Rest and Activity Patterns of Army Aviators in Routine and Operational Training Environments

Kyle A. Bernhardt; Amanda M. Kelley; Kathryn A. Feltman; Ian P. Curry

INTRODUCTION: Fatigue continues to be a leading cause of military aviation mishaps. Several factors, including reversed shift missions, can negatively affect sleep patterns and increase the risk of fatigue due to sleep restriction. Currently, there is a lack of objective data regarding the current rest and activity patterns of military aviators across multiple operational conditions. The purpose of this descriptive study was to document the rest and activity patterns of U.S. Army aviators in operational training and garrison (routine) environments using wrist-worn actigraphy devices.

METHODS: Actigraphy data were collected from U.S. Army aviators in training ($N = 20$) and garrison ($N = 77$) environments for a period of 1 wk.

RESULTS: Results from this study indicate that 90% of subjects in the training environment, even after accounting for small sleep bouts during the day, averaged less than the recommended 8 h of sleep daily across the recording week. Approximately half of subjects in garrison averaged less than 8 h of sleep daily after accounting for smaller sleep bouts. Sleep efficiency was relatively high and similar in both groups (~84%). Subjects in the training group averaged significantly more time awake and less time sleeping than those in the routine garrison group. Moreover, subjects in training were exposed to more light during sleep than those in garrison.

DISCUSSION: Training environments that are representative of deployed conditions restrict aviator restorative sleep. These results highlight the importance of continued research on aviator sleep and fatigue mitigation in operational environments.

KEYWORDS: actigraphy, aviator fatigue, sleep.

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Fatigue continues to present a serious threat to military aviation safety and mission success due to its detrimental effects on pilot cognitive functioning and flight performance.[5,6] Pilots flying in a fatigued state are more susceptible to increases in critical signal reaction times, negative affect, reductions in flight parameter maintenance, and increased slow-wave brain activity indicative of stage one sleep.[6] Estimates of Class A aviation mishaps due to fatigue range from 4 to 12% across military branches.[4] Moreover, between 1990 and 2011, fatigue was cited as the second leading cause of Naval Class A aviation mishaps.[1]

Military aviation operational conditions often impose frequent schedule changes, shifts between day and night missions, and disruptive environmental conditions on aviators that interfere with restorative sleep patterns. Multiple U.S. military branches have attempted to curtail these sleep disrupting factors by developing tools to assist in the scheduling of training, shift hours, and blocks of time reserved for sleep.[7] General military policies and doctrine outline strategies for facilitating adequate rest cycles and informing aviators of optimal sleep and recovery strategies;[3] however, unit commanders and flight surgeons provide fatigue mitigation strategies specifically tailored to support individual mission goals (see Army Regulation 95-1). Additionally, mission needs and other conflicting policies may further deprioritize fatigue mitigation.

Despite the large body of research reporting the negative effects of fatigue due to reduced sleep, little data exist on the actual sleep patterns of Army aviators. At the time of this

From the Warfighter Performance Group, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL.

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Address correspondence to: Kyle A. Bernhardt, Warfighter Performance Group, U.S. Army Aeromedical Research Laboratory, Bldg. 6901, Fort Rucker, AL 36362; kbernhardt53@gmail.com.

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manuscript, no research is readily available to suggest whether, and if so to what extent, current sleep facilitation strategies mitigate safety risks associated with fatigue in an Army aviation operational setting. Moreover, obtaining objective sleep data for understanding military pilot fatigue etiology is complicated by the dynamic daily environments military pilots operate in.

Advances in sleep monitoring technologies have made the objective measurement of sleep variables (e.g., duration and quality) possible in military environments where comprehensive physiological methods like polysomnography (PSG) are not feasible. One such method is actigraphy. Actigraphy involves the use of a small accelerometer device (usually worn on the wrist) to track gross motor movements to estimate sleep quality and duration. Additionally, these small devices can collect other variables, such as light exposure, that may also impact sleep. Wrist-worn actigraphy devices have been shown to be comparable to PSG recordings, with only minor limitations in identifying waking bouts during sleep across individuals.[10] Moreover, mathematical models incorporating actigraphy data have been shown to relate to cognitive task performance in aviators.[12] Thus, actigraphy provides a lucrative means for obtaining aviator sleep data in environments where PSG would impede mission efficacy and operational flow.

