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ORIGINAL CONTRIBUTION

Objective assessment of sleep and fatigue risk in emergency medicine physicians

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Abstract

Objectives: Fatigue is a state of physical and mental exhaustion in which people feel exhausted or drained of energy. Shift workers are highly vulnerable to fatigue, and this is especially true of emergency physicians (EPs). Shift scheduling (shift hours, frequency/length of breaks, time of shift, and number of hours off between shifts) can affect levels of fatigue in EPs. When EPs are fatigued, they experience decrements in cognition, resulting in an increased risk of errors. This study assessed the state of fatigue in EPs in the emergency department of a large, urban hospital using objective measures (sleep metrics and shift scheduling) over multiple months.

Methods: Seventeen EPs, nine females, wore wrist-activity monitors called ReadiBands for 2 months. The ReadiBand is an objective actigraphy measure that communicates with a smartphone application to quantify sleep metrics and predict future fatigue.

Results: Throughout the 3083 on-shift hours of data, analyses revealed that EPs have poor sleep quality (mean ± SD 7.71 ±1.84/10) and sleep quantity (mean ± SD 6.77 ±1.66 h), with sleep efficiency within "normal" ranges (mean ± SD 87.26 ±9.00). Participants spent 725 h (23.52%) on shifts with fatigue scores indicative of significant impairment (equivalent to BAC of .08%). In addition, results indicated that shift type (day, evening, night) was significantly associated with fatigue score, where night shifts were associated with higher fatigue scores.

Conclusions: Fatigue is an issue for many EPs. The present study addressed the percentage of time EPs are in a fatigued state when on shift over an extended duration of time. More research is needed to examine system-level interventions for reducing fatigue in EPs.

KEYWORDS
fatigue, fatigue risk, shift work, emergency medicine physician

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INTRODUCTION

Fatigue is a state of physical and mental exhaustion that leads people to feel tired, exhausted, drained of energy, or sluggish and can be caused by lack of sleep and/or disruption of a person's "internal clock." Shift workers are highly vulnerable to fatigue and fatigue-related risks. Shift work is typically defined as having scheduled work outside of the hours of 7 a.m.–6 p.m.[1] Shift workers often work when their bodies naturally want to be asleep, and they also have trouble getting proper sleep in their downtime, leading to sleep deprivation (i.e., restricted sleep compared to normal sleep need), circadian misalignment, and further accumulation of fatigue.[1] Shift workers show high levels of fatigue, with increased shift work frequency being correlated with increased perceptions of fatigue.[2] Shift work could contribute to fatigue directly, by reducing sleep quantity and quality, or it may contribute indirectly by acting on existing sleep problems. For example, shift workers who frequently work varying shifts report their fatigue to be similar in severity to that experienced by people with fatigue-related disorders, such as multiple sclerosis, lupus, and sleep-related disorders.[2]

When physicians are fatigued, they experience a decrease in their ability to perform basic cognitive functions, which results in decrements in vigilance, attention, and memory. One night of sleep deprivation decreases cognitive performance by 30%, but performance deficits are also observed in as little as 16 hours of awake time,[3] demonstrating that both sleep deprivation and extended hours decrease cognitive performance. Even people who lose only 2 or 3 h of sleep each night show significant decreases in cognitive performance, with effects seen after only one night.[4]

Shift work is common in healthcare, but especially in emergency medicine. Emergency departments (EDs) are open 24 h per day, 7 days per week, 365 days per year, which requires 8760 h of physician staffing for a single-covered ED. Shift schedules in EDs are complex and varied, but one commonality is the extent to which emergency physicians (EPs) are required to work shifts. EPs work jobs with high task demands that require constant attention or vigilance and must exert increased effort to maintain the same performance over time. The longer they are required to do high-demand tasks, the more fatigued they become. Shift scheduling plays a large role in fatigue, because the number of hours on shift, the presence, frequency and length of rest breaks, the time of day of shift, and the number of hours off between shifts can all affect levels of fatigue.[5] Fatigue risk has been demonstrated to have cognitive similarities to alcohol intoxication,[3,6] with sleeping fewer than 7 h per night resulting in cognitive deficits similar to someone who has consumed two or three alcoholic beverages.

