Impact of Fatigue Risk Management System on Fatigue and Situation Awareness of Surgical Intensive Care Unit Nurses

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Abstract: In healthcare sector, the consequences of shift work induced fatigue in healthcare professionals can adversely impact patient safety. However healthcare sector continues to manage shift work related fatigue risk through prescriptive hours of service guidelines. This study explores fatigue and situation awareness of Surgical Intensive Care Unit (SICU) nurses before and after the implementation of a performance based FRMS. Method: The study was conducted at SICU of a tertiary care hospital in Singapore. Participants were nurses doing rotating shift work. The study was designed to be conducted in a naturalistic setting and was carried out over 4 main phases: Preliminary studies, Pre FRMS, FRMS and Post FRMS. In the preliminary studies and Pre FRMS phase, fatigue and SA of nurses working in rotating shifts were analysed through roster analysis, fatigue survey, self-reporting of fatigue and sleepiness, actigraphy, vigilance testing and SA estimation. A customised performance based FRMS was developed based on the findings of the roster analysis and fatigue survey. FRMS included modifications to the SICU work roster to optimise their individual work and rest schedules, education of nurses on fatigue self-management, working with the SICU management for provision of alertness measures and fatigue countermeasures for the shifts identified as high risk. Measures for fatigue and SA were repeated in the Post FRMS phase. Results of Pre and Post FRMS phases were compared. Shift patterns (morning, afternoon and night shift) and shift timing (start and end of shift) were the main independent variables for intra shift and inter shift variation respectively. The dependant variables for fatigue and sleepiness were fatigue scores (Samn Perelli Fatigue Checklist), response time (Vigilance task) and sleepiness scores (Karolinska Sleepiness Scale). The dependant variables for situation awareness were the situation awareness scores (Situation Awareness Rating Technique). Statistical analysis was done for measures of fatigue, sleepiness, and response time and SA scores for Pre FRMS and for Post FRMS phase. The results were compared at start and end of shift and between morning, afternoon and night shifts. Pre and Post FRMS scores for each of the variables were then compared to study the impact of FRMS. The dependant variables for the shift patterns and shift timings were compared using Analysis of Variance (ANOVA) to test if there was any difference between the groups. Based on the outcome of ANOVA, if there were differences between the groups, \( t \)-tests were done. Results: The number of participants (n) that took part in the study varied based on the different phases of the study: Pre FRMS phase (n=36); FRMS phase (n=34); Post FRMS phase (n=28). 28 participants completed all the phases of the study and data from these subjects was used for the comparative analysis of the Pre and Post FRMS phase. Mean fatigue scores and mean sleepiness scores at the end of shift were higher compared to the start of shift for morning, afternoon and night shift. There was an overall decrease in mean fatigue scores and mean sleepiness scores in the Post FRMS phase as compared to Pre FRMS phase. SA scores at the end of shift were lower compared to the start of shift for morning and night shift and showed no difference for the afternoon shift. There was an overall increase in mean SA scores in the Post FRMS phase as compared to Pre FRMS phase. Discussion: The results provide an insight into the relationship between fatigue arising from shift work and SA in health care workers in a naturalistic field setting. Results showed that implementation of FRMS in SICU was associated with reduction in fatigue and sleepiness scores and improvements in SA scores. This study identifies the fatigue assessment tools that have the potential to be used in the healthcare sector for assessment of fatigue related to shift work. It also demonstrates the relevance and effectiveness of FRMS in nurses in SICU.

Keywords: Fatigue Risk Management System, Intensive Care, Nurses, Fatigue, Situation Awareness
1. Introduction

A large body of evidence shows that shift work, long sustained duty hours and limited opportunities for sleep causes circadian disruption which has an adverse effect on health and safety of shift workers. Shift work impacts the sleep wake cycle of individuals leading to cumulative sleep loss and fatigue (Czeisler & Gooley, 2007; Drake & Wright, 2011).

