(On the spine) IMPACT OF FATIGUE ON SITUATION AWARENESS OF HEALTHCARE PROFESSIONALS SARITA DARA 2014

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IMPACT OF FATIGUE ON SITUATION AWARENESS OF HEALTHCARE PROFESSIONALS

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Abstract

This study explores the impact of fatigue on Situation Awareness (SA) both before and after the incorporation of a Fatigue Risk Management System (FRMS). It explores the relationship between fatigue and SA and the impact of FRMS on both fatigue and SA.

Literature review showed that fatigue impacts workplace safety and health and public safety and health. In healthcare sector, the consequences of shift work induced fatigue in healthcare professionals can adversely impact patient safety. Workplace Safety and Health (Risk Management) Regulations in Singapore mandate the assessment and management of all identified risks and occupational safety and health best practices suggest performance based customised Fatigue Risk Management System (FRMS) as the best option. However healthcare sector continues to manage shift work related fatigue risk through prescriptive hours of service guidelines. Impact of fatigue on cognitive functions such as memory, attention and decision making have been extensively studied but the impact of fatigue on SA, which is an upstream indicator of cognitive presence is not clearly defined.

This study was conducted in Surgical Intensive Care Unit (SICU) nurses in a tertiary care hospital in Singapore 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, fatigue and sleepiness measures, actigraphy, vigilance testing and SA estimation. A healthcare model for FRMS was developed and implemented in SICU. FRMS included modifications to the SICU work roster to optimise the work and rest schedules, education of nurses on fatigue self-management during work as well as during the rest period, 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.

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 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.

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Table of Contents

List of Figures

List of Tables

Abbreviations

AMA - Australian Medical Association Ltd

DL - Duty Log

DLRT - Diery Leiwald Reaction Time

EEG - Electroencephalogram

EMG- Electromyogram

EOG- Electroculogram

ESS - Epworth Sleepiness Scale

FAID - Fatigue Audit Inter Dyne

FRMS - Fatigue Risk Management System

IARC - International Agency for Research on Cancer

ICAO - International Civil Aviation Organization

ILO – International Labour Organization

KSS - Karolinska Sleepiness Scale

PRC - Phase Response Curve

PSG - Polysomnography

PVT - Psychomotor Vigilance test

RT - Response Time

SA - Situation Awareness

SCN - Supra chiasmatic Nucleus

SICU - Surgical Intensive Care Unit

SL - Sleep Log

SP Checklist - Samn Perelli Fatigue Checklist

SSS - Stanford Sleepiness Scale

SWD - Shift Work Disorder

TSD - Total Sleep Deprivation

WSHA – Workplace Safety and Health Act

Chapter 1 Introduction

1.1 Background

Humans are designed to be diurnal. It is physiologically and cognitively natural for humans to sleep at night and work during daytime. However, this ideal state is not always achievable in our 24/7 society. Many people work at night, either permanently, or on a rotating basis. This challenges the circadian rhythm, which is not designed for daytime sleep and night time alertness.

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). Aspects of shift work such as shift start and end time, duration of work, off duty periods, shift rotation and speed of shift rotation influence the extent of circadian disruption experienced by shift workers (ILO, 2004).

Up to a quarter of working population in many countries in Europe and in United States of America, New Zealand and Chile perform shift work (Drake & Wright, 2011; Fransen et al., 2006; ILO, 2004). A 1991 survey of shift work in Singapore, showed that 32% of employees in the private sector establishments, with 25 or more employees, were engaged in shift work (Chan & Gan, 1993). In many countries, work patterns have evolved in recent times with employers adopting variable patterns of working time arrangement that have more than one shift system.

Recent data from International Labour Organisation provides interesting insights into global “working time” trends. A large number of countries have reduced their statutory normal weekly work hours from 48 hours per week to 40 hours per week in recent decade. This downward trend is likely influenced by greater awareness of the adverse health and safety effects of shift work. However, 44% of countries have exceeded the 40 hour per week threshold and these countries are mostly from Asia- Pacific, Middle East and Africa. Average weekly working hours in Singapore is noted to be 46.6 hours and this is relatively high compared to other developed nations (ILO, 2011).

According to ILO, “The specific incidence of shift work is closely linked to the sectoral composition of national economies, and is particularly prevalent in industries such as health and social work, hotels and restaurants, manufacturing and transport, storage and communications” (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 used surveys to gather information from the participants. The studies did not use a range of fatigue assessment measures or specific situation awareness measures to analyse fatigue or SA levels respectively.

In this study, known human factors instruments such as fatigue assessment methods and situation awareness (SA) methods have been used to assess the extent of fatigue and level of SA in nurses working in the surgical intensive care unit (SICU).

Traditionally, fatigue management has been limited to work time arrangements for nurses and doctors. While there is plenty of literature about fatigue and the consequent risks of shiftwork 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.

Awareness about the working conditions of the resident medical officers in the United States was triggered by the death of 18 year old Libby Zion in a New York Hospital. She was under the care of two resident medical officers who were working night shift and extended hours. Public outcry and investigations into the death of Libby Zion triggered the review of working hours of resident doctors in New York hospitals and how it impacts patient safety (Berlin, 2008). As an outcome of this sentinel event, New York state health regulation limited the working hours of resident doctors to 80 hours per week, this was called the "Libby Zion" Law. Subsequently this regulation was adopted by the Accreditation Council for Graduate Medical Education (ACGME) for all medical training institutions in the United States in 2003 (Berlin, 2008).

However, limiting work hours of healthcare professionals or prescribing work limits is over simplistic when it comes to managing fatigue at the workplace. Fatigue is a complex concept with multiple contributory factors. Work time regulation is a traditional one-dimensional method of managing work place fatigue and it has been used since the start of the industrial revolution in the 19th century. Despite new trends of regulating work hours, fatigue remains a hazard with negative effects on workplace safety (ILO, 2005).

In general, the employment laws of countries such as the Employment Act in Singapore, provides the overarching regulation that stipulates working hours, including for the healthcare sector. The Workplace Safety and Health (WSH) Act that guides occupational health and safety applies to all workplaces within Singapore, including the hospitals. WSH Act is not prescriptive but it moves the onus onto the stakeholders such as the employers and employees, to manage fatigue risk efficiently.

In the different industry sectors with unique operational requirements, varied working time arrangements exist for shift work and these are often dictated by collective agreement between the employers and unions representing employees (ILO, 2011; Ministry of Manpower, 2014a, 2014b).

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).

This research also studies the impact of a holistic performance based fatigue risk management system that uses a multidimensional approach to managing fatigue risk. Surgical Intensive Care Unit (SICU) is a dynamic clinical work environment that requires a high degree of cognitive presence from the nurses for performance of patient related tasks. SICU also has a wide range of rotating shift work patterns for the nursing staff. It was therefore identified as a "safety critical area" for assessment of fatigue risk.

This study explores how shift work and fatigue might have an impact on situation awareness of a nurses working in the surgical intensive care unit. The magnitude of fatigue and situation awareness is compared before and after the implementation of performance based fatigue risk management system.

1.2 Objectives

The primary objectives of this study are:

1. To study the relationship between fatigue and situation awareness in rotating shift workers.
2. To customize and evaluate an appropriate fatigue risk management system (FRMS).

The secondary objectives of this study are:

1. To assess if fatigue in a healthcare worker varies within a shift i.e., between start of shift and end of shift.

2. To assess if the situation awareness of a healthcare worker varies within a shift i.e. between start of shift and end of shift.
3. To assess if fatigue of a healthcare worker varies between different shifts when doing rotating shift work.
4. To assess if situation awareness of a healthcare worker varies between different shifts when doing rotating shift work.

The exploratory objectives of the study analyse the sleep duration of healthcare worker doing shift work.

1.3 Scope and Research Approach

The scope of this thesis is limited to studying fatigue and situation awareness of nurses working on rotating shift in the SICU. The research also involved customizing and evaluating the effectiveness of FRMS in SICU nurse participants. The study protocol was repeated twice, before and after applying a healthcare FRMS.

To achieve the objectives, the research entails the following key steps; literature review of knowledge and theoretical concepts about human body clock, shift work, fatigue, situation awareness and fatigue risk management ; identify the aspects of shift work that might impact fatigue and situation awareness; determine appropriate measures to assess fatigue and situation awareness in a field setting in a healthcare unit and conduct empirical investigations in the field using various tools to study the impact of fatigue on situation awareness and the impact of a comprehensive FRMS on fatigue and situation awareness.

This research involved using a combination of qualitative and quantitative research methods for data collection.

Qualitative methods included field observation of the nurses performing their tasks, survey of shiftwork patterns and rest patterns using a questionnaire, semi-structured and unstructured interviews with the nurses as well as the 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 shiftwork. The findings from the qualitative and quantitative assessment techniques were integrated to provide a holistic view of the shiftwork environment in SICU.

1.4 Organisation of the Thesis

The research was carried out in four main phases: review of literature, conceptualisation of the study design, identification of appropriate measurement tools for use in the field setting in the healthcare sector, and empirical investigation through field studies in a tertiary health care institution as Pre FRMS phase, FRMS phase and Post FRMS phase. Figure 1 outlines the structure of the thesis.

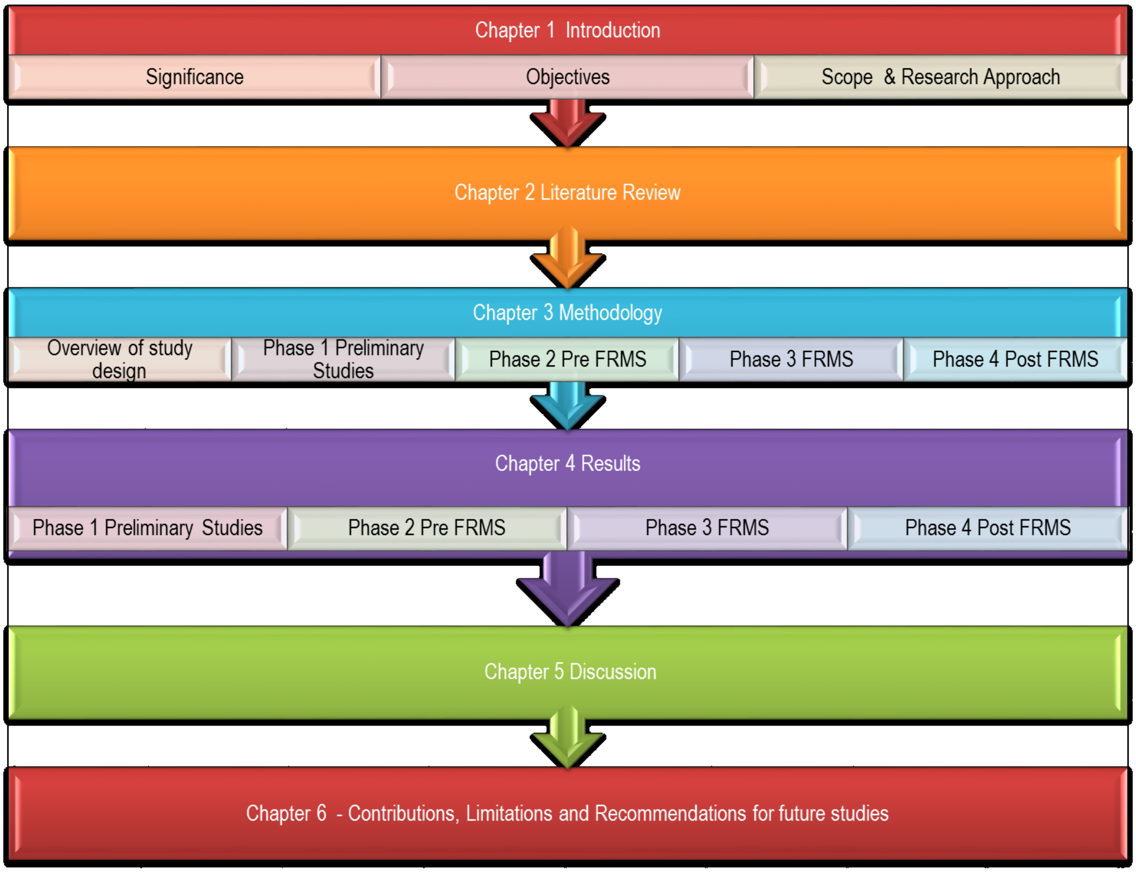


Figure 1 Structure of the thesis

Chapter 2 comprises of the literature review and covers the following key domains:

Section 2.1 Basic science of fatigue outlining the relevance of the human body clock and shift work that potentially disrupts the human body clock and contributes to fatigue.

