset was recorded.

Testing schedule. Subjects arrived at the laboratory at 1800 on Day 1 when the studies were explained, informed consent was obtained, and a medical evaluation was conducted. Subjects with past psychiatric or cardiac disorder, a history of sleep disturbances, or any current significant illness would have been

rejected, but none of these problems were found. Following wake up on Day 2, the aviators completed three practice sessions on all tests before retiring. In the zolpidem study on Days 3,5, and 7 tests were conducted to establish baseline. At the end of Days 3, 5, and 7, subjects in the zolpidem study were given a 2 hour zolpidem-induced nap, a placebo-induced nap, or 2 hours of rest, in a counter balanced order, from 2100-2300. They remained awake until 2205 on the following evenings (Days 4,6, and 8). On Days 3 and 5, in the exercise study tests were conducted to establish baseline. At the end of Days 3 and 5, subjects in the exercise study remained awake. This group exercised (treadmill running at 70%₂ VO₂max) or rested for 10 minutes every 2 hours beginning at 0100 and ending at 1900 on Days 4 and 6. Conditions were also counter balanced. The first test during the deprivation conditions began at 0100 in the Zolpidem group and 0120 in the exercise group. Testing continued until the participants retired at 2300.

RESULTS

Data were transformed to Change from Baseline using the formula Test score-Baseline score=Change score. The last baseline score prior to the deprivation period was used in the transformations. BMDP4V was used to conduct a series of analyses of variance (ANOVA) on mood and sleepiness.” The between-subjects factor was group (Zolpidem, Exercise, and Rest). The Rest group was not a true level of a between subjects factor as it was composed of data from the rest conditions of two studies and not an independent sample. However, in order to compare the effects of two interventions to performance under no intervention, rest data from all 30 subjects were pooled and treated as a third group. The within-subjects factor was session (10 levels for POMS and VAS and 6 levels for RTSW). Significant interactions and main effects were followed up by analysis of simple effects and/or pairwise contrasts. Huynh-Feldt adjusted degrees of freedom were used when violations of the compound symmetry assumptions were observed.

Mood evaluation

Change scores from each of the six scales on the POMS were analyzed with a two-way ANOVA. There were three levels of the between subjects factor group (Zolpidem, Exercise, and Rest) and 10 levels of the within subjects factor session (0100, 0300, 0500, 0700, 0900, 1100, 1300, 1500, 1700, and 1900). No main effects or interaction were observed on the depression-dejection or anger-hostility scales.

Tension-anxiety. The analysis indicated that there was a significant group by time interaction on self-repotted tension-anxiety (F(18,504)=1.63, p<.05). Simple effects tests showed that changes in tension-anxiety scores across sessions were significant only in the Zolpidem and Rest groups (figure 1).

Contrasts indicated that a sharp and significant increase in tension-anxiety was evidenced in the Zolpidem group at 1100. While ratings did decrease at the 1300 session, they remained higher than those reported during the first session at 0100. In the Rest group, tension-anxiety scores rose significantly between 0100 and 0300, and between 500 and 0700. With the exception of the 1500 session, ratings remained elevated above the 0100 through 0300 levels. Differences between groups were seen only at the 0300 and 0700 times, with the Exercise group reporting significantly more tension-anxiety than the Zolpidem group.

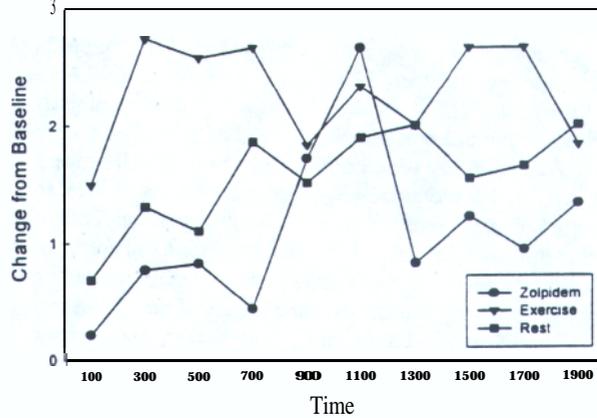


Figure 1. Effects of group and time on POMS tension-anxiety change scores.