Here we present descriptive actigraphy data on U.S. Army aviator sleep quality, sleep quantity, and light exposure (during sleep and waking hours) over the course of 1 wk in two settings: operational training and routine garrison (i.e., stationed on base in the United States). The goals of this study were to collect sleep data from two different military aviation environments that could: 1) document the current sleep patterns of Army aviators in two different work settings; and 2) could be used to inform future studies on sleep scheduling for military aviators across different working conditions.

METHODS

Subjects

This study protocol was approved in advance by The U.S. Army Medical Research and Materiel Command Office of Research Protections Institutional Review Board. Each subject provided written informed consent before participating. All subjects for both environments were required to be 18 yr of age or older, active duty Service Members (including National Guard or Reserve on orders), rated pilots currently serving in a Combat Aviation Brigade (CAB) unit, and not have a sleeping disorder or a profile that prevented physical activity or flying duties.

Volunteering to participate in the training environment phase of this study were 22 soldiers (20 men, 2 women) from a CAB at Fort Polk, LA, completing routine operational training exercises at the Joint Readiness Training Center (M_{age} = 31.14 yr, SD_{age} = 4.25). These subjects reported between 80 and 300 h of flight time on the controls (M = 130.50, SD = 53.97) within the past year.

For the in-garrison phase of this study, a total of 99 garrison-stationed soldiers from CABs stationed at Fort Bragg, NC, and Fort Rucker, AL, were initially recruited to participate. Of this initial sample, 15 subjects were excluded for not meeting flight requirements, resulting in a sample size of 84 (78 men, 6 women). There were 10 subjects who participated in both the training phase and the garrison phase (the garrison phase occurred after the training phase). Of the subjects, 73 were from Fort Bragg. Average age of this sample was 32.55 yr (SD = 6.74). Flight experience (on controls time) within the past year varied from 14 to 450 h (M = 133.13, SD = 74.77).

Materials

Demographic data and a brief medical history were collected from both groups of subjects. Subjects in both groups also reported tobacco use, caffeine and supplement (e.g., multivitamins) consumption, and current medications. Several self-report measures of variables potentially relating to sleep were also collected. These data are reported elsewhere.[2]

Subjects were provided with an Actiwatch Spectrum Plus (Philips Respironics, Bend, OR), a small watch-like device worn on the wrist that uses an accelerometer to monitor the subject's magnitude of motion. These watches contain an omnidirectional sensor (32-Hz sampling rate) which integrates the subject's degree and speed of motion, allowing for the identification of sleep and wake periods. Moreover, these watches incorporate a light sensor capable of measuring light exposure between 400 and 700 nm in wavelength. Watches recorded and logged data at 1-min epochs throughout the recording period. Data analysis with the Actiware software (Version 6.0.9, Philips Respironics, Bend, OR) identified four recording intervals per day (sleep, rest, active, daily) and exported average wake and sleep durations, sleep efficiency (defined as the ratio of sleep time to the sum of wake time plus sleep time for sleep intervals), white light exposure (in lx-min), and color light exposure (in $\mu W/cm^2$) for each recording interval over the course of the study measurement period. It should be noted that sleep intervals are a subset of rest intervals. Therefore, rest intervals include sleep interval observations. Daily intervals take into account all epochs in a given 24-h period.

Procedure

Potential volunteers at their respective sites were briefed in group settings. No supervisors were present during briefings. Volunteers interested in participating individually provided consent and were assigned a wrist activity monitor with a random identification number. Subjects were also provided with instructions for troubleshooting Actiwatch technical problems.

