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TESTING ALERTNESS OF EMERGENCY PHYSICIANS: A NOVEL QUANTITATIVE MEASURE OF ALERTNESS AND IMPLICATIONS FOR WORKER AND PATIENT CARE

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☐ **Abstract—Background: Establishing practical solutions to manage fatigue in health care settings could reduce errors. Predictive Safety SRP Inc.'s AlertMeter is a 2-min cognitive assessment tool currently used in high-hazard industries to identify fatigued staff. Objective: No prior study has attempted to address fatigue in emergency medicine (EM). We objectively assessed provider alertness to determine potential application of software-based fatigue recognition for risk reduction. Methods: In a double-blind, prospective evaluation from July 1 to September 30, 2016, we applied the AlertMeter to EM residents at an academic level I trauma center. The tool was applied before and after shifts to evaluate alertness in three types of shifts: day, evening, and night. All residents were invited to participate—27 of 30 enrolled. Analysis of covariance (ANCOVA) was implemented to examine shift and completion effects on alertness score using baseline score as a covariate. Additionally, three separate ANCOVAs were conducted to examine alertness score differences between portion (start vs. end) and type of shift (day, evening, or night). Results: Residents were significantly less alert at the completion of the evening shift. Scores at the end of the night shift were significantly lower than the start of the night shift. Conclusions: Alertness software can be reliably integrated into the emergency department. Alertness was lower at the end of the evening shift and end of the night shift. This work could have positive implications on shift and task scheduling and potentially reduce errors in patient care by quantifying providers' fatigue and identifying areas for countermeasures. © 2019 Elsevier Inc. All rights reserved.**

☐ **Keywords—workplace safety; patient safety; alertness; wellness; sleep**

INTRODUCTION

The field of medicine requires around-the-clock shift scheduling and the impact of fatigue among health care providers has gained attention over the past couple of decades (1–5). Research has demonstrated the effects of shiftwork on the health and safety of employees (1–3). Cognitive errors and oversights in patient care caused by fatigue and sleep debt have a negative impact on patient safety (4). A study by Landrigan et al. demonstrated that interns who frequently worked 24-h shifts made more medical errors (5). Because of the 24-h demands, health care occupations rank near the top in the number of nonfatal injuries and illnesses sustained, according to the Bureau of Labor Statistics (6). The fatigue problem is compounded because health care workers often feel as if their own health and safety must come second to that of their patients; that it is "acceptable for [them] to have less than optimal protections against hazardous exposures" (6). As a result, safety systems in health care settings should not distinguish between workers and patients, or even between levels of workers,

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but should be comprehensive enough to account for everyone in the environment (6).

Effective fatigue management is earning widespread endorsement as a practical way to mitigate risk, reduce medical errors, increase patient safety, and improve job satisfaction through more informed shift scheduling (7–11). Studies have demonstrated up to a $6.00 return for every $1.00 invested in effective health and safety programs, along with improvements in workplace safety and morale (6). Simple awareness of fatigue and effects on performance can “lead to the development of strategies to either reduce fatigue or to protect performance” (9). Knowledge of this concept could lead to a culture shift among physicians and other health care workers, driving them to consider their own health and safety to be equal that of their patients.

The AlertMeter is a graphical cognitive assessment designed to provide a measure of users’ alertness compared to their individual baselines, or average scores of unimpaired performance. The ability to detect nonalertness from fatigue was initially established in 1998, when trials showed that a short graphic test could measure human impairment from sleep deprivation (12). As a result of field trials and software improvements, a useful short test for workers is now in use in a variety of commercial settings.

Objective research into how shiftwork affects alertness and performance of medical staff has been lacking. To our knowledge, no study to date has used alertness testing, or fatigue testing overall, to evaluate shift work in medical providers. A recent study utilized alertness testing to evaluate duty hour effects on internal medicine residents, but no evaluation of shift work has been performed utilizing this technology (13). Using the AlertMeter, this investigation sought to conduct an evaluation of resident alertness before and after shifts. The technology was implemented among emergency medicine residents in an academic hospital setting to determine what effect shift work had on the participants’ level of measured alertness and, ultimately, to use these data to better understand and possibly intervene on the current work schedules to improve the ability of residents to practice.

METHODS

This study took place from July 1 to September 30, 2016 at a 3-year emergency medicine academic program at the University of Louisville, in Louisville, KY. Investigators applied the AlertMeter to emergency physicians before and after their shift to analytically evaluate group alertness and assess variation by type of shift. This was a double-blinded prospective investigation. A total of 27 residents took part in this study. This study was reviewed and approved by the Institutional Review Board.