Regardless of group assignment, ratings changed significantly across sessions during the deprivation period (F(9,504)=2.85, p<.003). An increase in tension-anxiety occurred during the deprivation period from 0100 to 0300. Tension-anxiety scores remained elevated throughout testing. A further increase in tension-anxiety was seen at 1100, but this elevation was not maintained (figure 2).

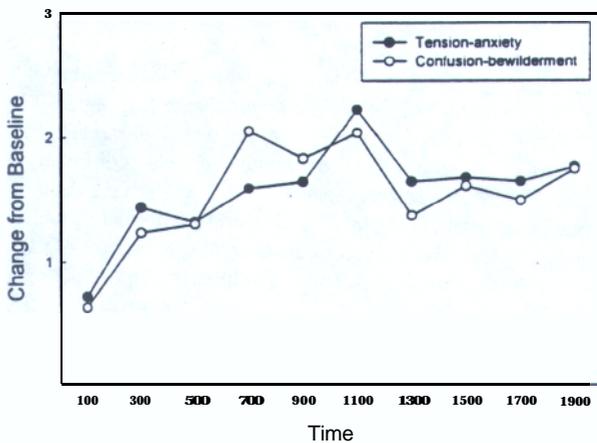


Figure 2. Effects of time on POMS tension-anxiety and confusion-bewilderment change scores.

Confusion-bewilderment. The analysis indicated that there were main effects for group ($F(2,56)=3.77, p<.03$) and time ($F(9,504)=5.73, p<.001$) but no group by time interaction. As illustrated in figure 2, confusion-bewilderment scores steadily increased from 0100, reaching a high at the 0700 session. Ratings remained elevated throughout the 1100 session and were followed by a decline at 1300. This level was then maintained throughout the rest of the deprivation period. Despite the decrease at 1300, ratings never returned to the levels seen during the first session at 0100. The main effect for group was attributable to the overall lower rating of confusion-bewilderment in the Zolpidem group than seen in either the Exercise or Rest groups (figure 3).

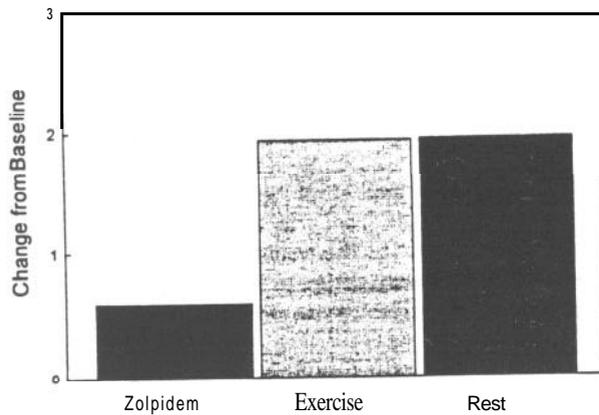


Figure 3. Effect of group on POMS confusion-bewilderment change scores.

Vigor-activity The analysis indicated that group assignment had no impact on vigor-activity scores (no group main effect or group by time interaction). A main effect for time was seen ($F(9,504)=12.12, p<.001$). As illustrated in figure 4, vigor-activity scores steadily and significantly declined from the 0100 to 0700 session. Ratings then plateaued throughout the remainder of the deprivation period, with the exception of a slight increase at 1300. This increase was not enough to return vigor-activity scores to the level initially seen during the first deprivation test at 0100.

Fatigue-inertia As shown in figure 4, changes in fatigue-inertia were mirror opposites of those seen in vigor-activity. A sharp and significant increase in fatigue-inertia occurred during the deprivation period from 0100 to 0700. Scores then remained elevated throughout testing, with the exception of a slight decrease at 1300. As with vigor-activity, this change was not enough to return fatigue-inertia scores to the level initially seen during the first deprivation test at 0100.