While fatigue has been assessed in many 24/7 industries, it has not been extensively studied in emergency medicine. To effectively manage fatigue-related risks in emergency medicine, it is important to first objectively measure fatigue longitudinally to establish the current state of fatigue risk over a prolonged time period. The present study assessed sleep and fatigue risk in EPs over the course of 2 months using a novel actigraphy device, the ReadiBand. The assessment of sleep and fatigue risk over the extended time period of 2 months permits an examination of physicians after working multiple shifts that often rotate from week to week, allowing for a more robust characterization of fatigue risk for individual physicians. The overall goals for the study were to characterize the percentage of time EPs spent in a fatigued state during shifts and to test the hypothesis that later shift start times would be associated with greater fatigue as a result of circadian rhythm disruption.

METHODS

Participants

A total of 17 EPs from the department of emergency medicine (DEM) at an academic medical center in the southeastern United States were recruited for this study. Descriptive data on the participants can be found in the results section. This study received institutional review board approval for human subject participation prior to recruitment of participants.

Materials

ED physician sleep periods were recorded using actigraphy (ReadiBand, Fatigue Science). The ReadiBand is a commercially available instrument that uses an accelerometer to record wrist movement. The ReadiBand is designed to be worn continuously on the nondominant hand, and it also serves as a watch for the wearer. The sleep data are recorded and stored on the ReadiBand, which then communicates with a smartphone application to provide feedback about the sleep metrics and fatigue scores.

The validity of the ReadiBand has been demonstrated by numerous studies.[7,8] Polysomnography is the most accurate representation of sleep metrics, and the ReadiBand accuracy is 93% compared with polysomnography,[9] making the ReadiBand a highly valid, continuously monitoring sleep device, which has been used extensively in industries such as aviation, military, and transportation. The ReadiBand has been used recently in health care research to assess effects of shift work on sleep health and cognitive effectiveness.[10]

The ReadiBand data are analyzed with a computerized application of the sleep, activity, fatigue, and task effectiveness (SAFTE) model. The SAFTE model is a biomathematical model that uses sleep metrics to predict fatigue and cognitive effectiveness. Fatigue is predicted based on the sleep metrics from the previous 24 h and beyond, resulting in a fatigue score (referred to hereafter as the Readiscore). These scores are given every hour as a function of the sleep metrics collected in the time leading up to the present. For the purposes of this study, Readiscores were averaged across the hours during each shift and the 2 h before the shift. So, each shift corresponded to a single Readiscore that represented the average of the hourly Readiscores just before and during the shift. The cognitive effectiveness score represents the inverse of fatigue risk, with higher ReadiBand scores indicating higher predicted cognitive capacity and lower fatigue risk.[11] The sleep metrics assessed by the ReadiBand, which are used to comprise the Readiscore, include: (a) sleep quality (a score of 1–10 based on fragmentation, latency, and wake after sleep onset, where higher scores indicate poor sleep quality and an optimal score is <6); (b) sleep duration (time spent asleep in minutes, where scores lower than seven are considered poor sleep duration); and (c) sleep efficiency (total sleep time divided by total time in bed), where scores greater than 80% fall within the "normal" or unimpaired range.[8,9] These scores are compiled across time to provide a current state of fatigue and cognitive impairment for individuals based on both chronic and acute sleep metrics (refer to Table 1 for more information on the sleep metrics assessed). The ReadiBand provides sleep metrics, SAFTE Readiscores, and alcohol impairment cognitive equivalents for each participant wearing the ReadiBand, allowing researchers to compile these data to examine fatigue across shifts.

Procedure

Participants were recruited to participate by email and word of mouth within the DEM. The recruitment email detailed the procedures for data collection and indicated that participants would be allowed to track their own sleep metrics and fatigue scores after 1 month of participation. No information about preexisting sleep issues (i.e., sleep apnea) was collected. In addition, participants were told they would receive $30 in gift cards for each month they participated (up to $60 total). An institutional review board invitation to participate was included in the recruitment email.