Section 2.2 Current knowledge about shift work and fatigue and the impact on workplace safety and health of shift workers.

Section 2.3 Fatigue as a human factors challenge in healthcare sector.

Section 2.4 Fatigue in an operational setting explores the methods of fatigue detection and measurement of fatigue in the operational environment. This review provides context for the choice of measurement tools in healthcare sector for a field study.

Section 2.5 Situation Awareness (SA) and methods of studying SA in an operational environment with specific focus on healthcare. This section also provides a context for the optimal SA tool that can be used in the health care sector in a field setting.

Section 2.6 Fatigue Risk Management System (FRMS) along with comparisons between current fatigue management practices with known best practices in the healthcare sector and other safety critical sectors. It also identifies the lack of robust FRMS that can be used in healthcare sector.

Section 2.7 Healthcare system in Singapore and describes the features of healthcare delivery by nurses in the Surgical Intensive Care Unit in the context of this research.

Section 2.8 summarises the literature review and provides a framework for hypotheses formulation.

Chapter 3 provides an overview of the methodology used for this research. It provides the hypotheses, details of all the study phases including the preliminary studies, details of the test battery and the procedure for testing in field setting.

Chapter 4 present the results for the three preliminary studies, Pre FRMS, FRMS and Post FRMS phase in the SICU nurses.

Chapter 5 discusses the findings of this research.

Chapter 6 provides an overall summary of findings, contributions, limitations of the current research and recommendations for future work.

Chapter 2 Literature Review

2.1 The Basic Science of Fatigue

This section describes the current understanding of the science of fatigue. It outlines the relevance of the human body clock and shift work that potentially disrupts the human body clock and contributes to fatigue.

2.1.1 Circadian Rhythm (Human Body Clock)

Humans have an internal timekeeping system that governs their biological processes in a regular and rhythmic manner. The “circadian clock” is a cluster of about 50,000 nerve cells located in a part of the brain called the Suprachiasmatic nucleus (SCN). It generates the circadian rhythms which have a periodicity of approximately 24 hours. The circadian clock synchronises with the 24 hour day / night cycle because it is sensitive to certain external time cues. Cues that help with synchronization are called *zeitgebers* (German - time givers) and include light, temperature, activity schedules, melatonin, rest especially the start and end of sleep periods and meal times (Cajochen, Krauchi, & Wirz-Justice, 2003; Wirz-Justice, 2007).

The important human circadian rhythms are sleep wake cycle, core body temperature (CBT) rhythm and melatonin production rhythm. CBT and melatonin are used as biomarkers of human circadian rhythm (Czeisler & Gooley, 2007).

With the discovery of the clock genes, it is now known that circadian regulation is driven by genetic mechanisms and not merely by external environments. Clock genes in the nerve cells of SCN regulate a rhythmic protein production, which generates circadian rhythms (Ko & Takahashi, 2006; Vitaterna, Takahashi, & Turek, 2001).

Human beings are biologically programmed to be awake at day time and sleep at night. Work could now be done 24 /7 due to the availability and abundance of artificial light. Humans reacted to the change in working patterns by working during the biological night and sleeping during the biological day thus disrupting their circadian rhythms.

In shift work there is a disruption to the sleep wake cycle of the shift workers in relation to the 24 hour light dark cycle. As shift workers have to work against the natural circadian physiology. This desynchrony causes fatigue and impacts the performance and physiological functioning of the body (Haus & Smolensky, 2006).

2.1.2 Circadian Phase and its Impact on Performance

Core Body Temperature (CBT) minimum temperature is the reference point for sleep wake rhythms. CBT is at its minimum in the early hours of the morning, around 5 AM. This also corresponds to the circadian low in terms of performance and sleepiness i.e., hard to stay awake (Gander, 2003a). The performance drop is noted in real world observations such as greater frequency of errors in night shift workers and greater incidence of road traffic accidents in early hours of the morning (Wickens et al., 2004). Night shift workers have to take additional measures to maintain alertness during early hours of the morning especially if they are sleep deprived when they started their shift. Wake drive, also referred to as internal alarm clock, reaches peak strength about 6 hours after CBT minimum. Generally sleep begins about 5 hours before the CBT minimum and wake up occurs around 3 hours after the CBT minimum. It is recommended that night shift workers maximize their opportunity to sleep as soon as they get off their shift in the morning, otherwise they do not get to maximize their sleep opportunity (Gander, 2003a). The circadian wake drive is the reason that most people cannot sleep past lunchtime regardless of when they get off at night shift.

The longest sleep is observed when a person sleeps before the temperature maximum of the CBT rhythm – this gives the greatest window of opportunity to sleep before the onset of wake drive as much as 14-15 hours. And the shortest sleep is noted if a person sleeps just after the temperature minimum of the CBT rhythm, there is a smaller window of opportunity for sleep as the wake drive becomes strong and does not maintain sleep.

Sleep undertaken during the day or early evening is of poorer quality than night sleep and contributes to overall sleep debt (Wickens et al., 2004). Studies have also shown that prolonged circadian desynchronization causes adverse health and performance outcomes (Gander, Rosekind, & Gregory, 1998).

Fatigue impacts workplace safety and health. Basic scientific research into circadian science and fatigue has identified many aspects that have translational relevance in the design of methods for identifying and managing fatigue risk. However, this knowledge has not yet been universally translated to practical operational guidelines for reducing the occupational risk of fatigue in shiftwork. Regulations and laws exist in some safety critical industries such as aviation and maritime sector in terms of “hours of work” guidelines or “duty rest regulations”. But it is being increasingly noted in that the “hours of work” guidelines alone are not sufficient to address the risk of fatigue, particularly in workers performing safety critical tasks. The application of the evidence based principles of the circadian science is the foundation of performance based fatigue risk management.

2.2 Shift work and Fatigue: Impact on Workplace Safety and Health

As per the International Labour Organization (ILO) (2004), shift work is defined as "a method of organisation of working time in which workers succeed one another at the workplace so that the establishment can operate longer than the hours of work of individual's workers at different daily and nightly hours."

ILO's definition can be considered to be a working definition of shift work as it covers a broad spectrum of working time patterns that exist in the industry. However, this definition does not delve into the details of shift work in terms of working times, duration of work nor does it address the impact of work time organisation at an individual worker level.

From a physiological perspective, shift work is defined as "any work pattern that requires an individual to change their sleep pattern "(Gander, 2003a). This definition incorporates various work patterns noted in workplaces such as working odd hours, long hours as in extended shifts and working overtime.

In recent years, a declining trend is noted for percentage of workforce engaged in shift work in developed as well as developing countries. This could be attributed due to the increasing awareness of the risks and adverse outcomes associated with shift work. In European Union, percentage of shift work reduced from 20% in 2000 to 17 % in 2009 - 2010. In the US, 17.7% are reported to work "alternate shifts" outside their normal daytime hours of 6 a.m. to 6 p.m. and similarly in Australia, 16% of workers usually perform shift work. Lower figures are reported from Japan, only 10.5% of workforce is engaged in shift work (ILO, 2011). Based on the available statistics, shift work prevalence is 22% in United Kingdom, 21.2% in New Zealand and 32% employees in private sector in Singapore (Chan & Gan, 1993; Drake & Wright, 2011; Fransen et al., 2006). According to Akerstedt (2007) more than 20 % of males and about 10 % women in Europe work night shifts.

2.2.1 Shift work and Fatigue: Impact on Health

The immediate and dominant health impact of shift work is on sleep wake cycle leading to disturbed quantity as well as quality of sleep. Akerstedt (2007) observed that at least three-fourth of shift workers report sleep disturbances and sleep loss was noted to be greatest after rotating night shifts. Sleep quantity in shift workers was reduced by 2 hours a day and the sleep quality was poor. Thus shift work can lead to cumulative sleep debt over time. Night shift workers often reported decreased alertness and increased sleepiness as compared to day shift workers. Between 10 to 20% of night shift workers reported falling asleep during work. Studies in which objective monitoring was done in shift workers such as process operators, vehicle and train drivers and airline pilots showed involuntary "microsleep" episodes during their night shift work and the frequencies were in excess of those that were subjectively reported (Drake & Wright, 2011).

Other health conditions were noted to be greatly associated with shift workers as compared to day workers such as higher incidence of digestive disorders, alteration in bowel habit and peptic ulcers (Knutsson, 2003; Knutsson & Boggild, 2010) ; 40% greater risk of cardiovascular diseases such as myocardial infarction and hypertension (Knutsson, 2003) ; irregular eating patterns (Lowden, Moreno, Holmback, Lennernas, & Tucker, 2010); higher risk of metabolic and endocrine disorders (Knutsson, 2003); an adverse impact on mental health (Bara & Arber, 2009); adverse pregnancy outcomes in women such as low birth weight, premature birth and increased risk of miscarriage, especially for those working rotating shifts and irregular hours (Knutsson, 2003); modestly increased risk of breast cancer in nurses doing night shift work and also in female flight attendants (Straif et al., 2007) and increased risk of other cancers for example prostate cancers, colorectal cancer, endometrial cancer and Non-Hodgkin's lymphoma (Costa et al., 2010 ; IARC, 2007).

Studies also report that shift work patterns caused a reduction in social interactions, affected personal relationship, family life and social life (Drake & Wright, 2011; Gander, Briar, Garden, Purnell, & Woodward, 2010; Harrington, 2001). Gordon, Cleary, Parker, and Czeilser (1986) reported that "men working variable shifts reported higher rates of heavy drinking, job stress and emotional problems while female shift workers reported higher rates of use of sleeping pills and alcohol as well as job stress and emotional issues."

2.2.2 Shift work and Fatigue: Impact on Safety

Fatigue related impairments in shift workers could be due to attentional lapses, microsleep, increased reaction time, poor decision making and poor communication. The main factors that influence performance during shift work are circadian influences, work factors and individual factors (Bonnet, 2005; Wickens et al., 2004). In terms of circadian influences, the greatest risk of performance decrement is noted in the early morning hours, as this time is correlated to a circadian dip in functioning. It is also noted that the longer the prior wakefulness, the greater the performance decrement (at a particular time in the circadian clock). Similarly, shift workers who start a work shift with sleep deficit or sleep deprivation are at a greater risk of performance decrement during the shift (Gander, 2003b).

Tasks that involves physical activity make it is harder to fall asleep compared to tasks that involves sitting for long periods. Tasks that require a high level of engagement can help maintain alertness although only for short periods. Work demands such as high workload or sustained work can adversely impact performance of shift workers. Work environmental factors such as light, noise and temperature may impact performance by interacting with the circadian system.