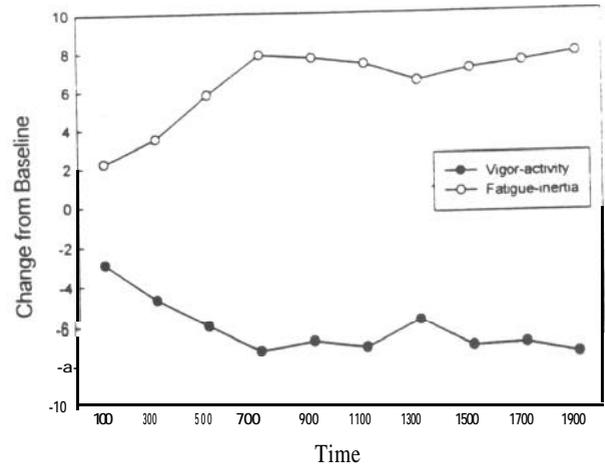


Figure 4. Effects of time on POMS vigor-activity and fatigue-inertia change scores.

Sleepiness evaluations.

Change scores from each of the eight scales on the VAS were analyzed with a two-way ANOVA. There were three levels of the between subjects factor group (Zolpidem, Exercise, and Rest) and 10 levels of the within subjects factor session (0100, 0300, 0500, 0700, 0900, 1100, 1300, 1500, 1700, and 1900). No main effects or interaction were observed on the anxiousness or jitteriness scales.

VAS alertness. The two-way ANOVA revealed a main effect for group, ($F(2,56)=4.72, p<.02$), a main effect for time ($F(9,504)=8.86, p<.001$), and a group by time interaction ($F(18,504)=2.36, p<.002$). As illustrated in figure 5, while self-rated alertness decreased to 9.58 below baseline after the zolpidem nap, alertness decreased twice as much in the Exercise (23.3) and Rest (22.67) groups.

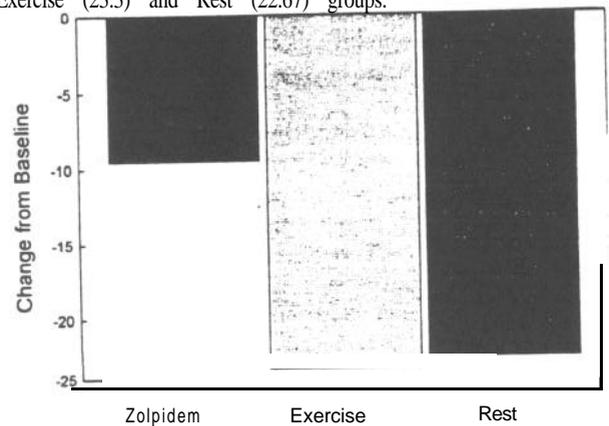


Figure 5. Effect of group on VAS alertness change scores.

Examination of the group by time interaction found that alertness ratings in the Zolpidem group did not change significantly across sessions. This differed from the Exercise and Rest groups. These groups exhibited very similar patterns of change across sessions (figure 6). Alertness declined steadily from the 100 to 0700 session. Some recovery was evident between 0900 and 1300; however, following the 1300 session, alertness began a slight decline which was maintained throughout the remainder of the deprivation period. Further, both the Exercise and Rest groups reported significantly lower levels of alertness than the Zolpidem group at 0500, 0700, 1500, 1700, and 1900.

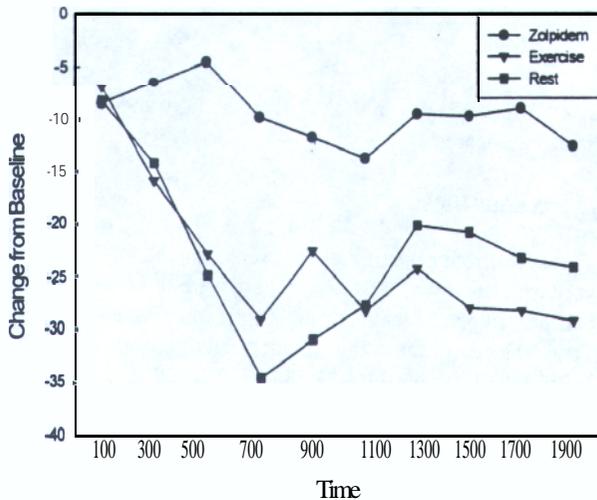


Figure 6. Effects of group and time on VAS alertness change scores.