Each participant was provided with a ReadiBand and was shown how to wear and charge the device. Participants were asked to wear it for 1 month continuously, or if they were unable to wear it at all times, they were asked to wear it every time they were going to be sleeping (including naps). After 1 month, participants received an email invitation to access the ReadiBand app. The ReadiBand app allowed participants to see all their sleep data and fatigue risk scores from the previous month as well as to track their sleep and fatigue data in real time for the next month. No significant differences between the 2 months were seen in ReadiBand scores or sleep metrics, so the data for the 2 months were combined for analysis.

In addition to ReadiBand data, each participant's work schedule (both scheduled and actual time worked) was obtained from DEM administration. SAFTE Readiscores were examined for 2 h prior to shift start, during all hours of the shift, and 2 h following the end of shift to account for changes in shift duration and commute for the shift. This also allowed the incorporation of fatigue level prior to the start of a shift and to account for time spent finishing work beyond the designated end-of-shift time.

Statistical analysis

Our analyses first involved descriptive analyses of demographic data to describe the current sample. We then conducted additional descriptive analyses on the ReadiBand data to provide a general description of those data. These included the means and standard deviations (SDs) of sleep-related metrics for the entire sample. We further examined the percentage of on-shift hours that were spent in each of the Readiscore zones. We then computed multilevel models (MLM) to assess the association between shift start times and Readiscores while controlling for individual differences. In other words, this analysis allowed for the examination of associations between shift start times and Readiscores while controlling for individual variation (e.g., differences in shift schedules, sequences, or frequencies). This type of analysis is appropriate for nested data structures; in this case shift start times for the 392 shifts were nested under the 17 EPs. All of the shifts in this study started between 6 a.m. and 11 p.m. Before running the MLM, we examined the intraclass correlations (ICCs) from a random intercepts model with Readiscores regressed on the individual ID (physician) variable. The ICCs are necessary to determine the amount of variance in the Readiscores that can be accounted for by physician (between-persons) variability (ICC1) as well as the extent to which physicians can be reliably distinguished by their Readiscores (ICC2). To build the MLM, we first included the grouping ID variable in a random effects model. We then included the Level 2 variable, shift start time, as a predictor. Finally, in addition to the linear MLM, we also computed the model with a nonlinear (quadratic) term to assess whether the data would exhibit better fit to a nonlinear curve. At each of these steps in the building of the MLM, we computed a chi-square difference test to assess whether

TABLE 1 Detailed information about metrics assessed by the ReadiBand

Term	Definition	Normal/ optimal range
Readiscore	Cognitive effectiveness, based on sleep/wake schedule	90+
Sleep duration	Time spent asleep in minutes	>420 (7 h)
Sleep quality	Scoring of quality (out of 10) where higher scores indicate poorer sleep based on increased sleep fragmentation, latency, and wake after sleep onset	<6
Sleep efficiency	Total sleep time divided by total time in bed	>80%

each step significantly contributed to the predictive utility of the overall model.

RESULTS

Of 131 EPs in the DEM, 17 participants volunteered for the study. Nine of the participants (53%) identified as female and eight of the participants (47%) identified as male. Two of the 17 EPs (12%) were full-time nocturnists; the other 15/17 worked a general distribution of shifts. Each EP worked at a minimum of two clinical sites, where shifts ranged from 8 to 10 h, with an average length of 8.33 h.

ReadiBand data were collected for the 17 participants across 392 shifts (3084 on-shift hours). On average, each physician logged 23.06 shifts (SD ± 8.43) for the study. The maximum number of shifts by any one participant was 41 shifts, and the minimum was 10. Descriptive analyses of sleep metrics across shifts revealed that EP sleep quality averaged mean ± SD 7.71 ± 1.84, which is indicative of poor sleep quality (increased fragmentation, latency, and wake after sleep onset). Sleep quantity was below recommended levels of 7–9 h (mean ± SD 6.77 ± 1.66 hours). Sleep efficiency was a mean ± SD of 87.26 ± 9.00, indicating that overall participants were below optimal performance, but the efficiency fell within "normal" range that you would expect from the given sleep duration.[8]

Readiscores for participants were assessed across time and across shifts. The percentage of time participants spent in each Readiscore zone can be seen in Table 2. On average, participants spent the bulk of their work periods in a high-performance state (50.6% of the time), spending 76.48% of the time in a state with low or very low risk of accident or serious error. However, that means that participants spent 725 h (23.52% of their work periods) with reduced or low ReadiBand scores (<80%), indicating impaired performance and elevated risk of error due to fatigue.