Work patterns that include working extended hours, night shift and rotating shift work are prevalent in the health care sector. Such shift work patterns combined with inadequate rest opportunities contribute to development of fatigue in healthcare professionals. Human error or performance failures occur due to impairments in cognitive functions such as in perception, memory, attention and decision making as well as impairments in physical motor action (Wickens, Gordon, Liu, & Lee, 2004). Sleep loss and fatigue create the latent conditions for healthcare professionals to make errors. Sleep deprived doctors and nurses are susceptible to the effects of fatigue and are at risk of making errors in the performance of safety critical tasks related to patient care. Shift work and its impact on health and safety of doctors and nurses has been a topic of increasing concern in recent years in the context of patient safety as well as from an occupational health and safety perspective.

From a human factors perspective, cognitive effects of fatigue on human information processing and performance are primarily based on experimental studies in the laboratory and critical analyses of major industrial accidents, where operator fatigue has been identified as a contributory factor. However there is limited and heterogeneous evidence from field studies in healthcare that explore the relationship between fatigue and situation awareness (Gander, Graeber, & Belenky, 2011; Wickens, Gordon, Liu, & Lee, 2004).

Cross sectional studies of trainee doctors and interns in hospital in United States, provide an insight about the effects of their work patterns and increased attentional errors during work as well as increased risk of motor vehicle crashes of interns returning home after work (Barger et al., 2006; Barger et al., 2005). While both these studies provide proxy evidence about the loss of situation awareness in specific circumstances in healthcare shift workers, the studies did not use a range of fatigue assessment measures or specific situation awareness measures to analyse fatigue or SA levels respectively.

Fatigue is a complex concept with multiple contributory factors. While there is plenty of literature about fatigue and the consequent risks of shift work to health and safety of healthcare professionals, there is limited evidence on how fatigue can best be managed in health care sector and how effective the prevalent fatigue management programs are in mitigating fatigue. Traditionally, fatigue management has been limited to work time arrangements for nurses and doctors. Limiting work hours of healthcare professionals or prescribing work limits is over simplistic when it comes to managing fatigue at the workplace. Managing fatigue by work time arrangements may create a false sense of security that as long as the individual follows the work time rules, they are safe. This is not the case always. Despite being provided adequate opportunity for sleep by the work time arrangements; often family, social and leisure activities compete with sleep opportunity. Hence, there is no guarantee that sleep opportunity is utilized as expected. Furthermore, illness or environmental factors such as noise or temperature may affect the quality of sleep. Thus in prescriptive work time regulations to manage fatigue, there is minimal capacity in the system to proactively monitor or mitigate fatigue risk on a continual basis.

Fatigue Risk Management System (FRMS) is a paradigm shift from prescriptive work time arrangements and it involves fatigue risk identification, fatigue risk assessment, fatigue mitigation as well as proactive fatigue monitoring on a continual basis. In other safety critical domains such as aviation sector, performance based fatigue risk management has shown promising results in countering shift work induced fatigue, while maintaining and even enhancing operational capabilities and productivity (Cabon et al., 2006). FRMS at the operational level goes beyond just regulating the hours of service or work duration. Multi-pronged countermeasures are applied in order to manage fatigue and include interventions at both individual level as well as organization level (Gander, Hartley, et al., 2011).

The research involved customizing a FRMS for the SICU and evaluating the effectiveness of FRMS in SICU nurse participants. The scope of this research was to study fatigue and situation awareness (SA) of nurses working on rotating shift in the SICU before and after implementing an FRMS program. In this study, known human factors instruments such as fatigue assessment methods and SA methods were used to assess the extent of fatigue and level of SA in nurses working in the surgical intensive care unit (SICU). The study protocol was repeated twice, before and after applying a healthcare FRMS.
2. Methods

The study was conducted at the Surgical Intensive Care Unit (SICU) of a tertiary care hospital in Singapore. Institutional Review Board approval was obtained prior to the conduct of the study. The study was designed to be conducted in a naturalistic or field setting to ensure the ecological validity of the measured data.