Contrasts on the main effect for time showed that alertness decreased steadily from 0 100 to 0700. Ratings then plateaued throughout the 1100 session. A slight increase in alertness was evident at 1300, followed by a decline at 1500 and 1700. The increase at 1300 was not enough to return alertness scores to levels initially seen during the first deprivation test at 0 100.

VAS energy. A main effect for group ($F(2,56)=3.50$, $p<.04$) and a main effect for time ($F(9,504)=7.63$, $P<.001$) were found. There was no significant interaction of group by time. Contrasts showed that energy ratings in the Rest group were significantly lower than those in the Zolpidem group (figure 7). While ratings in the Exercise group tended to be lower than Zolpidem, they were not statistically different.

Contrasts on the main effect for time showed that energy exhibited a similar pattern of change across sessions as was seen in alertness scores. Energy decreased steadily from 0100 to 0700. Ratings then plateaued throughout the 1100 session. A slight increase in alertness was evident at 1300. This

increase however, was not enough to return alertness scores to the level initially seen during the first deprivation test at 0100.

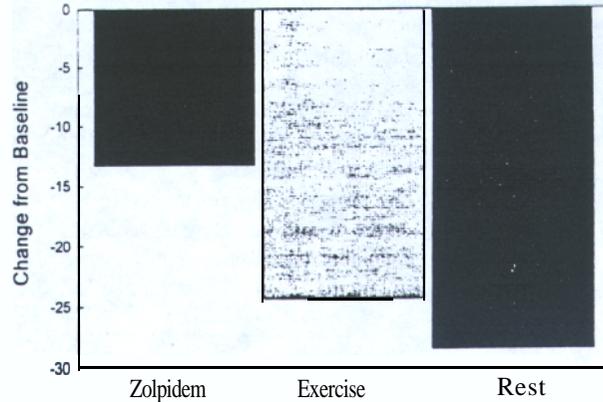


Figure 7. Effect of group on VAS energy change scores.

VAS confidence. Group assignment had no effect on confidence scores. No main effect for group or interaction with group was observed. There was a main effect for time ($F(9,504)=2.70$, $p<.005$). The changes in confidence scores across sessions were very similar to those seen in energy and alertness scores. Confidence scores decreased from 0100 to 0700. Ratings then plateaued throughout the 1100 session. Slight increases in confidence scores were seen at 1300 and 1900, however, ratings remained well below those of the first session at 0100.

VAS talkativeness. No main effect for group or interaction with group was observed. There was a main effect for time ($F(9,504)=3.24$, $p<.001$). As with other VAS measures, talkativeness declined from 0100 to 0700. Scores on this measure then began to increase such that the scores at 1300 and 1500 were not different than the one observed at 0100. A sharp decline in talkativeness was evident during the last two test sessions at 1700 and 1900.

VAS irritability. No main effect for group or interaction with group was observed. There was a main effect for time ($F(9,504)=4.33$, $p<.001$). Irritability slowly increased from 0100 to 0700 and plateaued through 1100. Irritability then declined at 1300 to the level seen during the first test session at 0100 and remained at this level throughout the 1900 session.

VAS sleepiness. The two-way ANOVA showed that there was no main effect for group, however, a group by time interaction ($F(18,504)=1.97$, $p<.01$) and time main effect ($F(9,504)=12.58$, $p<.001$) were seen. The main effect for time was due to the sharp and significant increase in sleepiness reported from the 0100 to 0700 session. Sleepiness then remained significantly elevated throughout the deprivation period. Analysis on the interaction of group and time found that the sleepiness ratings

did not change significantly across session in the Zolpidem group (figure 8). In the Rest group, sleepiness ratings increased sharply from 0100, reaching a high at 0700. Ratings then declined through the 1300 session but remained above those from the 0100 and 0300 sessions. Ratings began to climb during the last few sessions but never reached the highest level seen at 0700. In the Exercise group, sleepiness ratings increased sharply from 0100 to 0500. While slightly higher ratings were seen at 0700 and 0900, they were not significantly different from the 0500 session. A decline in sleepiness was seen at 1100. Sleepiness then steadily increased from 1300 to 1700, with scores reaching their highest at 1700. A slight decline was seen during the last session. Additionally, scores at 0500, 0700, and 0900 were significantly higher in the Rest group than the Zolpidem group.