Studies have also identified individual factors may impact shift work performance. Older individuals show less performance decrement than younger individuals. Some people are better performers at night while others are better in the morning. The so called "Healthy shift worker effect" is a known factor in population based studies - some people are survivors of shift work (Gander, 2003b).

Controlled sleep laboratory experiments show that Total Sleep Deprivation (TSD) in healthy young participants caused progressive deterioration in the performance on psychomotor vigilance task (PVT). PVT response speed declined over 10 minutes of the test with increasing time on task and declined across usual sleep time with extended wakefulness. This correlated with the time of circadian dip in the body's circadian cycle (Wesensten, Belenky, Thorne, Kautz, & Balkin, 2004). It was also noted that as the sleep loss became cumulative such as in extended wakefulness of up to 40 hours, participants were less able to judge their sleepiness as well as how they were performing in the tests (Gander, Graeber, & Belenky, 2011). In sleep deprivation marathons, where people voluntarily kept themselves awake for extended periods of time (Guinness book for world records for sleep deprivation was held for 264 hours of continuous wakefulness in 1965) – it was reported that people become sleepier, more irritable, had hallucinations and difficulty concentrating. Their reaction times were slower and accuracy in performance of tasks was reduced. The trend of performance decline was overall downward. But there showed variations in their daily performance based on the timing of the circadian body clock (Gander, 2003b). The peak performance for each day got lower with each day of sleep deprivation.

TSD is not merely a laboratory concept, it is encountered in sustained operations in the military, emergency services and healthcare (Wickens et al., 2004). In a nation-wide survey, anaesthetists in New Zealand were reported to have worked for 24 hours at a stretch and some up to 48 hours (Gander, Merry, Millar, & Weller, 2000). However, TSD is an extreme work condition. More commonly, chronic sleep restriction is noted in shift workers in various occupations and is a wider problem in shift work than TSD.

Belenky et al. (2003) showed that chronic sleep restriction of varying duration affected day time performance and that it affected the subsequent period of recovery from sleep deprivation. Results indicate that restoration of task performance to baseline level could take longer than 3 days. The effects of sleep restriction were cumulative and dose dependant. People did not subjectively report feeling more sleepy each day yet their performance declined. These results highlight the effects of chronic sleep restriction at night on performance in controlled laboratory conditions based on performance in specific tests. The results do not address the circadian disruption to the sleep wake cycle and the impact on chronic sleep restriction on performance, as noted in rotating shift workers. The current research proposes to study fatigue, sleepiness and performance due to rotating shift work in an operational environment. Fatigue leads to impairments in both physical and cognitive performance such as maintaining attention, decision making and communication (Gander, Graeber, & Belenky, 2011). Cognitive deficits associated with fatigue and sleepiness are perceptual impairments, decision making impairments, memory impairments particularly in learning novel tasks and in memory consolidation, diminished innovation and creativity, breakdown in monitoring and communication (Stickgold, 2005; Wickens et al., 2004).

Fatigue is identified as a contributor to accidents and incidents. Major industrial disasters including the nuclear power plant accidents in Chernobyl and Three Mile Island, Bhopal Gas Leak and Exxon Valdez oil spillage occurred during the graveyard shift and in each of these accidents, operator fatigue was identified as a contributory factor (Drake & Wright, 2011) .

Driver fatigue is thought to be a contributory factor in 13 % of fatal road traffic crashes for the period 2009 - 2011 and most of these accidents occurred in the early morning hours (Ministry of Transport New Zealand, 2013).

In their review, Harrison and Horne (2000) argued that skills that are required in an emergency in an operational environment are susceptible to sleep deprivation. Such skills include being able to attend to complex information, monitoring an evolving situation, assessing risk, ability to think laterally and innovatively, ability to monitor own performance and effective communication.

Other studies have explored shift work and work injuries in operational context in working populations. Salminen (2010) reviewed the effect of shift work and extended working hours on occupational injuries and reported that work in the afternoon and night shifts had a higher risk of occupational injury as compared to morning shift. The New Zealand Blood Donor's study also explored the association between shift work and occurrence of work injury requiring treatment by a doctor. Work injury was significantly linked with rotating shift work (Fransen et al., 2006).

A recent summary of epidemiological studies about accidents and shift work report that work duration of more than 8 hours increases the risk of accidents in safety critical activities, such as in transportation and healthcare. The accident risk after 12 hours is twice the risk at 8 hours. Rotating shift work that includes the night carries a substantially increased risk of accidents as compared to permanent night work (Wagstaff & Sigstad, 2011).

2.3 Fatigue in Healthcare

Fatigue in healthcare sector is of increasing concern. Despite being a safety critical domain, healthcare has been lagging behind other sectors in recognition and management of fatigue.

Traditionally the healthcare sector has operated as an outlier sector in terms of working hours with workers known to have worked well in excess of general industry norms but with limited guidelines and regulatory frameworks to address fatigue. The working time limits for junior doctors are up to 1.5 to 2 times more than the national maximum working hours in many countries.

In the United States, fatigue risk in resident doctors is managed by restricting their working hours to 80 hours per week, averaged over a 4 week period (Accreditation Council for Graduate Medical Education, 2011). It is also important to note that weekly working hour restriction does not ensure that fatigue will not occur. If a doctor or nurse works for longer hours due to work demands (which may happen for on call duties) – he / she may well be within the weekly regulations but the fatigue related risks continue to persist. Limiting work hours is therefore not the optimal solution though it is a step forward in the mitigation of the fatigue risk.

For the medical profession, long working hours are considered to be a normal part of the training and are traditionally associated with "professionalism" and "dedication" to patient care (Sexton, Thomas, & Helmreich, 2000). This has an impact on how doctors and nurses perceive fatigue in the context of delivery of healthcare.

"Selfless and error free work" is expected as a duty of care to patient and is prioritised over personal health and safety requirements. This expectation is also systemically created and ingrained during the entire medical training (Leape, 1994). The healthcare delivery system over centuries has fuelled this cultural environment and professional attitude and that is one of the reason for the resistance to recognise the impact of fatigue on the health and safety of the doctors and nurses and the quality of care that they can provide to their patients.

Sexton et al. (2000) have discussed in their comparative study on attitudes concerning error, stress and teamwork in medicine and aviation that physicians were more likely to deny the effects of fatigue on performance as compared to pilots (60% medical respondents versus 26% pilots). The authors attribute this observation to the fact that pilots train in crew resource management as well as recognize fatigue. The pilots acknowledge its impact on their performance and flight safety and take appropriate countermeasures. In the healthcare sector, however there is limited acceptance and awareness about fatigue and its impact on patient safety.

Barger et al. (2005) reported an increased risk of motor vehicle crashes among medical interns during their commute from work after completing extended work shifts. Similar finding were reported among nurses (Drake & Wright, 2011).

Interns working extended shifts were also associated with an “increased risk of medical errors, adverse events and attentional failures” (Barger et al., 2006). Doctors performing extended shifts were more likely to report fatigue related medical errors and preventable adverse events as compared to those without extended shifts.

Gander, Purnell, Garden, and Woodward (2007) reported the results of a nationwide survey of junior doctors. They reported that 42% of junior doctors in New Zealand hospitals could recall fatigue related errors in the course of their work and a quarter of them recalled falling asleep at the wheel when driving home from hospital.

Shift work is necessary in order to meet the society’s needs for 24/7 services, as well as for technical and economic needs of organisations. It is estimated that one in five workers engage in shift work that involves night work and extended work (Harrington, 2001). Increased risk of sleep disorders, obesity, diabetes, heart disease and breast cancer in women as well as the increased risk of errors and accidents are of particular significance in the context of promoting and maintaining the health and safety of shift workers.

The healthcare sector was chosen for this study based on an appreciation of the safety critical nature of the work, the high likelihood of prevalence of fatigue, the high consequences of fatigue in terms of its potential adverse impact on healthcare workers and patients and potential value of managing the risk associated with fatigue.

2.4 Fatigue in an Operational Setting

The International Civil Aviation Organisation (ICAO) defines fatigue as “a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member’s alertness and ability to safely operate an aircraft or perform safety-related duties” (International Civil Aviation Organisation, 2012).

The ICAO definition focuses on the impaired performance capability and on safety. This definition also provides a framework for management of fatigue in commercial aviation. This definition of fatigue shifts the focus away from the traditional approach of trying to describe and categorise work patterns towards effects of work patterns on human performance, safety and health. It also recognises that fatigue as a workplace hazard is caused not only by rotating shift work but also by extended day shifts (such as 12 hour shifts), over time, short breaks in between shifts, which leads to insufficient time for sleep and other non-work activities and also by extended periods of unbroken work.

Cause of fatigue is multidimensional and is influenced by both work and non-work related factors of shift work. Fatigue consequently impacts the performance, health and safety of the shift worker in both these domains as well as public safety. Figure 2 provides an overview of antecedents and consequences of shift work.

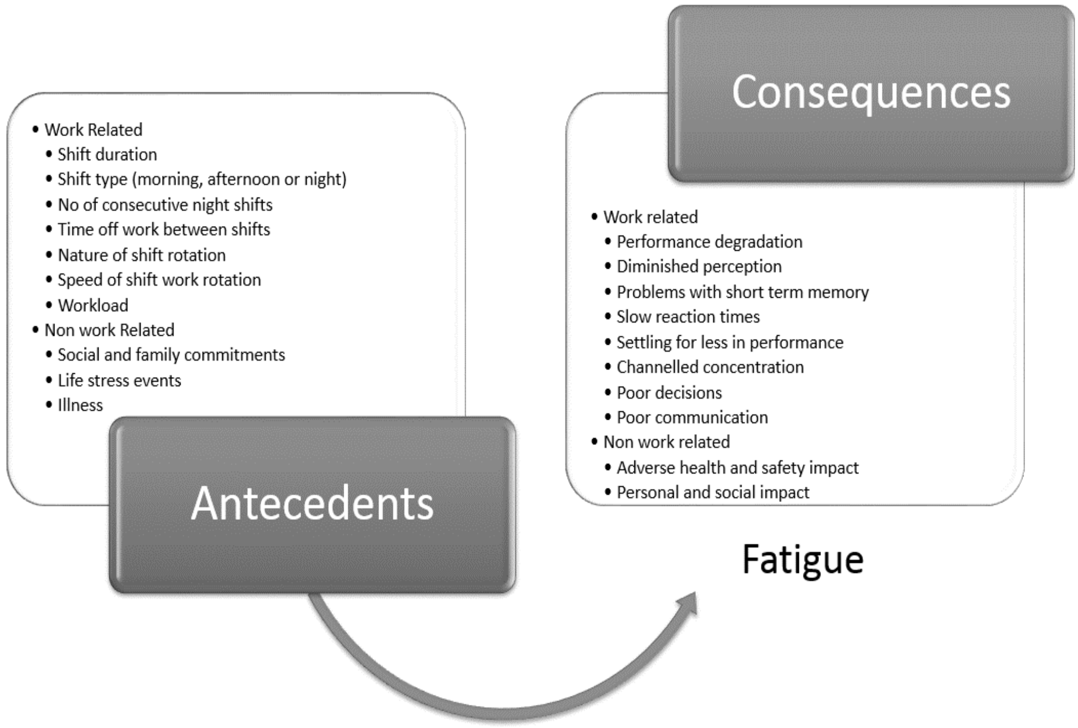


Figure 2 Overview of antecedent factors and consequences of fatigue

Fatigue and chronic sleep deprivation related to shift work can be managed by providing adequate opportunities for rest for individuals to recover from the sleep loss and to be able to sustain optimal performance. Experimental studies have shown that generally within 48 hours, the body will recover sleep; however performance recovery takes much longer (Gander, 2003a).