Both qualitative and quantitative research methods were used for data collection to provide a holistic view of the shift work environment and fatigue risk in SICU. Qualitative methods included field observation and task analysis of the nurses performing their tasks, survey, semi-structured and unstructured interviews with the nurses and nurse managers to understand the shift work rostering patterns. Quantitative data collection techniques were used for measurement and assessment of fatigue, situation awareness and performance in nurses performing shift work.

The main phases of the study were: Phase 1 – Preliminary studies; Phase 2 – Pre Fatigue Risk Management System phase (Pre FRMS); Phase 3 - Fatigue Risk Management System phase (FRMS) and Phase 4 – Post Fatigue Risk Management System phase (Post FRMS). This is a sequential prospective protocol with each phase leading onto the next phase.

2.1 Phase 1- Preliminary Studies

The preliminary studies phase was conducted to study the shift work environment of SICU nurses and to have an overview of their work patterns and rest patterns. Three main investigations were carried out during this phase. These were a) analysis of the shift work roster of SICU nurses, b) analysis of the demographics, work rest patterns and baseline fatigue assessment by conducting a fatigue survey and c) task analysis of the SICU nurses for identification of a task for situation awareness assessment during the shift work and for development of probes specific to the task identified.

2.1.1 Analysis of work rosters

Fatigue risk of SICU nurses was analyzed by using their work roster information for a defined 7 day period as standalone input information. The aim of this analysis was to describe the shift work patterns of the SICU and to perform a fatigue risk assessment of the work roster of each SICU nurse for the defined 7 day period. The Australian Medical Association’s (AMA) National Code of Practice was used as a guideline and benchmark Code of practice for risk assessment of fatigue in health care (Australian Medical Association Ltd, 2005). Factors such as shift length, number of consecutive shifts, night shift work, workload, and rest opportunities were taken into consideration to assess and stratify the individual fatigue risk within SICU. The analysis was done and the AMA fatigue risk scores were calculated.

2.1.2 Survey of the work and rest patterns in SICU

A questionnaire survey was conducted for SICU staff to evaluate the fatigue risk in the SICU based on the subjective reporting of the work patterns and sleep patterns and perform a fatigue scan about the relationship between the different aspects of work patterns and fatigue related outcomes. The questionnaire developed for assessment of fatigue risk and work patterns in Junior doctors was adapted and used (Gander, Purnell, Garden, & Woodward, 2007). The questions were finalised after initial pilot tests and in consultation with Subject Matter Experts that included senior nurses at SICU.

The survey questionnaire contained the following main parameters: demographic profile such as age, gender, work experience and general health status; social profile such as smoking, drinking habits , use of caffeine, commute time from home to work and study commitments; general work patterns such as working time, shift patterns; general sleep profile such as sleep and rest patterns, estimation of sleepiness using the sleepiness scales and subjective rating of fatigue using the Fatigue checklist; fatigue related error in the course of their work; shift work and fatigue education and options for any other comments in relation to perceived fatigue risk. Survey results were collated and analysed.

2.1.3 Identification of task for SA analysis

The SICU nurses perform a whole range of patient care activity during their work shift. Task analysis was conducted to identify a safety critical task that nurses performed routinely during the course of their work for situation awareness assessment. The main task selection criteria for SA assessment were that a) the identified task should be performed in all nursing shifts, b) task should be safety critical therefore incorrect
performance of the task could contribute to adverse patient safety outcomes, c) task involved the use of
cognitive functions such as perception, attention, communication etc., this was important because fatigue
affects cognitive functions before causing physical impairment and d) task should be part of their routine
work so that the SA assessment is not intrusive on their work. In view of the above considerations, the task
of “administering medications” to the patients was selected as the task for SA assessment as it fulfilled all
the criteria. SA probes of the SART questionnaire were customized based on this task.

2.2 Phase 2 - Pre FRMS

Pre FRMS phase formed the baseline data collection phase. Data collection included a test battery for
estimation of fatigue, sleepiness, SA and performance during each shift type – morning, afternoon and night
shift and at the start and end of each shift. A summary of test battery is shown in Table 1. Choice of
assessment measures in the test battery were considered based on the practicality of application in a field
setting in an operational unit. The assessment methods were non-intrusive, easy to perform in a few minutes
and required minimal training time.