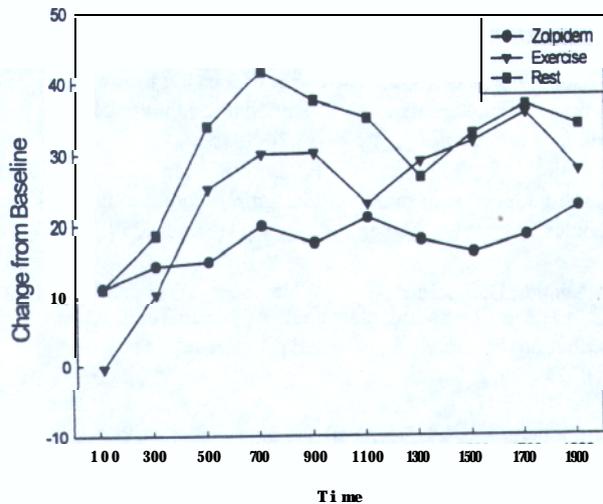


Figure 8. Effects of group and time on VAS sleepiness change scores.

RTSW. Change scores from the RTSW were analyzed with a two-way ANOVA. There were three levels of the between subjects factor group (Zolpidem, Exercise, and Rest) and 6 levels of the within subjects factor session (0110, 0510, 0910, 1310, 1710, and 2110). The ANOVA showed that there was a main effect for group ($F(2,56)=15.09, p<.001$) and a main effect for time ($F(3,78,211.71)=27.95, p<.001$). The main effect for group (figure 9) was due to the large decrease (in time to sleep onset) from baseline observed in the Rest group (-13.58 minutes). This decrease was significantly more than that exhibited by either the Zolpidem (-7.96 minutes) or Exercise group (-8.00 minutes). While the Zolpidem and Exercise groups did exhibit a decrease from baseline on minutes to stage 2 sleep, the decrease in both groups was nearly identical.

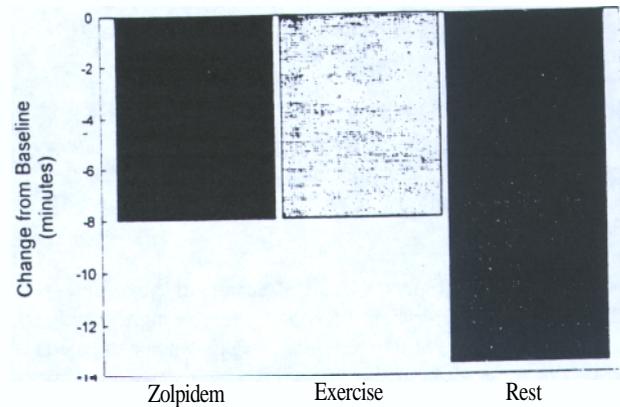


Figure 9. Effect of group on RTSW change scores.

Contrasts on the main effect for time showed that onset of stage 2 sleep decreased significantly from 0110 to 0910 (figure 10). This decreased level was maintained throughout the 1710 test. Some recovery was seen during the last session at 2110 (approximately 3 minutes).

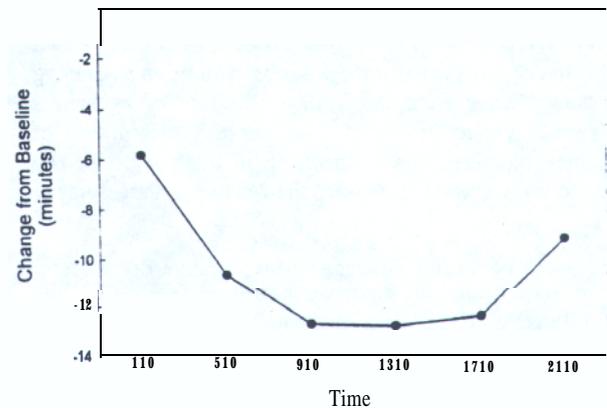


Figure 10. Effect of time on RTSW change scores.