All shifts took place at the same location, and all shifts were of a standard 10-h duration per the typical protocol of the institution. The study participants completed informed consent and were blinded from investigators through the assignment of random, unique identifier numbers.

The alertness software was installed on a computer just outside the emergency department, and subjects completed the alertness test at the beginning and end of shifts. Type of shift was recorded with each score. Although some outliers worked modified shifts, most day shifts began around 7:30 AM and ended around 5:30 PM; evening shifts began either at 1:00 PM (for postgraduate year [PGY] 1) or between 3:00 and 3:30 PM (PGY2 and PGY3). Evening shifts ended between 12:00 AM and 2 AM with most ending around 1:00 AM; and night shifts began around 10:30 PM and ended around 9:00 AM. The number of shifts for each PGY year is consistent among the trainees of that year and does not change based on shift type or PGY of training. Residents do attend conference 1 day per week on Wednesday and have a required attendance percentage. Residents on day shift attend conference regularly, the night shift residents can stay or can miss, depending on conference requirements. All residents work a mixture of day, evening, and night shifts equally among their class.

Each subject set a baseline alertness score prior to data collection by taking the test 10 times. The AlertMeter test assesses cognitive ability by measuring users’ reaction time and accuracy in determining which given collections of shapes are identical among distracting features and graphical elements. The test lasts 90 s to 2 min, and baseline scores for individual users are reliably established after 10 tests. Once an initial baseline is established, scores on individual tests are calculated using baseline. Depending on the individuals baseline, these scores can vary and the difference in start of shift to end of shift can be very small but significant, such as a change of 0.02 from baseline. The small change in score can be significant for one user, but not for another, based on the individual’s baseline. Because repetition of a task generally improves ability, it must also be noted that the scoring algorithm adjusts individual baselines to account for improved performance at the shape-identification task over time.

Analysis of covariance (ANCOVA) was implemented to examine shift effects (e.g., start of day shift vs. end of night shift) on alertness score. Additionally, three separate ANCOVAs were conducted to examine differences between alertness at the start and end of shift within each shift (day, evening, and night).

RESULTS

A total of 895 data points were included in this study. In order to be included there needed to be a match between an alertness test and a type of shift entered in the database. Descriptive statistics are provided in Table 1 and Figure 1; each show differences in alertness scores by shift and completion (start of shift vs. end of shift). Of note, the number of examinations is not equal between start and end of shifts. This can be attributed to resident compliance in completing their alertness test at the beginning or end of shift. This does not alter the alertness assessment, as the test looks at deviation from baseline and not from specific beginning and end of shift.

An examination of Figure 1 shows that for each type of shift, scores decrease from the start of the shift to the end of the shift. Additionally, results show that scores were highest at the start of the night shift and lowest at the end of the evening shifts. The evening shift typically ends between 12:00 AM and 2:00 AM. The start time to shifts are usually consistent, but the end time can vary based on clinical duties. The resultant end times in which the alertness test was taken by each individual can vary and exceed the hours scheduled for shift. This variability was included in the results, as it is more indicative of the nature of shift work and a better assessment of the decline in alertness due to hours in clinical care. To examine if these results were significant, ANCOVA was implemented.

ANCOVA results showed significant differences in score by shift and completion. Pairwise comparisons revealed there were significant differences for alertness scores, controlling with baseline scores, between those completing an evening shift (mean = .425) and those starting a night shift (mean = .450; 95% confidence interval [CI] .004–.047). It should also be noted that the biggest difference within each shift appears to be between scores at the start of night shift and the end of the night shift. Figure 2 demonstrates the difference in alertness from start to end for each shift. The largest delta being night shifts.

To examine if this was significant, three separate ANCOVAs were conducted to examine differences between start of shift type within each shift (day, evening, and night). Results showed that there were no significant differences between start of day shift and end of day shift or start of evening shift and end of evening shift. There were significant differences in alertness scores, when controlling with baseline scores, between the start (mean = .447) and end (mean = .428) of night shift $F(1, 289) = 6.7$ (95% CI .005–.033). Results of the ANCOVAs can be seen in Table 2.

Table 1. Alertness Scores by Shift and Completion

Shift and Completion	n	Mean	SD
Day start	178	.442	.081
Day end	140	.438	.071
Evening start	147	.439	.077
Evening end	156	.429	.077
Night start	132	.445	.086
Night end	142	.431	.079

SD = standard deviation.