Table 1 Test battery used for SICU nurses

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Measures</th>
<th>Assessment tool</th>
<th>Purpose</th>
<th>Data points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fatigue</td>
<td>SP Fatigue Checklist</td>
<td>Subjective assessment of fatigue</td>
<td>Start and end of shift</td>
</tr>
<tr>
<td>2</td>
<td>Sleepiness</td>
<td>ESS</td>
<td>Subjective assessment of general level of sleepiness</td>
<td>Start of Pre FRMS phase and Post FRMS phase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KSS</td>
<td>Subjective assessment of acute sleepiness</td>
<td>Start and end of shift</td>
</tr>
<tr>
<td>3</td>
<td>Sleep duration</td>
<td>SL</td>
<td>For subjective sleep duration</td>
<td>For the study duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Actiwatch</td>
<td>For objective sleep duration</td>
<td>For the study duration</td>
</tr>
<tr>
<td>4</td>
<td>Duty periods</td>
<td>DL</td>
<td>For recording shift type</td>
<td>For the study duration</td>
</tr>
<tr>
<td>5</td>
<td>SA</td>
<td>SART</td>
<td>For subjective assessment of SA</td>
<td>Start and end of shift</td>
</tr>
<tr>
<td>6</td>
<td>Task performance</td>
<td>PVT</td>
<td>Objective assessment of task performance</td>
<td>Start and end of shift</td>
</tr>
</tbody>
</table>

SP Fatigue Checklist- Samn Perelli ; ESS – Epworth Sleepiness Scale; KSS – Karolinska
Sleepiness Scale; SL – Sleep Log; DL – Duty Log; SART – Situation Awareness Rating Technique;
PVT – Psychomotor Vigilance Task

After the application of inclusion and exclusion criteria, participants that met the requirements were
given a briefing of the test battery and study procedure and volunteers were sought to participate in the
research. Prior to the recruitment into the study all participants gave written informed consent.
Participants were briefed about the experiment protocol and were provided the test kit and the written
checklist of study procedures. Briefing was done on the Day 1 and subjects were issued a test kit which
included actiwatch and a diary containing Sleep log (SL), Duty Log (DL), Samn Perelli (SP) fatigue checklist, Karolinska Sleepiness Scale (KSS), Epworth Sleepiness Scale (ESS), and Situation Awareness rating Technique (SART). The SL and DL as well as actiwatch were to be used for the entire period of monitoring. Psychomotor vigilance Task (PVT) testing station was set up within SICU. Test battery was to be performed at the start and end of morning, afternoon and night shift. The test kit was collected at the end of study period. Figure 1 outlines the study protocol.

Study period covered all the three shifts for any participant, for a 7 day period. There was a provision to extend the monitoring period beyond 7 days to cover all the three shift types, as far as practicable. The test procedure for the Pre FRMS and Post FRMS phase was the same.

Figure 0 Study protocol for Pre FRMS, FRMS and Post FRMS phase

2.3 Phase 3 - FRMS

Data obtained from the preliminary studies and pre FRMS phase were used to develop the fatigue risk management recommendations for SICU. Recommendations include the following key features: a) modification of work roster and recommendations for rostering; b) provision of nap time for night shifts and nap zone with good sleep hygiene; c) alertness recommendations such as strategic caffeine consumption and d) fatigue self-management and fatigue training for all SICU nurses. These are elaborated below:

a) Recommendations for work roster: Six main recommendations were proposed to reduce the fatigue risk of the work rosters based on work roster analysis. These were to increase the frequency of rest breaks during the shift; limiting the night shifts to no more than two per week; rest opportunity of at least 1 day after 5 days of continuous work; eliminate or minimise the afternoon followed by morning shift; adopt forward shift rotation and introduce a degree of predictability in roster schedules.