Then, subjects were given a questionnaire packet to complete. Finally, subjects returned the packet to the study team and were subsequently released back to their training leadership or routine garrison duties. Each subject wore the wrist activity monitor continuously for 1 wk. After the 1-wk data collection period, the study team returned to the data collection sites to retrieve the wrist activity monitors.

Statistical Analysis

Descriptive statistics were computed for the groups by recording interval. Outcome variables included sleep duration, wake duration, sleep efficiency, and light exposure (white, red, green, blue). Due to violations of normality (assessed with boxplots and Shapiro-Wilk tests), nonparametric, between-subjects Wilcoxon rank-sum tests were computed to compare the garrison and training groups on outcome measures. The Wilcoxon rank-sum test is a nonparametric analog to the independent samples *t*-test. Medians are reported for central tendency and minimum-maximum values are reported for distribution dispersion. Inferential tests for sleep and wake durations were computed using minutes, but for ease of interpretation these values are reported in hours. Additionally, the number of participants not averaging 8 h of sleep during the recording week were compared between the groups using Pearson's Chi-squared tests. This same procedure was used to test for group differences for those exceeding 13 h of active wake time. Fisher's exact tests were also computed to corroborate Pearson's Chi-squared tests. No differences in statistical significance (i.e., significant results changing to nonsignificant or vice versa) were observed between these tests, so Pearson's Chi-squared tests are reported. Statistical significance was set at $\alpha = 0.05$. All analyses were conducted using R.

RESULTS

For the training group, one subject failed to return their Actiwatch and one subject did not wear the Actiwatch for the required duration of the study, resulting in a usable training group sample size of $N = 20$. For the garrison-stationed group, 7 subjects did not wear the Actiwatch for a sufficient amount of time during the recording week, resulting in a final sample size of $N = 77$.

Across the recording week, subjects in training (Median = 6.13 h, Min-Max = 5.36–9.12) obtained significantly less sleep during sleep intervals than those in garrison (Median = 6.93 h, Min-Max = 4.19–9.47) (W = 367.75, $P = 0.02$, r = 0.24). Additionally, when accounting for smaller sleep bouts accumulated using daily level data, subjects in training (Median = 7.09 h, Min-Max = 5.22–9.39) still achieved significantly less sleep than garrison subjects (Median = 8.07 h, Min-Max = 4.34–11.21) (W = 1100, $P = 0.003$, r = 0.30). Subjects in training achieved a median sleep efficiency of 84.17% (Min-Max = 77.87–96.20) and those in garrison achieved a median sleep efficiency of 84.71% (Min-Max = 63.38–90.77). This comparison was not statistically significant (W = 746, $P = 0.83$, r = 0.02).

Moreover, 95% ($N = 19$) of training subjects and 92.21% ($N = 71$) of garrison subjects averaged less than 8 h of sleep per day during sleep intervals across the recording week. These proportions were not significantly different between the groups [$\chi^2(1) = 0.18$, $P = 0.67$]. When accounting for smaller amounts of sleep accumulated during all intervals (i.e., at the daily level), significantly more (90%, $N = 18$) of training subjects did not average 8 h of sleep per day during the recording week than garrison subjects (49.35%, $N = 38$) [$\chi^2(1) = 10.75$, $P = 0.001$].

During active intervals, subjects in training (Median = 13.61, Min-Max = 11.55–18.61) spent significantly more time awake than subjects in garrison (Median = 11.30, Min-Max = 7.92–15.59) (W = 178, $P < 0.001$, r = 0.54). A similar pattern was observed when accounting for smaller waking bouts at the daily level (W = 458.50, $P = 0.01$, r = 0.28; Training: Median = 13.79, Min-Max = 11.21–15.78 vs. Garrison: Median = 12.76, Min-Max = 7.06–15.37). Overall, significantly more training subjects (70%, $N = 14$) averaged more than 13 h of daily wake time per day than garrison subjects (14.29%, $N = 11$) during the recording week [$\chi^2(1) = 25.76$, $P < 0.001$].