The implications of such performance decrements and recovery in more complex systems and dynamic operational scenarios such as in the healthcare sector are not clearly defined.

Managing fatigue risk therefore involves multiple interventions relating to shift work parameters such as work rosters as well as imparting fatigue self-management measures to the shift workers that will enable them to manage their non-work related factors. This research was conceived to bridge this knowledge gap in the healthcare sector.

2.4.1 Fatigue Evaluation

Fatigue is a subjective experience and therefore difficult to measure. Measurement of fatigue is done by adopting several proxy measures. The first step in measuring fatigue is by recognising it and reporting it. Once identified, fatigue can be measured using some subjective measures like fatigue reporting scales or sleepiness scales and objective measures of sleep such as actigraphy. Evaluation of fatigue also extends to proactively predicting the risk of fatigue by use of bio mathematical models or fatigue prediction tools (IATA, ICAO, & IFALPA, 2011; International Civil Aviation Organisation, 2012). These tools have been used to review shift work rosters to evaluate fatigue risk associated with the roster.

2.4.1.1 Recognition of Fatigue

Recognising fatigue is important in order to be able to report it. Fatigue can manifest itself through varying combinations of physical, cognitive or behavioural changes, some of which are listed in Table 1. There are individual variations in the perception, understanding and manifestation of fatigue, and therefore reporting of fatigue varies between individuals. In shift work environment, fatigue recognition is important from both an individual and a team perspective.

Table 1 Symptoms and signs of fatigue (Adapted from Queensland Government, 2009)

Physical	Cognitive	Behavioural
Yawning Eyes closing Head drooping Falling asleep	Diminished perception Memory lapses - forgetful Difficulty concentrating Channeled concentration – Fixation Poor communication General lack of awareness Slow reaction times "Settling for less" in performance	Quiet and withdrawn Lethargy Lack of motivation Irritable Changes in mood - depressed

Actions to counter fatigue can be taken only when a person recognises that he / she or a team member is experiencing fatigue. Therefore in the assessment of fatigue in an operational environment –shift workers need to self-monitor signs and symptoms that herald the onset of fatigue. This will make it possible for them to initiate countermeasures before significant impairment occurs. At a team level – knowledge about the signs and symptoms of fatigue can be used by team members to look out for each other.

2.4.1.2 Measurement of Fatigue

Fatigue measurement tools that are used in a particular setting must be able to measure the appropriate aspect of fatigue that is being studied. In the selection of assessment tool, in addition to reliability and validity, the practicality of administration of the tool in a field setting was considered. A brief review of the main assessment tools used in the study are presented in this section along with their advantages, rationale for use and their limitations.

2.4.1.2.1 Fatigue and Sleepiness Assessment by Subjective Methods

Subjective methods for assessment of fatigue are easy to use, can be administered rapidly and cause minimal intrusion in an occupational setting. In the aviation environment, subjective methods such as self -reporting of fatigue, Samn Perelli (SP) Fatigue Checklist and Karolinska Sleepiness Scale (KSS) have been used for quick fatigue scan (International Civil Aviation Organisation, 2012). Sleepiness is considered a proxy measure of fatigue, hence in fatigue research, sleepiness scales complement the assessment by fatigue scales and are often used simultaneously. Some limitations of the subjective ratings are that they may not always provide accurate measures of performance impairment or sleep loss, especially when chronic sleep restrictions cause a loss of self-awareness of the extent of fatigue.

Self-reporting of fatigue – It is a simple way of documenting fatigue by asking the individual to report fatigue using a "subjective fatigue report". The report includes information on recent sleep history (such as wake duration, sleep quantity and quality in the prior 72 hours) as well as duty history (work patterns in the prior 72 hours), time of day of the event, and other fatigue scales or sleepiness scales (Queensland Government, 2009). Self-reporting of fatigue is not universally prevalent in most work domains with the possible exception of the aviation industry where there exists an overarching safety management system and "just culture" environment that does not penalize reporting of hazards.

Fatigue Survey – For subjective assessment of sleep in a large populations or occupational groups – surveys can be used as is often the case in occupational and research settings. Surveys provide an opportunity to quickly collect data from a large group of subjects and help to perform a "fatigue scan". The results yield a cross-sectional snapshot view of fatigue. Fatigue surveys could also include subject demographics such as age, gender, experience; sleep patterns including duration and quality of sleep; work patterns including shift work duration, timing, rest opportunity, experience of fatigue during work and any other relevant probes to gain insight into existing fatigue management strategies. Validated scales and standard questions / probes should be used for gathering information on common topics such as sleep and work patterns. This will help in comparing the responses over time in the same group as well as between different groups. One example is the fatigue survey developed for healthcare sector by Gander et al. (2007) with validated questions for sleep and work patterns that has been used in this study.

Surveys can be designed based on recall of recent sleep or assessment of sleep and fatigue at any particular point in time. A snap-shot cross-sectional survey is usually short and can be used several times during a shift to query fatigue and sleepiness at any point in time. They often include probes for fatigue, sleepiness and mood (International Civil Aviation Organisation, 2012). Surveys have some limitation in terms of reliability particularly for retrospective fatigue surveys, sleep patterns and quality, which may be difficult to recall and are not accurately reported leading to recall bias.

Samn Perelli (SP) Fatigue Checklist - Subjective fatigue can also be assessed using the SP Fatigue Checklist (Samn & Perelli, 1982). The checklist is a 7-point rating scale with descriptors as shown in Table 2.

Table 2 Samn Perelli Fatigue Checklist (Samn & Perelli, 1982)

Rate	State
1	Fully Alert
2	Very lively
3	Okay
4	A little tired
5	Moderately tired
6	Extremely tired
7	Completely exhausted

It has been used widely for assessment of fatigue in aviation both in research and operational settings. Flight crew members are asked to provide a subjective rating of their fatigue level just after they board the aircraft, during flight and just before they walk off the aircraft. A score of 5 which corresponds to 'moderately tired' is considered as a threshold for taking fatigue countermeasures action.

SP checklist is easy to use in a field environment and it is a validated fatigue scale. The checklist can be used multiple times during a shift: at the start and end of a shift, and following a nap at work. The results can be used to evaluate if a shift can be extended, when an individual reports fatigue, when a co-worker picks up fatigue signs and symptoms, error committed during work or picked up or in case of an incident. The advantages are that it helps in recognition of fatigue and helps the person to initiate personal countermeasures when a set threshold is exceeded, for example, to take a short nap or take a break. The main limitation of using a subjective rating is the issue of reliability. The subjective rating may not correlate with performance decline as a fatigued individual has poor insight into the magnitude of fatigue he or she is experiencing.

Karolinska Sleepiness Scale (KSS) is used to assess acute or current sleepiness (Akerstedt & Gillberg, 1990). It is a 9 point rating scale with descriptors for 1, 3, 5, 7 and 9 as shown in Table 3. The intermediate values are also used, but they have no descriptors. Modified version of KSS with descriptors for each rating is also widely used (Appendix I, Sleepiness Scale).

Table 3 Karolinska Sleepiness Scale (Akerstedt & Gillberg, 1990)

Rate	State
1	very alert
2	
3	alert
4	
5	neither alert nor sleepy
6	
7	sleepy, but no difficulty staying awake
8	
9	very sleepy, fighting against sleep, requiring great effort to stay awake

The KSS has been used in many studies and has been validated with electroencephalogram. The KSS may be used stand-alone or together with the Karolinska Sleep Diary (KSD). The KSD is used to assess daily variations in the subjective aspects of sleep and recovery as experienced in the morning. The sleep dairy has been validated against polysomnography and shows good correlation with the objective EEG sleep measures (Akerstedt, Hume, Minors, & Waterhouse, 1994). Like the other subjective rating scales discussed earlier, the main issue is that subjective reporting does not always reliably correlate with objective measures of performance.

Epworth Sleepiness Scale (ESS) is used to measure a general level of daytime sleepiness or global level of sleepiness (Johns, 1991, 1992). ESS is a self-administered questionnaire. Subjects are asked to rate on a scale of 0 – 3, how likely they would be to doze off or fall asleep in certain situations. Subjects are to make an assessment both about the feeling of tiredness as well as the chances of falling asleep. They are also advised to attempt all situations either based on actual experience or based on their imagination by extrapolating similar situations that they may have encountered. ESS is shown in Appendix III.

ESS scores are calculated by adding up the individual score for each situation. The scores are interpreted as follows: 0 - 10: Normal range; 10 - 12: Borderline; 12 - 24: Abnormal. Clinically, ESS scores of more than 16 are indicative of high level of daytime sleepiness and warrants further evaluation. However, in field research settings, a threshold score of 10 is indicative of high risk of daytime sleepiness. ESS scores are significantly correlated with objective measures of sleepiness such as sleep latency (during day) measured with the Multiple Sleep Latency Test (MSLT) and at night with Polysomnography. ESS has been widely used in research as well in clinical medicine for evaluation of sleep disorders. ESS has also been translated into other languages (Spanish, Greek) and had been successfully validated. Papp et al. (2004) have used the ESS for evaluation of sleep propensity in doctors and found that the levels of sleepiness recorded during the study were equivalent to those found in some clinical populations of patients with sleep disorders such as narcolepsy or sleep apnoea.

<u>Sleep Log (SL) and Duty Log (DL)</u> are simple and inexpensive tools to monitor sleep and duty patterns. SL and DL can be used in conjunction with objective measures of assessment of fatigue such as actigraphy. This enables the researcher to analyse the recent duty periods, the rest periods and sleep history and derive information about the place, timing, quantity and quality of sleep from the subject's perspective. Usually the pattern of duty in the days immediately prior to the study session (i.e. rested or non-rested) is recorded in the daily duty diary. Likewise recent sleep history is logged in i.e., amount of sleep obtained in the 24 hours prior to the start of the study session. SL and DL are generally used prospectively and have good face validity (Owens, 2007). Diaries can be paper or electronic format. (Signal, Gale, & Gander, 2005) compared the

subjective sleep recorded on sleep logs with objective measures such as Polysomnography (which is the gold standard for measuring sleep) and found good correlation for average sleep duration. However sleep logs were not reliable in estimating sleep quality. The SL alone may be useful for measuring the average sleep duration of groups of individuals but are not useful in accurately estimating sleep duration of any one individual.

2.4.1.2.2 Fatigue Assessment by Objective Methods

Fatigue and sleepiness can be studied objectively. This section focuses on objective fatigue and sleepiness assessment methods in an occupational field setting, such as Polysomnography, Actigraphy and Psychomotor Vigilance Testing (International Civil Aviation Organisation, 2012; Signal et al., 2005) . Objective measures are more reliable and robust in providing an assessment of fatigue. However the use of these measures often requires appropriate hardware, technical expertise and hence has limited applicability in operational situations.

Polysomnography (PSG) is the gold standard for assessment of sleep. The polysomnography sleep measurements include Electroencephalogram (EEG) which is the measurement of brain's electrical activity, Electromyogram (EMG) which is the recording of muscle activity and Electroculogram (EOG) which is the recording of eye movements. These measurements have been seen as the most effective and accurate ways to assess the physiological attributes of sleep including sleep onset, sleep architecture and periods of wakefulness.