DISCUSSION

In terms of the effectiveness, POMS data revealed a zolpidem-induced nap was clearly better than exercise or rest at attenuating the increase in confusion and bewilderment typically seen during long periods of sleep loss. Smaller increases in tension and anxiety ratings were also seen at several time points during the deprivation period in the Zolpidem group. The VAS results indicated that subjects in the Zolpidem group experienced smaller decrements in alertness and energy than subjects in the Exercise or Rest groups. Additionally, sleepiness ratings were lower at 0500, 0700, and 0900 in the Zolpidem group than in the Rest group (times when it is particularly difficult to remain alert). Thus, it is clear that

zolpidem-induced naps were superior to rest alone in terms of sustaining subjective feelings of alertness during sleep deprivation. These findings are consistent with those of Bonnet,⁵ who found that self-reports of vigor were improved by a 200-minute nap in comparison to a no-nap condition. It was also evident that in many instances a nap produced better effects on mood and subjective alertness when compared to 10 minute bouts of exercise.

The results from the Repeated Tests of Sustained Wakefulness indicated that both zolpidem naps and exercise significantly increased the subject's ability to remain awake, when compared to rest, during a 40-hour period of continuous wakefulness under conditions designed to make this very difficult (lying down in a dark, quiet room). While subjects were able to remain awake much longer following a nap or when exercising throughout the deprivation period, they still entered stage 2 sleep approximately 8 minutes faster than when they were not sleep deprived. Scores obtained from the RTSW, an objective measure of sleepiness/alertness did not totally match the self-reported sleepiness/alertness scores from the VAS, a subjective measure of sleepiness. Subjects in the Exercise group reported being significantly less alert than the Zolpidem napping group, yet the RTSWs were virtually equivalent (-8.00 and -7.96, respectively). A similar trend was observed when examining the energy scale from the VAS. This lack of agreement between subjective and objective measures of sleepiness/alertness is not surprising in light of previously reported low correlations between the two types of measures.⁴⁶⁻⁴⁸

The results of the RTSW suggest that, despite decreases in subjective measures of alertness, exercise produces alerting physiological effects equivalent to those produced by a zolpidem-induced nap. These results should, however, be tempered. The RTSWs used in this comparison were conducted 20 minutes following exercise. Results from the awake EEGs conducted 50 minutes following exercise showed that the subjects were less alert than if they had not exercised.⁴¹ Conversely, in the zolpidem study, central nervous system activation was significantly improved by napping.⁴⁰ Thus, our overall conclusion is that a zolpidem-induced nap is superior to exercise in terms of attenuating mood and alertness decrements typically associated with sleep deprivation.

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REFERENCES

1. Dinges, D. F., and Broughton, R. J. 1989. Sleep and alertness: Chronobiological, behavioral, and medical effects of napping. New York, NY: Raven Press.
2. Williams, H. L., Lubin, A., and Goodnow, J. J. 1959. Impaired performance with acute sleep loss. Psychological Monographs: General and Applied, 73: 1-26.
3. Hockey, G. J. R. 1970a. The effect of loud noise on attentional selectivity. Quarterly Journal of Experimental Psychology, 22:28-36.
4. Hockey, G. J. R. 1970b. Changes in attention allocation in a multi component task under sleep loss. British Journal of Psychology, 61:473-480.
5. Bonnet, M. H. 1991. The effect of varying prophylactic naps on performance, alertness and mood throughout a 52-hour continuous operation. Sleep 14(4):307-315.
6. Naitoh, P., Englund, C. E., and Ryman, D. 1982. Restorative power of naps in designing continuous work schedules. Journal of human ergology, 11(Suppl):259-278.
7. Dinges, D. F., Ome, M. T., Whitehouse, W. G., and Ome, E. C. 1987. Temporal placement of a nap for alertness: Contributions of circadian phase and prior wakefulness. Sleep 10(4):3 13-329.
8. Gillberg, M. 1984. The effects of two alternative timings of a one-hour nap on early morning performance. Biological psychology 19:45-54.
9. Nicholson, A. N., Pascoe, P. A., Roehrs, T., Roth, T., Spencer, M. B., Stone, B. M., and Zorick, F. 1985. Sustained performance with short evening and morning sleeps. Aviation, Space and environmental medicine, 56:105-114.
10. Bonnet, M. H. 1990. Dealing with shift work: physical fitness, temperature, and napping. Work and stress, 4:261-274.
11. Akerstedt, T., and Torsvall, L. 1985. Napping in shift work. Sleep, 8(2):105-109.
12. Dinges, D. F., Whitehouse, W. G., Ome, E. C., and Ome, M. T. 1988. The benefits of a nap during prolonged work and wakefulness. Work & stress 2(2):139-153.
13. Haslam, D. R. 1985. Sleep deprivation and naps. Behavior research methods, instruments & computers 17(1):46-54.