Table I displays descriptive statistics for light exposure metrics by recording interval for the two groups. Light exposure distributions were positively skewed and quite variable. Examining median colored light exposure values revealed that red light exposure predominated followed by green and blue light for all recording intervals. Excluding daily intervals, active intervals, as expected, were characterized by more light exposures across all light wavelengths, followed by rest and sleep intervals, respectively. Because of the literature concerning light exposure prior to sleep, we tested differences in light exposure

Table I. Light Exposure Descriptive Statistics for Training Aviators ($N = 20$) and Garrison Aviators ($N = 77$) by Interval.

	TRAINING			GARRISON		
VARIABLE	**MEDIAN**	**MIN**	**MAX**	**MEDIAN**	**MIN**	**MAX**
White Exposure (lx-min)						
Rest	1377.80	0.24	166,299.30	44.46	0.00	23,086.46
Active	214,193.40	46,632.72	716,390.50	103,462.20	6094.18	411,266.20
Sleep	1319.28	0.01	159,586.80	19.66	0.00	23,084.56
Daily	173,819.85	40,804.15	663,514.30	108,864.20	6094.99	411,277.60
Red Exposure (μW/cm²)						
Rest	1790.00	1.06	328,000.00	136.00	0.00	40,500.00
Active	287,000.00	84,500.00	1300,000.00	177,000.00	11,800.00	847,000.00
Sleep	1715.00	0.20	305,000.00	51.00	0.00	40,400.00
Daily	292,500.00	83,300.00	1300,000.00	186,000.00	11,800.00	967,000.00
Green Exposure (μW/cm²)						
Rest	1580.00	0.45	411,000.00	79.50	0.00	28,300.00
Active	192,500.00	48,400.00	949,000.00	112,000.00	5440.00	560,000.00
Sleep	1525.00	0.00	394,000.00	26.80	0.00	28,300.00
Daily	183,000.00	42,300.00	1070,000.00	116,000.00	5440.00	640,000.00
Blue Exposure (μW/cm²)						
Rest	1029.00	0.17	208,000.00	50.70	0.00	12,500.00
Active	125,000.00	29,200.00	567,000.00	66,200.00	4080.00	275,000.00
Sleep	990.50	0.00	201,000.00	21.30	0.00	12,500.00
Daily	120,500.00	25,500.00	551,000.00	70,800.00	4080.00	315,000.00

between training and garrison subjects during sleep intervals. Subjects in training were exposed to significantly more white, red, green, and blue light during sleep than those in garrison (Ws = 320–349, *P*-values $<$ 0.001), with effect sizes ranging from r = 0.38 to 0.41.

Finally, we investigated the potential effects of high and low blue light exposure during sleep on sleep duration and efficiency by splitting the garrison participants at median blue light exposure, creating high and low exposure groups. No significant difference in sleep efficiency (W = 830.50, *P* = 0.26, r = 0.12) or sleep duration (W = 817, *P* = 0.33, r = 0.11) were found between subjects exposed to either high or low levels of blue light.

DISCUSSION

This study sought to document the sleep and wake patterns of Army aviators in training and garrison environments using wrist-worn actigraphy devices. This research was also intended to catalyze further research into military aviator sleep patterns across multiple work environments. Results indicated that subjects in garrison generally spent more time sleeping and had more opportunities for smaller bouts of sleep than those in the training environment. Additionally, aviators in the training environment were exposed to more light during sleep intervals than aviators in garrison.

Examining strictly sleep intervals, 95% of subjects in the training group and 92% of subjects in the garrison group averaged less than 8 h of sleep per day during the recording week. When factoring in additional sleep from shorter rest periods, however, significantly more subjects in the training group (90%) averaged less than 8 h of sleep per day compared to garrison subjects (49%). This likely reflects more opportunities for garrison-stationed aviators to nap compared to those in the training environment, making training and high-paced operational conditions more of a concern for sleep scheduling and fatigue management.