Electrodes are placed on the scalp and face and connected to a recording device. In an operational environment, such as in aviation, portable recorders are used to monitor in-flight sleep as well as waking alertness (International Civil Aviation Organisation, 2012). However, PSG is intrusive to task performance and requires trained personnel to perform the tedious analysis. Hence, despite the high reliability, it can be too time consuming and expensive to use routinely in operational setting.

Actigraphy – It is a method to record sleeping and waking activity. An actiwatch is an accelerometer that is used to record gross motor activity of the wrist. Actiwatch is a good proxy device for EEG registered sleep duration and therefore useful in the assessment of sleep and wakefulness (Sadeh & Acebo, 2002). Subjects are advised to wear the actiwatch on the non-dominant wrist during the whole study period, except when taking a shower or during strenuous physical activity.

The actiwatch is capable of logging data for extended periods of time up to 30 days based on its memory capacity and battery charge. In addition, duty and sleep logs are to be maintained by the subjects wearing the actiwatch to correlate the bedtimes, rising time and special circumstances for monitoring. Subjects are instructed to press the event button of the actiwatch at bed time and upon rising.

Actiwatch data is evaluated by the analysis software that comes with the device. Periods of waking and sleeping were scored automatically by the actiwatch algorithm. The software also calculates total sleep time and sleep efficiency which is percentage of time that was actually spent sleeping.

While Polysomnography is very reliable, it is not practical to use this technique in certain field studies such as in healthcare for extended periods of time due to intensive instrumentation. Actigraphy can however be used for sleep duration assessment. It is a more practical tool for field studies as it is non-intrusive, relatively low cost and provides an objective method of assessment of fatigue and sleepiness and can be used for extended periods of time. Studies have collected data on sleep measurement in flight crew, comparing actigraphy and subjective estimates to polysomnography. For estimating mean sleep duration, actigraphy estimates are sufficiently close to PSG values (Signal et al., 2005). There was a high correlation between actigraphy and PSG estimates of sleep duration (Monk, Buysse, & Rose, 1999).

According to the International Civil Aviation Organisation (2012), actigraphy is useful to examine aircrew's sleep and work patterns objectively over periods of time. Similarly, actigraphy can be used for monitoring healthcare workers doing rotating shift and objectively assess their sleep patterns and sleep duration during working days and rest days. The main limitation is that actigraphy does not directly measure sleepiness or fatigue, it measures movements of the wrist as a proxy measure of sleep. It also does not provide information about sleep quality.

Psychomotor Vigilance Task (PVT) has been used as an objective measure to assess the performance consequences of sleep loss and fatigue. The PVT is a widely accepted test of neuro-behavioural performance. It simulates a sustained attention task and can be performed very easily with minimal training time. It takes about 10 minutes to complete the test.

Studies have shown that PVT is sensitive to the effects of fatigue (Dorrain, Rogers, & Dinges, 2004). Lamond, Dawson, and Roach (2005) had devised a modified version of PVT called the "5 minutes PVT" to assess fatigue in the field. 5 minutes PVT was reported to be a useful substitute for the 10 minutes PVT in field studies for its ease of administration (as it can be self-administered) and offers minimal time away from primary work responsibilities, for performance of test. The 5 minutes PVT has also been used widely in assessment of fatigue on the flight deck in aviation in recent years (International Civil Aviation Organisation, 2012).

In fatigue research, especially in an operational environment, it is possible to combine an objective measure of sleep and fatigue such as an actiwatch with a subjective measure of sleepiness / subjective assessment of fatigue such as sleepiness scales and sleep and duty logs. Table 4 summarises the main assessment methods for sleep, fatigue and performance.

Table 4 List of main assessment methods for sleep, fatigue and performance

Subjective measures	**Effectiveness**
Fatigue scales (Samn Perelli Fatigue Checklist)	Subjective fatigue ratings are cost effective, easy to administer and analyse. These are of value in field setting, to perform a fatigue scan of large groups of people and to identify those at greatest risk. Provides a quick insight to level of perceived fatigue. However the main limitation is that subjective fatigue ratings do not always reliably reflect objective measures of performance impairment or effects of cumulative sleep loss.
Sleepiness scales (Epworth Sleepiness Scale and Karolinska Sleepiness Scale)	Subjective sleepiness ratings provide an insight into the effects of sleep loss. Epworth Sleepiness Scale is used for identifying global levels of sleepiness due to cumulative sleep loss over a period in time while Karolinska Sleepiness Scale is for acute or current levels of sleepiness. However the main limitation of subjective sleepiness ratings are that they do not always reliably correlate with objective measures of sleepiness and performance impairment.
Sleep Log and Duty Log	Sleep Log and Duty Log are used for self-reporting of sleep and duty patterns. These help in gathering information on the average amount of sleep (sleep duration) obtained in relation to their shift work roster and hours worked each day (work patterns and duration). The information obtained can be used in conjunction with the objective monitoring of sleep as well as work roster. The main limitation is that it is reliant on accurate self-reporting. Data analysis for large groups can be time-consuming.
Objective measures	**Effectiveness**
Polysomnography	Polysomnography provides detailed information about sleep profile including both sleep duration and sleep quality. It is a gold standard measurement for sleep. However, polysomnography is expensive, time-consuming to set up and intrusive to task performance. Hence it is not suitable for use in a field setting. It also requires specialised technical expertise to download and interpret the data.
Actigraphy	Actigraphy is very useful for obtaining objective recordings of the sleep/wake patterns over multiple days. This is currently the most practical and reliable way of monitoring sleep duration in field environments. Actigraphs are small and unobtrusive to wear, and cost effective compared to polysomnography. The main limitation of actigraphy is that it does not directly measure fatigue or sleepiness but measures activity as proxy measure of sleep.
Performance tests (5 minute Psychomotor Vigilance Test)	Simple performance tests are considered 'probes' or indicators of a person's capacity to carry out his or her duties. The 5 minute Psychomotor Vigilance Test (PVT) is sensitive to the effects of fatigue and is used widely in fatigue research in field setting. Performance tests measure very specific aspects of performance (for example, reaction time, vigilance, short-term memory etc.), not the complex combinations of skills needed by individuals in the course of their work.

2.4.1.3 Predicting Fatigue

Fatigue can be predicted by using bio-mathematical models. Fatigue prediction tools have been used in certain sectors to manage fatigue through design of shift cycles or rosters as well as to monitor fatigue on an on-going basis. Various bio mathematical models have been developed that incorporate aspects of shift work and fatigue science for scheduling work rosters by predicting fatigue risk levels. Most of the current models are still in evolution and are not considered reliable enough for operational implementation. They are therefore not used as a primary modality in the assessment and monitoring of fatigue. However they have an useful adjunct role (Civil Aviation Safety Authority, 2010). The main limitations of the predictive fatigue models is that they predict fatigue risk for population averages rather than fatigue levels of individuals; they may not consider all aspects of circadian physiology in their calculation of risk, but only limited validation studies have been done for various operational settings. Some of the predictive models that are commercially available and validated for the aviation sector are Circadian Alertness Simulator (Lucassen, Rother, & Cizza, 2012) and Fatigue Avoidance Scheduling Tool (Fatigue Science, 2013). These are often expensive and need skilled interpretation.

Another commercially available tool is Fatigue Audit Inter Dyne (FAID) which has been developed for generic shift work for industry (Dawson, Fletcher, & Roach, 2004). FAID helps to quantify work-related fatigue associated with a work roster by using duration of work (i.e., start and end times of work periods) as the primary input. The model assumes that fatigue associated with a duty roster is determined by a balance between fatigue accumulated during work periods and the amount of sleep obtained during non-work periods. FAID was developed to quantify the work related fatigue associated with past, current and proposed duty schedules. Since FAID uses "hours of work" as the input parameter, it enables estimation of the work related fatigue associated with a duty schedule both prospectively as well as retrospectively. The algorithm takes into account roster factors such as shift time and length, previous work schedules and rest periods to produce fatigue likelihood scores for each shift. Main limitation of FAID is that it relies solely on measures of work duration and does not account for sleep duration or sleep opportunity in calculation of risk. FAID estimates fatigue related risk for groups of individuals using a particular work schedule rather than using an individual schedule. Light exposure, sleep at work such as naps, circadian phase are not considered in the estimation of fatigue risks

2.4.1.4 Other Methods

Fatigue Calculator – It is a portable, hand held unit, that allows for self-assessment of an individual's fatigue risk levels. The calculators are commercially available units, and can be used for a quick estimation of fatigue based on hours of sleep. There is also an electronic version as apps that can be installed on a mobile device (Fatigue Calculator, 2013).

Fatigue calculator uses fatigue likelihood algorithm, which was developed by Centre of Sleep Research, University of South Australia (Dawson & McCullogh, 2005). The individual fatigue likelihood algorithm takes into consideration sleep in the prior 24 hours, sleep in the prior 48 hours and the length of wakefulness from awakening to the end of shift. It is schematically shown in Figure 3. Fatigue calculators have been used for monitoring fatigue in road transportation and can be used in many other work place setting such as healthcare (Queensland Government, 2009).

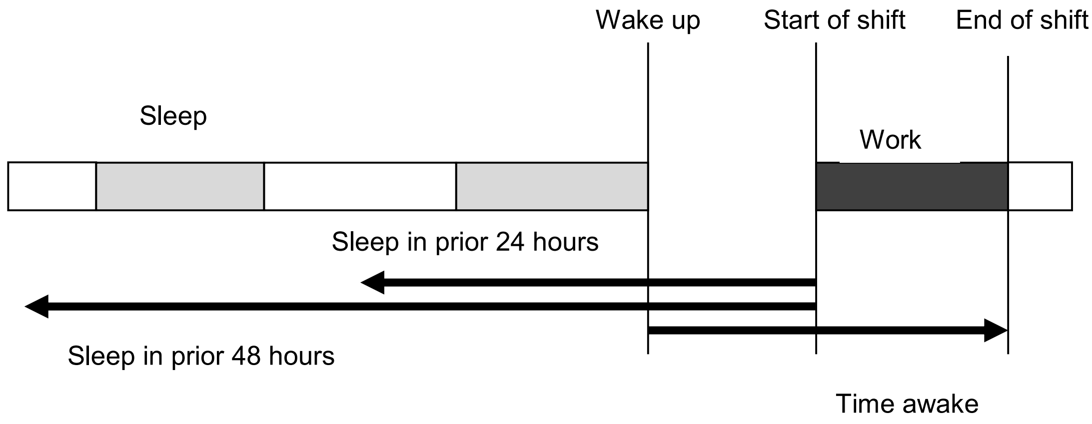


Figure 3 Individual fatigue likelihood algorithm (Dawson & Mc Cullogh, 2005)

Australian Medical Association's (AMA) National Code of Practice - hours of work, shift work and rostering for hospital doctors: AMA's national code of practice is the only tool for fatigue assessment that is available in health care sector. The fatigue risk assessment framework was developed for use in doctors to assess fatigue risk associated with long hours of work, shift work and on call duties for a period of 7 to 14 days. The AMA fatigue risk assessment tool is multidimensional tool and has 11 risk factors. These risks are scored for low, significant or high risk scenarios with a total calculated score ranging from 11 to 33 points. Each of the risk factors have points, thus providing a numerical value to fatigue risk, and help to understand the attributes that contribute greatest to the fatigue risk during the 7 day period of interest. The AMA risk assessment framework is shown in Appendix VIII.