DISCUSSION

This study sought to provide insight on the effects of shiftwork on emergency medicine residents and to determine whether alertness testing could be a viable aid to assessing risk to residents and patients due to shiftwork-related fatigue. This is a modality validated in other high-risk shift-work professions. Results from this study show resident alertness is lowest at the end of an evening shift (typically from 12:00 AM to 2:00 AM). Additionally, results showed that the largest decrease in alertness occurs during the night shift.

Several innovations are becoming available for fatigue management in safety-sensitive workplaces and occupations, including long-haul trucking and transport, mining, manufacturing, agriculture, and construction. Many of these technologies incorporate "bio-tracking," requiring wearable devices, including cameras; GPS trackers; fitness watches; or clothing, such as hats, that monitor heart rates; pulse pressure; brain waves; geographical location; and steps taken. Fatigue risk is calculated for individual employees from these data, designed to allow intervention by supervisors when an employee is perceived to present a potential risk.

However, the need for wearable devices and thorough "bio-tracking" to monitor fatigue risk may be unnecessary with the use of software such as the AlertMeter. Predictive Safety's PRISM fatigue management platform, which incorporates the AlertMeter, has demonstrated success in reducing fatigue-related incidents in high-hazard industries like mining, using noninvasive preshift alertness testing and predictive algorithms based in circadian science (14).

Some researchers have asserted that fatigue risk can be best minimized through selective employment or shift scheduling. For instance, Folkard has offered that, because night-shift workers are often "trying to work when many of their performance capabilities are at a low ebb," night shifts should be taken by "a nocturnal sub-society that. . . remains on a nocturnal routine on rest days," thus eliminating the need for body clock adjustment to night shifts (2). This is obviously not a universal solution, as there will never be enough physicians (or health care workers) who choose to work exclusively at night. Additionally, even if adapted to a night-shift schedule, individuals have to battle against a circadian ebb—when the body naturally expects to be asleep. Humans cannot will or train themselves to better handle sleep deprivation; the detriments to their performance

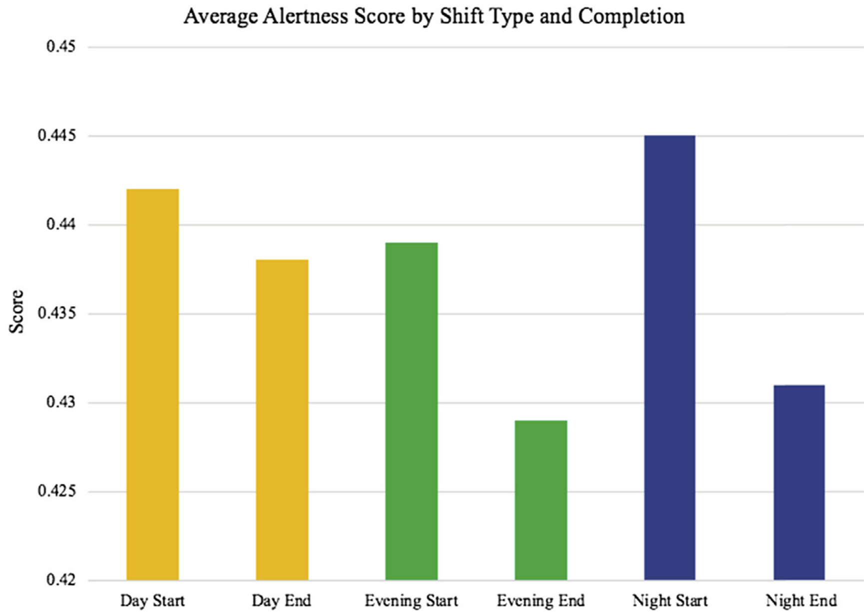

Figure 1. Alertness score means by shift and completion.

will persist. Plus, sleep-deprived people often do not even notice that their performance is diminished (15,16). This study is an introduction into the assessment and evaluation of residents in emergency medicine regarding alertness. Using this information to better understand fatigue, the next steps would be to evaluate patient care outcomes, mitigation techniques, and shift scheduling, and ultimately using the information to optimize and reduce possible error causing fatigue.