The sleep duration results obtained for the training group in this study are similar to those obtained in a deployed, nonaviator Army combat sample where soldiers reported receiving approximately 5 to 6 h of sleep per day.[9] More importantly, approximately half of the soldiers surveyed by these authors reported that when they made a mistake affecting mission outcomes, sleepiness was the main cause.[9] This same sleep pattern, when translated to the highly demanding aviation environment, can significantly reduce performance and mission effectiveness.[5] In this study, both groups averaged a relatively high sleep efficiency across the recording week. That is, while subjects were in bed, they spent a high percentage of time actually asleep. Despite the training group having reduced sleep durations overall, this group's sleep efficiency was not significantly different from garrison-stationed group. This high sleep quality may buffer against some of the negative effects of reduced sleep durations during training.

Additionally, light exposure during sleep was significantly higher for aviators in training compared to garrison. Light influences the circadian timing in humans. Exposure to blue light before sleep can alter brain electrophysiological activity and shorten rapid eye-movement sleep.[11] Although we did not find significant differences between garrison-stationed subjects exposed to high and low blue light during sleep on measures of sleep duration and sleep efficiency, the light data obtained from this study suggest that the training environment might pose a risk to Army aviators for light-related disruptions in sleep (relative to the garrison environment). However, further research with more experimental control is needed to determine the effects of light exposure in the training environment on aviator sleep and subsequent flight performance outcomes.

One limitation of this study is that the exact causes (other than a rigorous training schedule) of decreased sleep duration in the training environment were not specifically recorded. A number of factors can influence sleep durations over the course of training beyond just a demanding training schedule. The data collected for this study only give a "top-down" view of sleep patterns and durations. It should be noted that we attempted to use self-report logbooks along with actigraphy data for subjects in training; however, these logbooks hindered subjects from completing their duties, resulting in low response rates. We therefore could not report any meaningful self-report sleep data that could augment actigraphy recordings.

Another limitation is the relatively small sample of subjects in training compared to garrison. A larger training sample would stabilize data variability. Relatedly, this sample consisted only of Army aviators, which limits the generalizability of these results to other branches of the military. Finally, only one measure of sleep quality (sleep efficiency) was obtained during the study period. Sleep quality is a multidimensional construct that is difficult to capture in a single measure.[8] Additional measures of sleep quality could provide a more holistic picture of aviator rest.

Several directions for future research are possible in light of these results. First, these data provide an overview of aviator sleep quality and quantity, but do not allow for inferences to be made regarding flight and mission performance. Fatigue forecasting systems using actigraphy data have been shown to predict laboratory-based cognitive task performance in aviators deployed in combat.[12] Future studies should determine the degree to which these fatigue forecasting models using actigraphy data actually predict flight performance and mission success in high-fidelity environments. Second, the light exposure data indicate that aviators in more demanding operational environments are exposed to higher levels of light during sleep. Future studies should experimentally investigate the extent to which light exposure during sleep impacts aviator flight performance. We also recommend the development of a minimally intrusive (potentially electronic) instrument that aviators can use to self-report sleep events. These self-report data can be used to enhance actigraphy data. Finally, the data presented here would benefit from other military branches reporting the current patterns of their aviator rest and activity patterns.

In conclusion, the results of this study reinforce the notion that operational environments restrict sleep durations in Army aviators. A majority of aviators in the training environment were not receiving the optimal 8 h of sleep per day recommended for peak performance. Furthermore, opportunities for and/or use of shorter sleep periods throughout the day in operational environments resembling a deployed environment appear to be less than those available in the garrison environment. Future research should employ a minimally intrusive subjective measure of sleep events to assess causes for significant sleep reductions in operational environments. Additionally, the light exposure results of this study potentially warrant future experimental investigations into the effects of increased light exposure on sleep quality and aviator performance.

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Authors and affiliation: Kyle A. Bernhardt, B.S., M.A., Amanda M. Kelley, M.S., Ph.D., Kathryn A. Feltman, M.A., Ph.D., and Ian P. Curry, B.S., M.D., Warfighter Performance Group, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL.

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