b) Recommendations for workplace naps and nap zone: In the context of workplace nap zone, walkthrough survey of the staff rest area was done and sleep environment was assessed. The staff room had sofas which were used for the naps for night shift nurses. It was recommended to the SICU management that foldable sofa cum bed or a portable bed be used to replace the couches so that they could provide a good sleep surface for a nap during the night shift. Nap environment recommendations included identification of a designated nap zone. The designated nap zone should be relatively quiet area away from noise and disruptions and darkened room. Nap times (power naps up to 45 minutes) were recommended particularly for the night shift nurses.

c) Recommendations for maintaining alertness: Sleep loss effects are most severe in the early morning hours. Countermeasures against sleep loss such as caffeine are effective in promoting alertness during this early morning phase. Provision of caffeine as caffeinated beverages was an alertness recommendation at work.

d) Recommendations for fatigue self-management and fatigue training: Fatigue management training module was developed for the SICU nurses. The training module covered information about sleep physiology and hygiene measures, fatigue recognition, alertness management recommendations and fatigue self-management skills. The module was delivered as a workshop of 2 hours duration. A total of eight training sessions with open session for discussion were conducted at SICU. The sleep physiology and fatigue management training was evaluated by all the participants and a feedback form was given to them.
All of the above recommendations were discussed and implemented as far as practicable with the support of the SICU management in the FRMS phase. Effectiveness of key FRMS interventions was assessed during the Post FRMS phase.

2.4 Phase 4 – Post FRMS
Post FRMS data collection procedure was similar to the Pre FRMS data collection process as highlighted earlier and shown in Figure 1.

3. Results
The results obtained from the Phase 1- Preliminary studies informed the experiment procedure in Phase 2 – Pre FRMS and Phase 3 - FRMS. The key results are summarised below.

3.1 Results of Preliminary studies
3.1.1 Analysis of work rosters
After the application of the inclusion and exclusion criteria, the final sample size for the work roster analysis was 51 (75% of the total eligible work rosters). The shift work patterns of the SICU nurses showed a great variability. SICU had 32 types of shift work arrangements which include 5 types of morning shift, 12 types of day shift, 8 types of afternoon shift, 2 types of night shift as well as 5 types of half day shifts based on different start and end times.

There was no identical or predictable roster pattern noted in the 51 rosters included in this analysis. The mean duration worked in the shift from start time to end time for the 7 day period was 43.46 hours. The minimum working hours noted was 25 hours and the maximum working hours was 55 hours per week. 82% rosters showed weekly work duration between 40-50 hours.

Shift length more than 10 hours was noted in every roster that was scheduled for night shift (69% of the rosters) and contributed to the significant score with 2 points. Nature of shift rotation also contributed to the high scores especially for the backward rotation in case of an afternoon shift followed by a morning shift such as A6 (1300-2130) followed by M3 (0700-1600)- off duty rest opportunity was less than 10 hours in such situations. 56.8% of the rosters examined had afternoon morning pattern.

Based on the AMA risk assessment analysis, the AMA risk scores lie between the minimum value of 14 and maximum value of 21. These scores were in the significant risk zone. The mean fatigue risk score was 16.98 (n=51), with 29.4% scoring 18 and 25.5 % scoring 16 and 17 respectively. Off duty rest opportunity ranged from a minimum of 1 to maximum of 4 days with an overall mean of 2.25 days. The higher the number of off duty days, the lower was the AMA risk scores.

The number of night shifts in the 7 day period of study ranged from 0 to 3 nights. All night shifts were either followed by a rest day or another night shift. A maximum of 2 consecutive night shifts was rostered. Of the 35 rosters with night shifts, 23 rosters (65.7%) had 2 or more night shifts per 7 day study period and of these 23 roster, 19 rosters (82.6%) had 2 night shifts rostered consecutively. The higher the number of night shift per week, the greater were the AMA risk scores.

This is a cross sectional analysis and hence provides only a snapshot of the fatigue risk for the 7 days. However it facilitates a better resolution of the factors that were contributing to fatigue risk in SICU.

3.1.2 Survey of the work and rest patterns in SICU
Response rate for survey was 73.7%. Some key findings of the survey are outlined here.

Demographic Profile: 84% of the staff was between the ages of 21 to 40 years. 97% of the respondents were females.