MLM analyses revealed relatively high ICCs (ICC1 = 0.62, ICC2 = 0.97), indicating that there were substantial individual differences between physicians in Readiscores. Therefore, MLM was warranted given its ability to control for this between-persons variability.

We next included shift start time in the model as a predictor, in addition to the grouping ID variable. This model showed that shift start time was a significant predictor of Readiscores, with a small, negative effect ($B = -0.19$, $SE = 0.10$, $t = -2.01$, $p < 0.05$), indicating that shifts starting later in the day were associated with lower Readiscores (see Figure 1). ICC values showed that shift start time accounted for approximately 1% of the variance in Readiscores, while individual differences accounted for approximately 60%. We conducted a chi-square difference test comparing the model with shift start time to the model without shift start time. This test revealed a significant improvement in predictive utility ($\chi^2 = 4.02$, $p < 0.05$) of the model when shift start time is included as a predictor.

Upon plotting the Readiscores and shift start times, we noted that as shift start times became later in the day, Readiscores actually increased initially through the morning hours before decreasing through the late afternoon and into the evening. While this resulted in an overall negative effect in the linear model, it appeared that a nonlinear model could be more appropriate. Upon adding a quadratic term along with the shift start time predictor, results showed that the model accounted for approximately 26% of the variance in Readiscores (compared to just 1% in the linear model). The new quadratic term still yielded a significant negative estimate ($B = -0.29$, $SE = 0.02$, $t = -14.14$, $p < 0.001$). The increased variance accounted for and stronger effect indicate that the quadratic term indeed served as a better predictor. As further evidence that this model held increased predictive utility over the previous (linear) model, the chi-square difference test revealed a significant improvement in predictive utility ($\chi^2 = 156.69$, $p < 0.001$). In other words, the association between shift start time and Readiscores was in fact nonlinear, as could be seen in Figure 1.

DISCUSSION

This study elaborates on prior research demonstrating that shift workers, including EPs, have poor sleep quality and lower-than-recommended sleep quantity.[2,3,5,12] In support of the primary goal of the present study to determine the percentage of time EPs spend in a fatigued state on shift, overall Readiscores for the work periods for the duration of this study demonstrated that EPs spend approximately 50% of their shift in a high state of cognitive readiness, and they spend almost 25% of their time in a reduced or significantly impaired state (<80 Readiscore). These findings are also similar to those found by James et al.[10] with regards to nurse sleep health and cognitive readiness. Unique to this study is the finding that these sleep deficits, along with factors related to shift work, can impact EP fatigue and fatigue risk. In regard to the hypothesis that later start times would be associated with increases in fatigue in a linear

TABLE 2 Percentage of work time participants spent in each Readiscore zone

	Readiscores	Percentage of time spent in each	Reaction time slowed by	BAC equivalent	Risk of accident or serious error
High	90+	50.6	5%	0%	Very low
Reduced	80–90	25.88	18%	0%	Low
	70–80	13.23	34%	0.05%	Elevated
Low	60–70	7.43	55%	>0.08%	High
	0–60	2.85	100%	>0.11%	Very high