In the 2006 Safe Hours Audit done by AMA, nearly two thirds of hospital doctors were assigned working hours that showed a significant risk of fatigue. The AMA audit revealed that many doctors worked similar number of hours but often had a very different fatigue risk rating. Fewer hours of work do not guarantee safety; however by improving rostering arrangement, fatigue can be reduced (Australian Medical

Association, 2012). This fatigue risk assessment tool has been used for assessment of work patterns of doctors in New Zealand (Gander et al., 2007).

Some limitations of this framework are that it does not consider actual sleep quantity and quality, work type and workload in the hospital in the calculation of fatigue risk. However it can be considered to be a minimum standard that needs to be adopted in the medical setting for managing fatigue risk and it provides a comprehensive multidimensional framework for roster development and management. This tool has been used in the assessment of fatigue risk of the SICU work roster in the Pre FRMS phase.

There are various methods of assessment of fatigue, each with some strengths as well as limitations as summarised in Table 4. Often in fatigue research, laboratory as well as in field studies – a combination of both subjective and objective measures are used to assess fatigue. While fatigue analysis and predictive tools such as FAID are available commercially, their use is dependent on expert analysis as well as availability of resources and hence they are difficult to operationalise. In this study for healthcare sector, various fatigue assessment tools have been reviewed and only those tools that have been validated for use in field environment have been included.

2.5 Situation Awareness: Relevance in Healthcare

2.5.1 Situation Awareness

Situation Awareness (SA) refers to the level of awareness that an individual has of the current situation or simply “knowing what is going on” (Wickens & Hollands, 1999). Situation Awareness is: “The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1995).

SA involves three processing components which are perception, comprehension and projection. *Perception (Level 1 SA)* is related to the individual's ability to receive information from the external environment and understand important characteristics within the environment. For a nurse this involves being aware of the patient's signs and symptoms on an ongoing basis. *Comprehension (Level 2 SA)* requires the individual to process the information from level one in order to develop an overview of current situation in the present environment. For a nurse, this involves understanding the status of the patient based on the patients signs and symptoms and other information in the medical charts. *Projection (Level 3 SA)* requires the individual to anticipate the actions of those components in level two. This is crucial in the development of SA as it is essential to have prior knowledge and experience of the environment to project an accurate future status. For a nurse, this would require the ability to understand the significance of the signs and symptoms and patient monitor alerts based on previous experiences and infer about the progress of the patient in the next few minutes or hours. This awareness forms the basis of subsequent actions and therefore impacts the final outcome; such as, in this case, patient safety.

Each of these 3 levels require different cognitive processes and breakdown at one level can cascade to a breakdown in the next level as shown in Figure 4. Also the measures required to be taken to prevent loss of situation awareness need to be specific to the levels of breakdown (Endsley, 2000). For example breakdown of Level 1 SA such as the failure of the nurse to be alerted to the patient's vital signs on the patient monitor would lead to potentially adverse patient outcome and therefore a mitigating strategy to enhance patient safety could be achieved through the creation of a better alerting system.

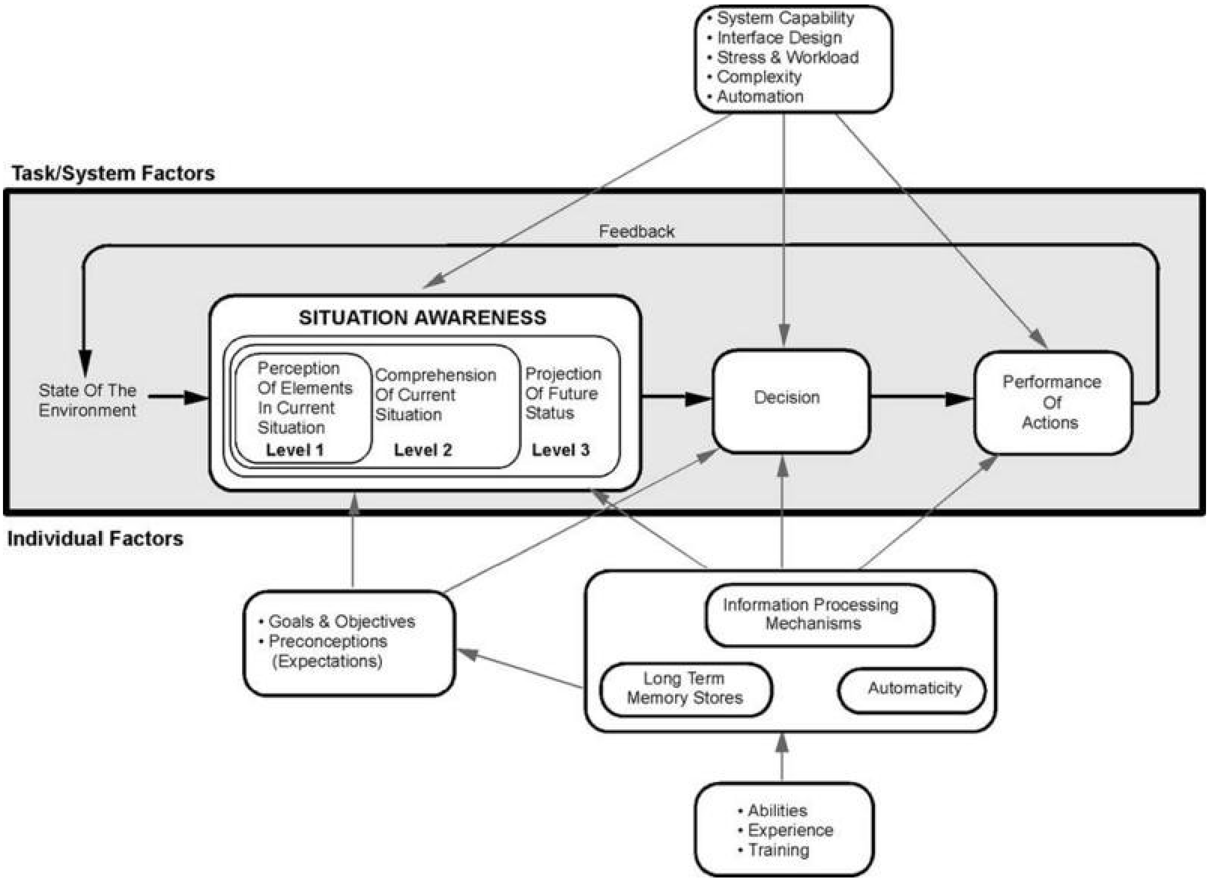


Figure 4 Situation awareness framework (Endsley, 1995)

2.5.2 Mechanism of Acquiring and Maintaining SA

SA is an iterative "process" and is most relevant in dynamic systems where the environment is changing constantly over time. SA results from the interaction of information available in the environment (system / task factors), an individual's pre-existing domain knowledge and experience (objectives and expectations) and cognitive processing skills as is shown in the Figure 4. Time plays an important role in the formulation of SA such as how much time is available to make a decision and act before certain event takes place. Hence long term working memory (prior experience) and its associated mental models are relevant to developing good SA (Wickens, 2008).

SA is a precursor to decision making and performance. Endsley (1995) depicts that SA is different from decision making and performance of action but there is a link between SA, working memory, attention, workload and stress. What this means is that while it is important for an individual or operator to have good SA for performance, SA alone is insufficient to guarantee good performance if the operator does not have adequate knowledge or motor execution skills to perform the task. Hence, the relationship between SA, decision making and performance can be described as a probabilistic link: Good SA should increase the probability of good decisions and performance, but does not guarantee it (Endsley, 2000). As an example, a trainee nurse who is administering medication to a patient may be accurately administering a medication and dosage as per the doctors instruction but may have very little awareness of the exact mechanism of action of the medication. The trainee nurse may not be able to identify a warning sign in the patient that requires immediate notification of the doctor should the patient develop an adverse side effect to the medication. In a similar situation, a more experienced nurse, administering the same drug to the same specification, may be able to contribute to enhanced patient safety.

SA of an individual is affected by both individual factors such as stress and workload as well as system / task factors such as automation, system complexity, and interface design. Ma and Kaber (2007) have explained that the three components in situation awareness, i.e., perception, comprehension and projection, are essential functions in the information processing involved in dynamic situations such as in driving. This observation would also hold true in dynamic environments such as in aviation or the emergency room of a hospital. Situation awareness of medical workers is recognised as a vital skill for patient safety (Parush et al., 2011; World Health Organisation, 2009).

2.5.3 Situation Awareness Evaluation

SA evaluation is important to assess the effect of new technologies and training interventions upon SA and also to examine the factors that affect SA such as stress and workload (Wickens, 2008). There are various techniques for evaluation of SA. These measures can be broadly categorised as query, rating and performance based techniques.

In “Query” techniques, specific probes are used to ask the operator about his or her perception of the situation being experienced. Query based techniques are useful to do objective measurement of SA and are able to identify elements in the system that impact SA. These can also be done by an experienced observer recording another person’s SA. For example - Situation Awareness Global Assessment Technique (SAGAT).

In “Rating” techniques – probes are used to rate situation awareness. The rating can be done by the observer or operator. The subjective rating techniques are widely used for their ease of administration. These techniques can be applied to a wide range of domains both in real world and experimental settings and are minimally intrusive. Performance based techniques are based on assessment of SA from performance outcomes such as performance on a primary or secondary task. The secondary task can be an embedded task. Performance based techniques consider the interaction of multiple cognitive processes and can be use embedded tasks so are minimally intrusive (Endsley, Selcon, Hardiman, & Croft, 1998; Grugle, 2005).

Two popular methods of SA assessment are Situation Awareness Rating Technique (SART), a technique for subjective measurement of SA and Situation Awareness Global Assessment Technique (SAGAT), a technique for objective measurement of SA.

Situation Awareness Rating Technique (SART) was developed by Taylor (1990). It is a self-rating technique. SART was developed for assessment of pilot SA in military aviation and has been extensively validated in aviation domain as well as other generic domains. It is easy to learn and apply to a wide variety of task. SART can be applied to work situations with minimal customisation.

SART uses the ten dimensions to measure operator SA, so it is also known as 10 D – SART. These ten dimensions have bipolar scales or Likert like scales that assess aspects of perceived demands of the operator for demands on attentional resources, understanding of the situation and supply of attentional resources. The ten SART dimension are shown in Figure 5.

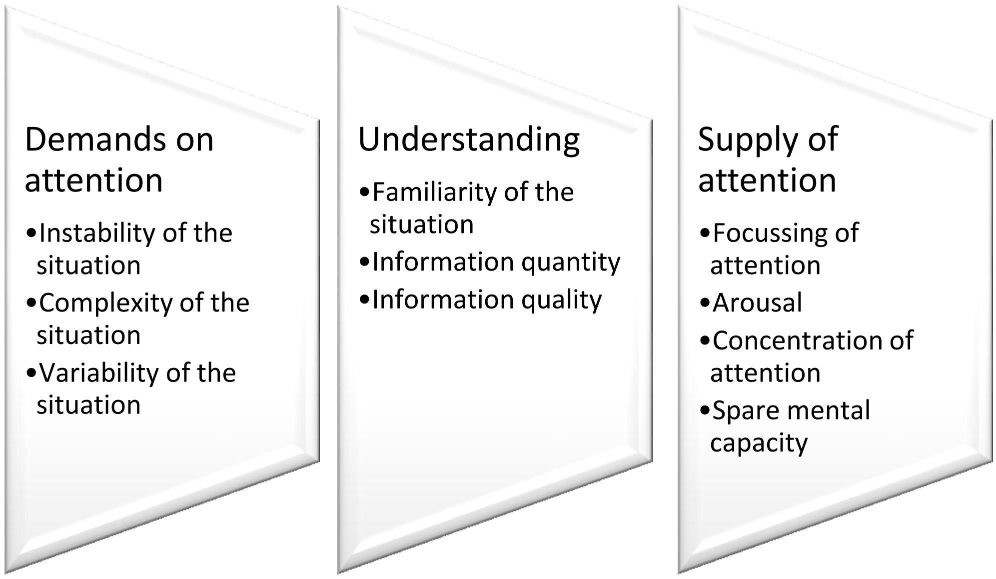


Figure 5 SART dimensions (Adapted from Taylor, 1990)

Participants are to provide a rating for each dimension on a 7 point Likert scale (1 = low, 7 = High) in order to derive a subjective measure of SA. The scores for the dimension are aggregated and a total SA score is calculated.