Social Profile: 14% of the respondents indicated that they are currently studying/ on a training program. In the survey, 83% responded that it takes less than 1 hour to get to work. 72 % responded that they consumed various caffeinated beverages such as coffee and tea. 81 % indicated that they consumed less than 2 cups / cans of caffeinated beverages per day.

General Sleep Profile: 17 % of respondents reported that they never or rarely get enough sleep and 25 % indicated that they never or rarely wake up feeling refreshed. Based on the responses for sleep duration in the last 7 days, SICU staff was getting mean sleep duration of 6.15 hours per sleep period during the working week as compared to their normal mean sleep duration of 7.4 hours per sleep period. These results
indicate that over the working week, on an average the nurses would lose about 1.3 hours of sleep every day that could accumulate to 6.5 hours of sleep debt over a 5 day period (cumulative sleep loss), which is almost equivalent to loss of one night’s sleep. However, this is a simplistic estimate as the actual sleep duration could vary from day to day based on the actual shift rotation pattern. Sleep quality for the past 7 days prior to the day of the survey was assessed using a 7 point sleep quality scale with rating of 1 being very poor quality sleep and 7 rating being very good quality sleep. Based on the responses, 28 % respondents indicated that their sleep quality was ≤ 3, which is at the poor end of the spectrum. However, the mean score for the sleep quality in the past 7 days was 4.16. Daytime sleepiness was measured on the Epworth Sleepiness Scale (ESS) which is an indicator of cumulative sleep debt. Scores of more than 10 are considered to be indicative of excessive sleepiness. 31 % of the respondents had ESS of more than 10.

Work Pattern Profile: 96 % of the SICU staff described their work pattern as rotating shifts with varied shift timings. Full day shift durations varied between 8, 10 or 12 hours. 72 % of the SICU staff responded that they work between 8 to 10 hours per shift in the past 7 days. More than 50 % of the staff indicated that they worked longer than the rostered duty in the preceding 2 weeks. The results show that average number of days that nurses worked longer than rostered was 5.2 days for the “last 7 days”, and 3.4 days for “the week before”.

3.1.3 Identification of task for SA analysis

The SA assessment method for this study was identified to be Situation Assessment Rating Technique (SART). SART has 10 rating queries which were modified for SICU for the task of “administering medication”. SART probes specific to the administration of medication were developed.

3.2 Results of Pre FRMS and Post FRMS phases

The number of participants (n) that took part in the study varied based on the different phases of the study: Pre FRMS phase (n=36); FRMS phase (n=34); Post FRMS phase (n=28). All subjects who enrolled in the Pre FRMS phase were automatically included for the FRMS phase and Post FRMS phase. 28 participants completed all the phases of the study and data from these subjects was used for the comparative analysis of the Pre and Post FRMS phase. Participants were all females, with mean age of 26.7 years (Range 21 - 48 years). Data was pooled from all subjects who participated in this study.

Statistical analysis was done for measures of fatigue scores, sleepiness scores, and response time and SA scores for Pre FRMS and for Post FRMS phase. The results were compared at start and end of shift and between morning, afternoon and night shifts. Pre and Post FRMS scores for each of the variables were then compared to study the impact of FRMS. The dependant variables for the shift patterns and shift timings were compared using Analysis of Variance (ANOVA) to test if there was any difference between the groups. Based on the outcome of ANOVA, if there were differences between the groups, t- tests were done. The main results for the Pre and Post FRMS phase are summarised in Table 2.

Fatigue scores: Pre FRMS and Post FRMS mean fatigue scores were compared between morning, afternoon and night shifts as well as at the start and end of each type of shift as shown in Table 2. The mean fatigue scores at the end of the shift were higher compared to the start of shift for all shifts in both Pre and Post FRMS phase. However, in the Pre FRMS phase the differences in scores were not significant except for the morning shift and the Post FRMS phase, the differences in mean fatigue scores were noted to be significant for all the shifts except the night shift. In general, all the Post FRMS mean fatigue scores were lower as compared to the Pre FRMS scores. A comparison between the overall scores at the Pre FRMS and Post FRMS phase shows that there is a reduction in the mean fatigue scores both at the start and end of shift and the difference was statistically significant.