14. Lumley, M., Roehrs, T., Zorick, F., Lamphere, J., and Roth, T. 1986. The alerting effects of naps in sleep-deprived subjects. Psychophysiology, 23(4):403-408.
15. Matsumoto, K., and Harada, M. 1994. The effect of night-time naps on recovery from fatigue following night work. Ergonomics, 37(5):899-907.
16. Mullaney, D. J., Kripke, D. F., Fleck, P. A., and Johnson, L. C. 1983. Sleep loss and nap effects on sustained continuous performance. Psychophysiology, 0(6):643-651
17. Naitoh, P., and Angus, R. G. 1989. Napping and human functioning during prolonged work. In D. F. Dinges and R. J. Broughton (Eds.), Sleep and alertness: Chronobiological, behavioral, and medical aspects of napping, pp. 22 I-246. New York: Raven Press, Ltd.
18. Rogers, A. S., Spencer, M. B., Stone, B. M., and Nicholson, A. N. 1989. The influence of a 1 h nap on performance overnight. Ergonomics, 32(10):1193-1205.
19. Rosa, RR. 1993. Napping at home and alertness on the job in rotating shift workers. Sleep 16(8):727-735.
20. Webb, W. 1987. The proximal effects of two and four hour naps within extended performance without sleep. Psychophysiology 24(4):426-429.
21. Dinges, D. F., Ome M. T., and Ome, E. C. 1985. Assessing performance upon abrupt awakening from naps during quasi-continuous operations. Behavior research methods, instruments, & computers 17(1):37-45.
22. Blois, R., Gaillard, J., Attali, P., and Coquelin, J. 1993. Effect of zolpidem on sleep in healthy subjects: A placebo controlled trial with polysomnographic recordings. Clinical therapeutics, 15(5):797-809.
23. Merlotti, L., Roehrs, T., Koshorek, G., Zorick, F., Lamphere, J., and Roth, T. 1989. The dose effects of zolpidem on the sleep of healthy normals. Journal of clinical psychopharmacology 9(1):9-14.
24. Quera-Salva, M. A., McCann, C., Boudet, J., Frisk, M., Borderies P., and Meyer, P. 1994. Effects of zolpidem on sleep architecture, night time ventilation, daytime vigilance and performance in heavy snorers. British journal of clinical pharmacology 37:539-543.
25. Richens, A., Mercer, A. J., Jones, D. M., Griffiths, A., and Marshall, R. W. 1993. Effects of zolpidem on saccadic eye movements and psychomotor performance: a double-blind, placebo controlled study in healthy volunteers. British journal of clinical pharmacology, 36:61-65.
26. Sicard, B. A., Troucherie, S., Moreau, J., Vielillefond. H., and Court. L.A. 1993. Evaluation of zolpidem on alertness and psychomotor abilities among aviation ground personnel and pilots. Aviation, space and environmental medicine, 64:371-375.
27. Caldwell, J. A. and Caldwell, J. L. 1998. Comparison of the effects of zolpidem-induced prophylactic naps to placebo naps and forced rest periods in prolonged work schedules. Sleep 21(1):79-90.
28. Palminteri, R. and Narbonne, G. 1988. Safety profile of zolpidem. In J.P. Sauvanet, S.Z. Langer, and P.L. Morselli (Eds.) Imidazopyridines in sleep disorders. pp 351-360. New York: Raven Press.
29. Physician' Desk Reference. 1995. Ambien (brand of zolpidem tartrate), pp 2304-2307. Oradell, NJ: Medical Economics Co., inc.
30. Wilkinson, R. T. 1963. Interaction of noise with knowledge of results and sleep deprivation. Journal of Experimental Psychology, 66:332-337.
31. Tassi, P., Nicolas, A., Seegmuller, C., Dewasmes, G., Libert, J. P., and Muzet, A. 1993. Interaction of the alerting effects of noise with partial sleep deprivation and circadian rhythmicity of vigilance. Perceptual and Motor Skills, 77:1239-1248.
32. Angus, R. G., Heslegrave, R. J. and Myles. W. S. 1985. Effects of prolonged sleep deprivation, with and without chronic physical exercise, on mood and performance. Psychophysiology, 22:276-282.
33. Ryman, D. H., Naitoh, P., and Englund, C. E. 1985. Decrements in logical reasoning performance under conditions of sleep loss and physical exercise: The factor of sentence complexity. Perceptual and Motor Skills 61:1179-1188.
34. Englund, C. E., Ryman, D. H., Naitoh, P., and Hodgdon, J. A. 1985. Cognitive performance during successive sustained physical work episodes. Behavior Research Methods, Instruments, & Computers 17:75-85.
35. Plyley, M. J., Shepard, R. J., Davis, G. M., and Goode, R. C. 1987. Sleep deprivation and cardiorespiratory function. Influence of intermittent submaximal exercise. European Journal of Applied Physiology 56:338-344.