Self-rating techniques are usually administered post trial / event. Key limitations of SART are that operators are unable to rate their own SA especially if they do not have knowledge of the situation i.e., they do not know what they do not know. Operators may tend to rate their perceived SA based on their perceived performance on task i.e., good performance equates to good SA reporting. Since the reporting of SA depends on "recall" and occurs "after the trial", operators are prone to forgetting the periods of the trial when they had poor or low SA (Endsley et al., 1998). Despite these limitations, subjective SA or self-report data are noted to have higher validity and utility for SA researchers than behavioural measures; good correlation with subjective measures of workload and have usefulness when combined with a test battery (Endsley et al., 1998).

Situation Awareness Global Assessment Technique (SAGAT) is an objective measure of SA. SAGAT uses randomly occurring queries or probes in a simulation scenario regarding the SA requirements for the task or environment under analysis. SAGAT is the most widely validated of all SA techniques. It was initially developed for military aviation domain but its applicability has extended to other domains such as air traffic control room (Endsley & Smolensky, 1998), process control in nuclear power plants (Hogg, Folleso, Strand - Volden, & Torralba, 1995) and in a medical simulation scenario (Wright, Taekman, & Endsley, 2004).

SAGAT is a simulator based online freeze technique that can be used to assess SA across all three levels of SA. The development of probes requires and in depth cognitive task analysis for each domain that SAGAT is used in. Participants are queried about their SA with task specific probes, during random freezes in a simulation of the task or scenario under analysis. This technique allows SA data to be collected immediately and removes the recall bias associated with collecting the data post trial. Time to respond to SAGAT probe at the random freeze in the simulation is recorded as well and can be used as a measure. Operator's response to the queries is scored in accordance to the actual happening in the simulation at the time of each freeze.

SAGAT allows for an objective assessment of SA across a wide range of elements that are important for SA in a particular system. The main limitation of SAGAT is the simulation "freeze" that may be intrusive to the primary task and therefore limits its applicability to simulation only (Endsley et al., 1998). Nevertheless, SAGAT has a high degree of validity and reliability for measuring the actual SA and has been found to be useful in predicting operator performance in certain situations.

For the healthcare domain application, Hogan, Pace, Hapgood, and Boone (2006) reported that SAGAT is a valid, reliable assessment tool for trauma trainees in the dynamic clinical environment created by human patient simulation. Similarly Wright et al. (2004) suggest that SAGAT has potential to be used as a training tool in assessment of trainees performance in medical simulation scenarios more objectively. Therefore, SAGAT is not designed to be used in a field setting or in real world.

Endsley et al. (1998) have compared two techniques most often used in the cognitive human factors research arena - Situation Awareness Rating Technique (SART) and

Situation Awareness Global Assessment Technique (SAGAT) in the evaluation of an aircraft display. SART and SAGAT were both able to contribute SA information with sensitivity and diagnosticity. SART levels were highly correlated with subjective measures of performance and the subjective measures of operator's confidence level in their SA. SART was able to provide diagnostic information that the benefits of display in showing improved ratings for the subjective understanding component. SAGAT provided a similar but better diagnosticity in regards to changes in SA. However SART and SAGAT measures were not correlated with each other. Endsley et al. (1998) reported that subjective rating such as SART may not provide a true indication of person's actual SA but provides a perceived quality of SA that may help the person to act on that SA.

2.5.4 Situation Awareness: Relevance to Fatigue

In the Human Information Processing model proposed by Wickens and Hollands (1999), information cascades through the phases of perception (guided by attention and working memory) to Decision Making to Motor Action as shown in Figure 6. Level 1 SA (perception) therefore is an upstream indicator of cognitive presence.

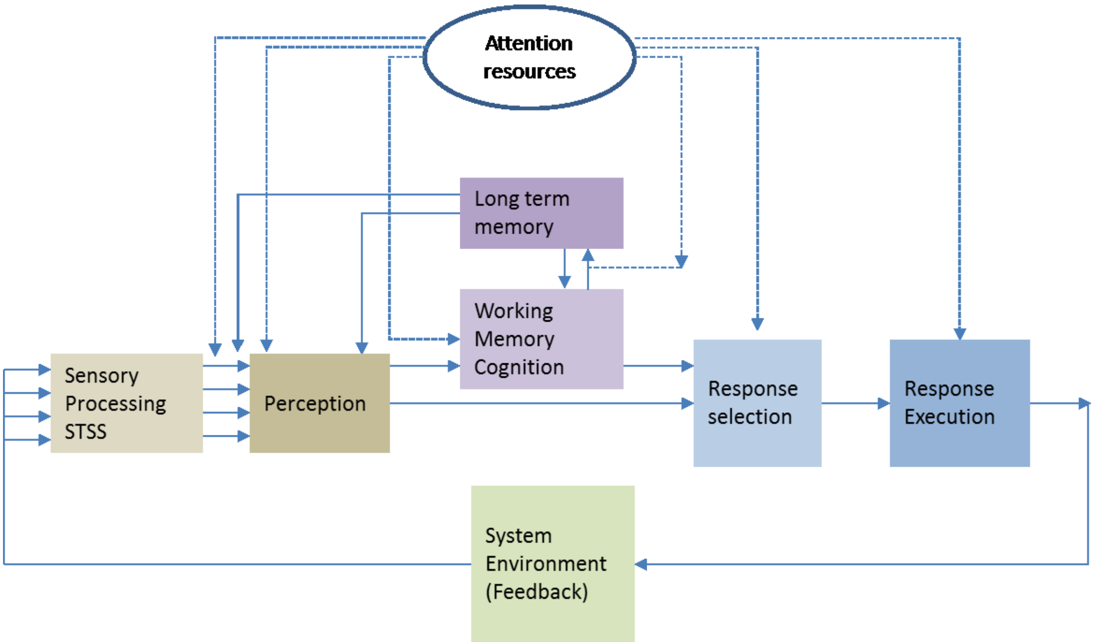


Figure 6 Model of human information processing stages (Wickens & Holland, 1999)

Factors such as stress and workload that reduce our information processing ability would also affect SA as is shown in Endsley (1995) framework in Figure 4. Studying SA within the framework of the human information processing is more appropriate than studying it as an isolated construct (Grugle, 2005).

Shift work and fatigue are stressors. Fatigue can affect both information processing (perception, attention, decision making, response time, response execution) as well as memory as well as performance of action (Grugle, 2005). SA requires a high level of cognitive functioning; therefore an individual must possess the skills as well as the functional state to acquire SA from his or her operating environment. Sleepiness, high levels of fatigue, inattention and cognitive overload are some operator states that are common and interfere with an operator's ability to maintain proper SA.

Sleep deprivation and its impact on situation awareness have been extensively researched in the military aviation operations and are noted to be one of the top primary causal factors for aviation accidents (Grugle, 2005; Knapp & Johnson, 1996). A review of civilian air craft accidents (1989 – 1992) showed that human error, particularly loss of SA, was most common contributory factor in 71 % accidents. Also notable was that the one third of accidents due to loss of SA had fatigue as the second contributor (Jones & Endsley, 1996).

In aviation, up to 18% of SA errors based on NASA's Aviation Safety Reporting System reports (using SA error taxonomy) are attributed to fatigue (Endsley & Robertson, 2000). Despite the fact that large numbers of aviation accidents due to human error are related to fatigue, accident reports rarely cite fatigue as a primary causal factor. Primary causal factors that are frequently cited are distraction, complacency, spatial disorientation and poor resource management, each of these can result from sleepiness and fatigue (Caldwell, 1997; Knapp & Johnson, 1996). Fatigue often stands out as a critical latent condition or pre-condition that leads to a safety adverse outcome in a safety critical task.

Simulator based studies of sleep deprivation included studies that induced "fatigue" and subsequently performance in driving was studied by Barfield, Rosenberg, and Furness (1995). The authors reported that with increasing sleep deprivation, driving accident rates increased. In addition to sleepiness, cognitive functions such as degraded perception and vigilance (sustained attention) showed decline. These cognitive functions are related to level 1 SA. Memory impairments and slowed response times were also noted with sleep loss (Gander, 2003b). Jones et al (2006) assessed the psychomotor performance and subjective self-ratings of SA for driving and reported that there was a persistent overconfidence in one's own driving ability under conditions of sleep deprivation, a matter of road safety concern. This reflects a loss of Level 2 SA.

In Endsley (1995) model as shown in Figure 4, SA is affected by stress and workload. However the model does not explicitly state the relation between fatigue and SA. Based on evidence from sleep deprivation studies, it can be inferred that fatigue might impacts SA by affecting Level 1 (perception) as well as Level 2 SA (comprehension) and failures in these levels cascade to failure of the Level 3 SA (projection) as depicted in the Figure 7.

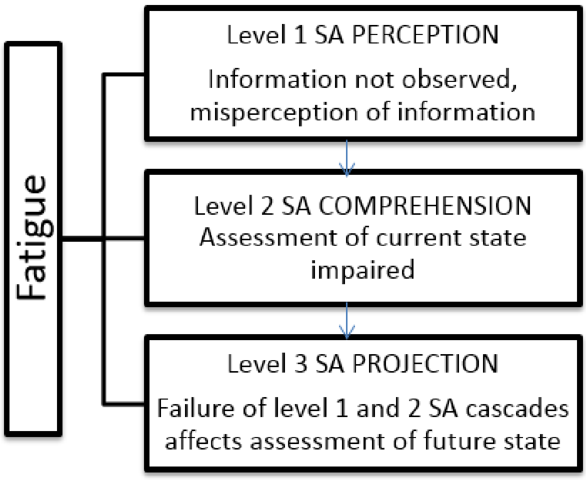


Figure 7 How fatigue might impacts perception, comprehension and projection

Fatigue is a continuum that could range from mild levels of fatigue to extreme fatigue as demonstrated by the fatigue scales described in Section 2.4.1.2.1. Likewise it can be expected that SA could have a continuum that can range from low operator SA to optimal SA or high operator SA. While these are reasonable extrapolations, these relationships have not been explicitly studied in healthcare settings and represent a gap in knowledge that this study strives to address.

In the context of complex operational environments such as military operations, flight operations, emergency and intensive care in hospitals, the safety and effectiveness of the entire system depends on the effectiveness of performance of each and every unit / individual such as timely recognition, decision making, coordination, communication and performance of assigned task. Fatigue is therefore a paramount concern as it is noted to be associated with cognitive decline that can cause loss of situation awareness. Fatigue is an outcome of the interaction of some of the individual factors as well as task and systems factors.

While sleep deprivation and situation awareness in highly demanding operational environments have been studied , there are few studies that have explored the relationship between chronic sleep deprivation induced fatigue and situation awareness such as that related to shift work, particularly in the healthcare domain. This study explores the effect of fatigue on situation awareness for nurses doing rotating shift work in the surgical intensive care unit (SICU). Despite its limitations, SART is the tool of choice for assessment of SA in the nurses because of the operational considerations in the busy SICU setting.