Sleepiness Scores: Pre FRMS and Post FRMS mean KSS scores were compared between morning, afternoon and night shifts as well as at the start and end of each type of shift as shown in Table 2. The mean KSS scores at the end of the shift were greater compared to the start of shift for all three shifts in both Pre and Post FRMS phase. It is noted that the magnitude of change in the mean KSS scores between start and end of shift is greatest for the night shift in both the Pre FRMS and Post FRMS phase. In the Pre FRMS phase, the differences in mean KSS scores were statistically significant for morning and afternoon shift, however in the Post FRMS phase; the differences in mean KSS scores were not statistically significant in any of the shifts.
Response Time (RT) on Vigilance Task: Pre FRMS and Post FRMS mean RT to vigilance task was compared between morning, afternoon and night shifts as well as at the start and end of each type of shift as shown in Table 2. In the Pre FRMS and the Post FRMS phase mean RT at the end of shift were greater compared to the start of shift for all three shifts. The differences in mean RT were statistically significant for afternoon and night shift in Pre FRMS and for afternoon shift only in post FRMS phase. Overall, mean response time on vigilance task was increased in Post FRMS phase as compared to Pre FRMS phase.

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<th>Night</th>
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<tr>
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<td>Statistical significance</td>
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Table 2 Pre and Post FRMS results

Situation Awareness (SA) Scores: Pre FRMS and Post FRMS mean SA scores were compared between morning, afternoon and night shifts as well as at the start and end of each type of shift as shown in Table 2. In the Pre FRMS phase, mean SA scores at the end of the shift were lower compared to the start of shift for morning and night shifts and showed no difference for the afternoon shift. However, the differences in mean SA scores were not statistically significant in any of the shifts. In the post FRMS phase, the mean SA scores at the end of shift were lower compared to the start of the shift for morning shift but were greater in the night shift and showed no difference for the afternoon shift. The differences in SA scores were not statistically significant in any of the shifts. In general, all the Post FRMS mean SA scores were higher as compared to the Pre FRMS mean SA scores, exception being the Post FRMS scores in the night shift. A comparison between the overall mean SA scores at the Pre FRMS and Post FRMS phase shows an increase in scores both at the start and end of shift but the difference was not statistically significant.

It is noted from these observations that mean SA scores decreased between start and end of shift. Mean SA scores showed an overall improving trend in the Post FRMS phase but the differences were not found to be significant. Also in comparison to fatigue scores which showed a decreasing trend, the SA scores showed an improving trend in Post FRMS phase. Correlation between fatigue and SA score during both Pre FRMS and Post FRMS showed very weak correlation. No statistically significant correlations were noted for all the comparison that was done.
4. Discussion

Developing FRMS in the context of this research involved fatigue recognition, fatigue assessment, mitigation and monitoring. In this research, the actual FRMS interventions were put in place in Phase 3 FRMS, however, to get to the customisation of FRMS for SICU and develop appropriate interventions for the nurses, it was essential to recognise the areas of fatigue risk in SICU and assess the fatigue risk using appropriate methods and measures. FRMS was developed through evidence based approach by use of roster analysis, fatigue survey, fatigue and sleepiness assessment, SA assessment and vigilance testing. This evidence obtained guided the selection of FRMS interventions that were most likely to be effective in an operational environment.

The roster analysis of the Pre FRMS phase with the AMA fatigue risk assessment tool showed that the fatigue risk in the SICU was in the significant range and there was a potential to reduce it further to lower levels by modifying certain aspects of the work roster. The roster analysis helped in development of the FRMS interventions and recommendations for SICU. The fatigue survey helped to provide information about the actual work rest patterns of SICU nurses and identify the shifts and people at greatest risk of fatigue.

The application of AMA fatigue risk assessment tool to diagnose and predict fatigue risk was useful in roster planning for the FRMS and Post FRMS phase in SICU. This aspect was tested in this research. It was noted that there was additional potential for the AMA fatigue risk assessment tool to be used in fatigue monitoring in an operational environment such as SICU, on an ongoing basis.