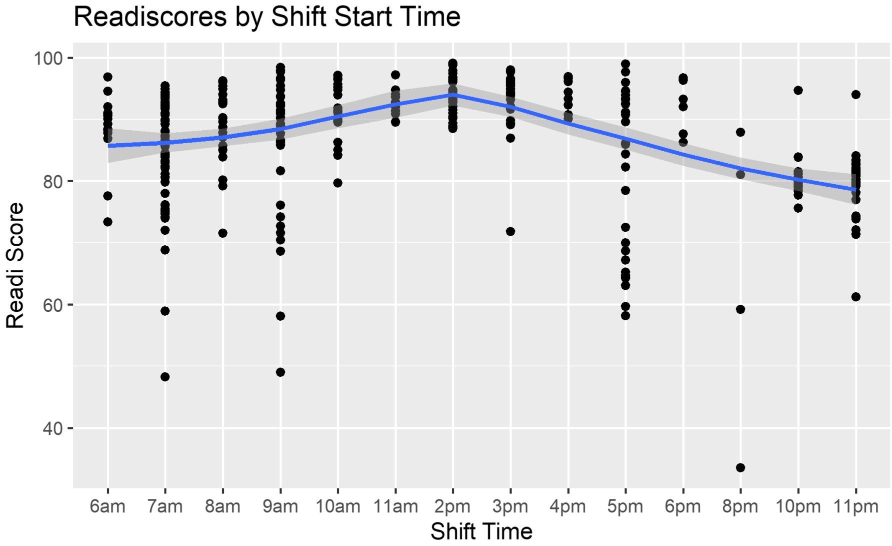

FIGURE 1 Readiscores by shift start time. The line represents the trend in Readiscores across all shift start times through the day.

manner, we actually found a curvilinear relationship between shift start time and Readiscores, such that Readiscores increased for shift start times 6:00 a.m.–2:00 p.m., but then decreased from 2:00 p.m. to 11:00 p.m. This effect may be a function of EPs adjusting to shifts with an early afternoon start time by taking a brief nap prior to the shift. In terms of the decreased readiness for night shift start times, one recommendation would be the strategic use of naps during night shifts. Unfortunately, as occupancy goals for inpatient units have generally risen for hospitals, the ED has become repurposed as a surge area for admitted patients. This has increased the overnight census, making naps difficult during the overnight period.

LIMITATIONS

Limitations of this present study include that this was a convenience sample of EPs being examined at a single academic emergency department. Given some physicians at academic emergency departments work fewer shifts given their academic or administrative responsibilities, these results may differ for community EPs who work a greater number of shifts. However, we expect that estimates of fatigue would only be higher in this population, given the larger number of shifts worked (EP typically work approximately 1560 scheduled clinical hours per year). Secondly, there was also a lack of effect in the present study between Month 1, where participants did not have access to the app for the program, and Month 2, where they had access to the app. This lack of a difference was likely a function of few participants utilizing the app. One direction for future research is to examine potential interventions consisting of personalized feedback and recommended changes for reducing fatigue based on initial indicators of fatigue. The small sample size was a third limitation to this study. While only 17 EPs participated, we were able to collect data from almost 400 shifts (more than 3000 shift hours), which provides a wealth of information about individual EP fatigue for those shifts. Future studies should incorporate larger numbers of participants where possible, to increase the ability to generalize to all EPs and to examine how different sleep metrics influence the Readiscore across EPs. In addition, since fatigue can be influenced by additional factors, such as insomnia and obstructive sleep apnea, data about individual sleep disorders should be collected from participants and incorporated into the analyses. Finally, the present study was primarily interested in documenting the presence of fatigue using an objective device over an extended duration of time. Therefore, additional predictors of fatigue were not examined in the present study and should be examined in future research. Future research should also attempt to understand how fatigue fluctuates between work and off time. Eliciting baseline levels of fatigue could be helpful in determining the severity of the impact of EP work on health. With this, future studies should examine the sequence of shifts leading up to the fatigue state, that is, rather than using the singular shift start time as a predictor, examine whether varying sequences of shift start times (e.g., all mornings, rotating schedules, all nights) differentially impact fatigue as well.

CONCLUSIONS

The present study examines baseline readiness indicators for emergency physicians to compare interventions designed to reduce fatigue among physicians. That is, this study shows that Readiscores can be used to index emergency physician fatigue and therefore can be used to evaluate interventions designed to reduce fatigue in emergency physician populations. This research further demonstrates that factors influencing fatigue are both individual and systemic and should be studied further, both in emergency medicine and in other areas of medicine. While several previous studies examine emergency physician sleep, fatigue, and shift work,[12,13] and sleep and fatigue have been measured in emergency medicine residents,[13] this study is, to our knowledge, the first to longitudinally and objectively assess fatigue in emergency physicians, as well as demonstrating fatigue risk by shift, and it lays the groundwork for future investigations into emergency physician fatigue.

AUTHOR CONTRIBUTIONS

All authors participated in the design and execution of the study. Lauren A. Fowler wrote the manuscript, Zachary Klinefelter conducted statistical analyses, and all authors revised and contributed to the final product.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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