36. Davey, C. P. 1972. Mental performance after physical activity. Australian Journal of Sports Medicine, 4:25-33.
37. Davey, C. P. 1973. Physical exertion and mental performance. Ergonomics, 16:595-599.
38. Home, J. A., and Foster, S. C. 1995. Can exercise overcome sleepiness? Sleep Research, 24A:437.
39. Martin, B. J. 1981. Effects of sleep deprivation on tolerance of prolonged exercise. European Journal of Applied Physiology, 47:345-354.
40. Caldwell, J. A., Jones, R. W., Caldwell, J. L., Colon, J. A., Pegues, A., Ivenon, L., Roberts, K. A., Ramspott, S., Sprenger, W. D., and Gardner, S. J. 1997. The efficacy of hypnotic-induced prophylactic naps for the maintenance of alertness and performance in sustained operations. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 97-10.
41. Leduc, P. A., Caldwell, J. A., Ruyak, P. S., Prazinko, B., Gardner, S., Colon, J., Norman, D., Cruz, V., Jones, R., and Brock, M. In Press. The effects of exercise as a countermeasure for fatigue in sleep deprived aviators. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory.
42. McNair, D. M., Lorr, M., and Droppleman, L. F. 1981. Manual for the profile of mood states. San Diego: Educational and Industrial Testing Service.
43. Penetar, D., McCann, U., Thome, D., Kamimori, G., Galinski, C., Sing, H., Thomas, M., and Belenky, G. (1993). Caffeine reversal of sleep deprivation effects on alertness and mood. Pharmacology, 112:359-365.
44. Hartse, K. M., Roth, T., and Zorick, F. J. 1982. Daytime sleepiness and daytime wakefulness: the effect of instruction. Sleep 5:S107-S118.
45. Dixon, W. J., Brown, M. B., Engelman, L., Jennrich, R. I. (Eds.) 1990. BMDP statistical software manual. Berkeley: University of California Press.
46. Johnson, L. C., Freeman, C. R., Spinweber, C. L., and Gomez, S. A. 1991. Subjective and objective measures of sleepiness: Effect of benzodiazepine and caffeine on their relationship. Psychophysiology, 28:65-71
47. Chervin, R. D., Kraemer, H. C., and Guilleminault, C. 1995. Correlates of sleep latency on the multiple sleep latency test in a clinical population. Electroencephalography and Clinical Neurophysiology, 95: 147- 153.
48. Caldwell, J. A. and Ruyak, P. S. 1997. Predicting the ability to maintain alertness during sleep deprivation: The accuracy of subjective evaluations. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory USAARL Report No. 97-05.