The overall reduction in the mean fatigue scores in the Post FRMS phase provides evidence of the impact of FRMS in managing fatigue at both start as well as end of shift. In the FRMS phase, various interventions were used. It was not possible within the scope of this research to further assess and identify which of the interventions was most effective for the SICU. However, the reduction in mean fatigue scores in Post FRMS phase could indicate that both individual level interventions such as fatigue management training and organisational interventions such as roster modification, provision of naps, nap zone and alertness recommendations could have played a role in creating awareness and facilitating the participants to manage their fatigue levels better.

The increase in mean fatigue scores between start and end of each shift is an expected observation because fatigue levels increase as individuals work through the shift. However, in an organization that actively embraces FRMS, there is the possibility that the fatigue levels at the end of the shift would have been significantly less as compared to without an FRMS. The results of this study confirm this assumption and hypothesis.

It is noted from the results that mean KSS sleepiness scores showed an overall increasing trend between start and end of shift for morning, afternoon and night shifts. This is not an unexpected observation as both fatigue and sleepiness are expected to increase as the shift progresses. Overall mean KSS sleepiness scores showed an improving trend in Post FRMS phase as compared to Pre FRMS phase. The differences of overall mean KSS scores at the end of shift were found to be significant. Thus, like mean fatigue scores which showed a decreasing trend (Pre FRMS versus Post FRMS), the mean KSS scores showed a decreasing trend in Post FRMS phase. Thus, fatigue scores and sleepiness scores showed a similar trending pattern i.e., reduction in scores in the Post FRMS phase. Both these are aspects of fatigue that were being measured and assessed in this research and hence similar trends in fatigue and sleepiness scores provide an internal validity for the findings. Based on these observations, it can be concluded that subjective sleepiness during work was reduced with the implementation of FRMS. This could be evidence regarding the effectiveness of the FRMS interventions in the SICU.

SA scores showed improvements with reduction of fatigue after the implementation of FRMS, although the differences were not found to be statistically significant. This demonstrates that the perceived SA, though less based on subjective feedback, may not demonstrate statistical significance. It is possible that the nurses were compensating for fatigue and retaining their SA through other factors such as experience on task. It could also be that an objective assessment of SA could reveal a different outcome. This has been recommended as a concept for the future research though the setting needs to be one that is less safety critical therefore allowing probes to be used without compromising patient safety.

The results also show the observation of increased mean RT which does not generally agree with the decreased fatigue and improved SA trend. This increase in RT trends could be related to poorer motivation at this monotonous repetitive task as the participants were required to do this task several times during the shift for each shift type. While response time on vigilance task is indicative of the performance and is
sensitive to sleep deprivation and fatigue particularly in a controlled experimental setting, it is important to recognize that vigilance is not a holistic measure of cognitive performance due to its isolated transferability to real world performance task. The reason for the increased RT scores is difficult to isolate. There are many influences on cognitive performance which are based on task type, mental process requirement and the extent of external influences such as caffeine intake on the performance of the vigilance test. Since all the external contributory factors such as caffeine intake and the impact of all the FRMS interventions could not be isolated and controlled in this operational study, it is not possible to provide an adequate explanation for this observation. It is however worth noting that a study that solely uses such psychomotor response measures as representative of cognitive presence may reach inappropriate conclusions and reinforces the construct validity of this study in its exploration of situation awareness to understand cognitive presence. The study shows the reduction in measures of fatigue (fatigue scores and sleepiness scores) and improvements in SA scores after the FRMS interventions.

5. Conclusion

The study shows an association between fatigue and situation awareness of nurses performing nursing tasks. It was observed that when fatigue increased, sleepiness increased and SA decreased. After the implementation of the fatigue risk management interventions and recommendations, there was evidence of reduction in fatigue and increase in SA. While this provides some evidence of the impact of FRMS, it does not provide resolution about the aspects of FRMS interventions that were most useful. This field study opens the possibility for more comprehensive probing of this association in the future possibly with objective probes in areas where this can be done without compromising patient safety.

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