Limitations

One limitation of this study is that shift start and end times were not strictly enforced, allowing for some outlier subjects to begin or end shifts before or after the typical starting or stopping times. This may have influenced the subjects' own alertness scores and thus the average baseline for a particular shift. Although this circumstance should have had a negligible influence on

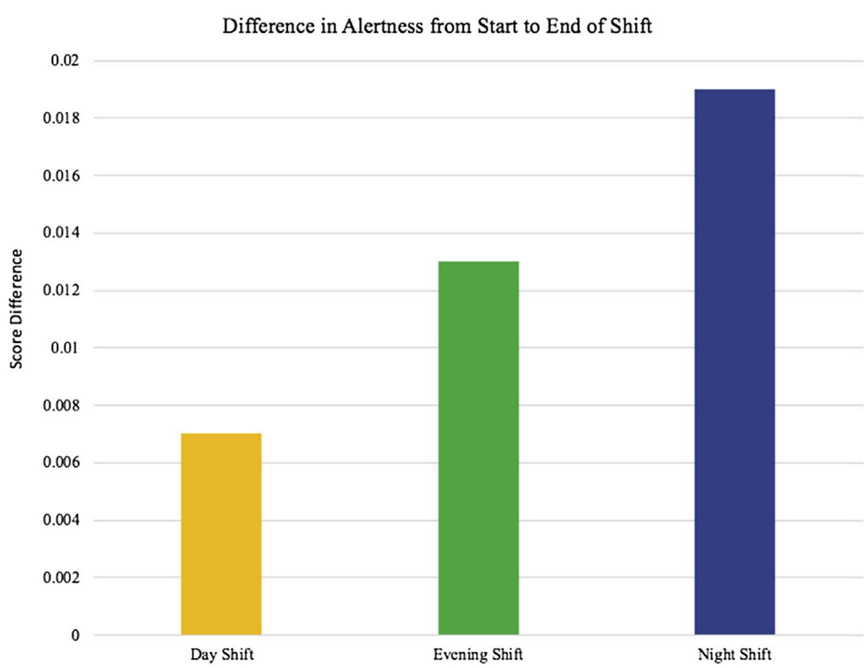

Figure 2. Difference in alertness from start to end of shift controlling with baseline.

Table 2. Analysis of Covariance Results: Examining Differences in Resident Alertness by Shift

					95% CI for Differences	
Shift Start	Shift End	Mean Difference	SE	*p* Value	Lower Bound	Upper Bound
Day start	Day end	.007	.007	.273	−.006	.020
Evening start	Evening end	.013	.007	.072	−.001	.027
Night start	Night end	.019	.007	.010	.005	.033

CI = confidence interval; SE = standard error.

this study, future studies may benefit from more fixed and regimented shift clock-in and clock-out times for the physician subjects. Additionally, each alertness score was treated as a separate data piece, thus, those who tested alertness more or worked more shifts contributed more to the study; future research should examine treatment (shift/completion) differences within each subject using repeated-measures analyses of variance. Finally, in addition to current work schedule, some physicians in the study worked shifts at other locations in addition to their shifts at the level I trauma center study setting, and any implication this may have had on the study or its findings was not considered.

CONCLUSIONS

Overall, providers demonstrated the lowest alertness scores at the end of the evening shift and the greatest reduction in score during the night shift. The alertness software technology appears to be a viable method for monitoring alertness among emergency physicians regardless of shift time or length. The ability to monitor, measure, and quantify individual alertness as exhibited in this study marks the potential for physicians to manage their own fatigue and alertness in real time. This could have positive implications on shift and task scheduling and potentially reduce errors in patient care by providing a prompt, objective measure of fatigue so that countermeasures can be taken. Future research could involve real-time feedback of scores to residents to inform such countermeasures.

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ARTICLE SUMMARY

1. Why is this topic important?

Fatigue causes risks for both provider and patient. Its prevalence and mitigation are key components to optimal health care functioning. Fatigue has been associated with circadian rhythm mismatch, implicating emergency medicine specifically as a high risk area for fatigue.

2. What does this study attempt to show?

This study demonstrates novel use of an alertness instrument to determine fatigue among emergency physicians.

3. What are the key findings?

Although emergency providers demonstrate some level of fatigue adaptation, night shift represents the greatest drop in cognitive alertness. Cognitive functioning coupled with subjective awareness seems to follow a sigmoid decay curve, with rapid drop beyond a threshold.

4. How is patient care impacted?

An alertness measurement device could be used to determine the fatigue of the provider, lending credence to departmental policy changes in time off and shift time scheduling. It is conceivable that a score below a certain threshold could indicate a provider as “unfit for duty,” allowing an on-call provider to relieve the fatigued doctor.