2.6 Fatigue Risk Management

2.6.1 Prescriptive Hours of Work

Traditionally, workplace fatigue has been addressed at a regulatory level by using work and rest time limits. Such limits were useful in managing the physical fatigue that was associated with 8 AM to 5 PM work time, in the early days of the industrial revolution in the 19th century. However, with the evolution of shift work that challenges the circadian physiology and with increasing use of technology that minimises physical labour, cognitive fatigue emerged to be a more pressing concern.

Regulation of working hours vary between different countries and generally contain some or all of the following elements: Hours of work per day, maximum over- time hours, maximum total hours per week, minimum rest breaks and day off after a period of work cycle. Regulation of work duration was intended to address two primary issues: health and safety of employees and work life balance (ILO, 2005).

In Singapore, the Employment Act provides the regulation for "conditions of work" and these provisions set the minimum standards and requirements that employers have to comply with (Ministry of Manpower, 2014a). Working hours and shift work regulations are considered in the Part IV of the Act which state that "a shift worker is allowed to work up to 12 hours a day, provided that the average working hours each week do not exceed 44 over a continuous three week period". Overtime work, overtime allowance and rest breaks are also covered in the provisions of the Act (Ministry of Manpower, 2013).

Prescriptive "hours of work" are easy to apply, enforce and monitor in the industry. They are familiar and easily understood. However, based on the evidence in the past decades, fatigue continues to be a risk in the industry despite the prescriptive work hour limits and their effectiveness in ensuring safety, performance and well-being of shift workers is being increasingly challenged (Dawson & McCullogh, 2005; ILO, 2004). Managing fatigue in shift workers by limiting the working hours is a simple "one size fits all" solution and does not address the variability and context of the operational environment such as workload and has minimal consideration to circadian disruption

(Gander, Hartley, et al., 2011). It also assumes that as long as the individual follows the rules, they do not succumb to effects of fatigue. However such an approach may not ensure that fatigue will not occur. An individual may not sleep well because of social commitments or because of illness or environmental factors such as noise, bright lights despite adhering to the prescriptive rules of working hours. In addition, many organisations may not have in place strategies to detect and act on inadequate sleep or fatigue. There may be occasions when sleep may have been obtained adequately but due to the time of the shift work, for example, early morning hours (circadian dip), fatigue related behaviours may still occur. Hence, limiting the work hours is a single defence strategy and plugs only one of the holes in the multiple layers of James Reason's Swiss cheese model (Reason, 2000).

Multidimensional aspects of fatigue are being increasingly recognised in the context of shift work such as considerations to circadian cycles as well as other non-work factors that contribute to fatigue risk.

2.6.2 Performance Based Fatigue Risk Management

"A Fatigue Risk Management System (FRMS) is an integrated set of management practices, beliefs and procedures for monitoring and managing the risks posed to health and safety of individuals by fatigue"(International Civil Aviation Organisation, 2012).

In other words, FRMS is a safety management system which is focussed on managing fatigue risk. FRMS is based on scientific principles and data driven i.e., based on objective analysis of fatigue data. FRMS adopts a holistic approach to managing fatigue. It helps in management of fatigue in a flexible manner appropriate to the level of fatigue risk based on the probability of fatigue risk and the consequences of fatigue. Recent work suggests that FRMS which is performance based should be integrated as part of the overall Safety Management System of the organisation as it has potential to maintain and even enhance the organisations operational capabilities and productivity (Gander et al., 2011a; Cabon et al., 2006).

According to the International Civil Aviation Organisation, which is currently at the forefront of addressing fatigue in aviation – FRMS is data driven, with fatigue monitoring addressing fatigue identification and measurement, integrating multiple tiers of defences to mitigate the measured fatigue risk in the operational environment. FRMS is flexible, proactive and allows for continuous improvement and has capability to monitor and manage fatigue risk. The main components of aviation FRMS are hazard identification, risk assessment, risk management and fatigue monitoring. The fatigue monitoring component is also linked to developing and implementing the safety assurance process for monitoring the performance of FRMS and for continuous improvement. The tools for measuring aviation fatigue are validated for the aviation environment and are specific to aviation sector. The aviation FRMS is modelled to enable the use of multiple tiers of defensive strategies and to be flexible to meet the operational demands on a day on day basis and to anticipate fatigue risk proactively.

Hence, the aviation FRMS is specifically aligned to the aviation environment. The nature of the safety management systems and operational practices in aviation are different as compared to other occupational settings.

The main challenges of performance based FRMS lies in its implementation because of lack of adequate knowledge base of the fatigue risks in different operational environments, lack of regulations for fatigue, lack of safety culture and the challenges in monitoring fatigue risk on a regular basis and in enforcement of FRMS. However despite the challenges, performance based FRM is the benchmark that the healthcare sector should work towards developing and adopting.

While the operational models of FRMS for aviation exist, these cannot be directly exported and used in other work place settings such as in healthcare. The methods of hazard identification and risk assessment in healthcare setting needs to be identified based on the sector specific requirements. Hence in this research, the healthcare specific assessment tools were used for identifying and measuring the fatigue risk associated with rotating shift work in nurses.

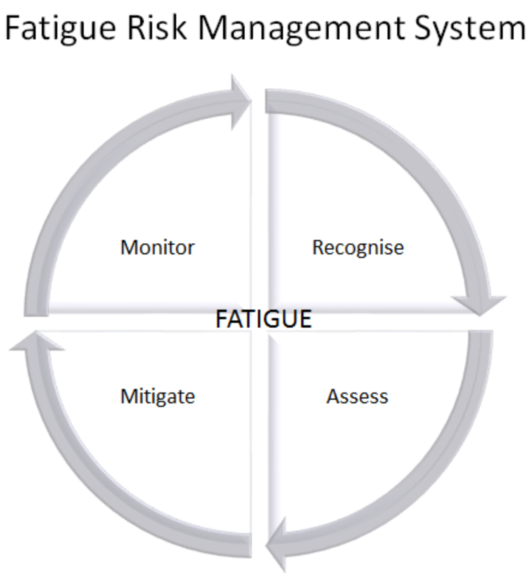


Figure 8 Healthcare FRMS Model

In the healthcare domain, there are currently no benchmark standards for fatigue risk management. This research proposes to adopt the principles of FRMS and design a specific operational model for fatigue risk management for use in healthcare. The operational model of FRMS as outlined in Figure 8 includes fatigue risk identification, fatigue risk assessment, fatigue mitigation and fatigue monitoring.

Fatigue risk identification involves identifying individuals at risk for fatigue and also identifying shifts that pose the greatest fatigue risk such as nights shift work and extended shift work. *Fatigue risk assessment* involves making an empirical estimation of the likelihood (probability) and severity (consequences) of fatigue of the identified high risk roster / shifts and therefore integrates knowledge from the domains of Fatigue Management and Risk Management. *Fatigue mitigation* involve a combination of measures based on the identified problem areas and includes designing work schedules around circadian rhythms, using fatigue countermeasures principles such as use of timed bright light, exercise, the use of caffeine to promote wakefulness, strategic napping during night shifts and extended-duration shifts to reduce fatigue and imparting fatigue self-management education about coping strategies. *Fatigue monitoring* is an essential part of FRMS to ensure that fatigue risk remains manageable. It may involve predictive and reactive monitoring based on work roster analysis and fatigue incident reports respectively.

2.6.3 Fatigue Risk Management Practices in Healthcare

Due to socio, cultural and organization factors, fatigue as a workplace hazard in healthcare is largely unattended and therefore no structured mitigation measures are in place (Helmreich & Merritt, 2001).

In Singapore, the overarching Workplace Safety and Health Act as well as Employment Act provide some legislative framework for mitigating fatigue risk (Ministry of

Manpower, 2013). However, there are no healthcare specific legislations for managing shift work in the health care professionals.

In many countries including Singapore, the working hours of healthcare professionals are guided by the employment contracts, which are often created as collective agreements with the Unions (Healthcare Services Employees Union, 2010; New Zealand Resident Doctors Association, 2012). While the collective agreements recognise the overarching labour laws, they fail to address the health and safety consequences of deviating from the stipulated maximum; instead the collective agreements adopts monetary compensation, also called "shift premiums" for working beyond the stipulated maximum hours or for working shifts that are known to have a high fatigue risk such as night shifts. There are "shift premiums" for afternoon shift with work hours ending on or after 9 PM and for night shifts (Healthcare Services Employees Union, 2013). This approach does not address the consequences of fatigue in the healthcare sector rather it perpetuates the incorrect approach by providing monetary compensation.

The Harvard Work Hours study was a prospective randomised clinical trial that was conducted in the intensive care unit and it compared two shift patterns in interns – a traditional shift with every third night on call (shifts of 24 hours or more and average 85 hours per week) versus an intervention shift (shifts of 16 hours duration and average 65 hours per week). It was noted that with intervention shift – the interns got an average of 5.8 hours more per week and attentional failures reduced by less than half (Lockley et al., 2004). Serious medication and diagnostic errors were reduced by 17 and 82% respectively (Landrigan et al., 2004). The data from these studies show that decreased extended wakefulness periods and increased night time sleep opportunities, through modification of work hours, will lead to improved outcomes in terms of performance and safety. However, limiting work duration alone is not enough as it does not address the other multifactorial causes of fatigue especially the disruptions that are caused to the circadian clock. The use of fatigue countermeasures within the framework of FRMS is the way ahead to improve workplace safety and health as well as patient safety in healthcare.

In the context of health care, performance based FRM guidelines are still evolving. The Australian Medical Association (AMA)'s National Code of practice provides a comprehensive framework for fatigue risk assessment and monitoring in doctors (Australian Medical Association Ltd, 2005). However, much more needs to be done to manage fatigue in other health care professionals such as nurses, who are exposed to fatigue risk due to shift work.

In Singapore, the Workplace Safety and Health (WSH) Act stipulates best practices in managing work place risks such as fatigue due to shift work. The WSH Act is not prescriptive however it requires every person at workplace (both employers and employees) to adopt reasonably practicable measures to ensure the safety and health of every workplace and worker. The employers have a duty to conduct risk assessment and develop solution to provide reasonably practicable work environment that is safe and without risk to the health of the employees. This includes mitigating the risks of fatigue by organising and planning shift work arrangements. The guidelines for fatigue management in Singapore are generic in nature and not industry specific (Ministry of Manpower, 2014b; WSH Council, 2010). There are no healthcare specific shift work guidelines in Singapore. In the context of nurses, given the operational constraints and the specific requirements of the Singapore healthcare system, working hours including shift work, rest breaks and overtime work are guided by the Health Services Employees Union collective agreements (Healthcare Services Employees Union, 2010, 2013).

Similarly, in a comparable healthcare system such as New Zealand, the Health and Safety in Employment Amendment Act (2002) recognises that shift work and fatigue are hazards that need to be managed at workplaces. Both employers and employees have a shared responsibility to manage fatigue arising from shift work.

In Europe, the European Working time Directive covers shift work patterns more comprehensively and elaborates limits on working hours as well as rest periods. It is briefly outlined here: "Working hours no more than 48 hours per week, minimum daily rest period of 11 consecutive hours, minimum 20 minutes rest break in any work period longer than 6 hours, minimum weekly rest of 24 uninterrupted hours for each 7 days' work and maximum night shift work duration of 8 hours" (European Commission, 2003). This Working time directive is an effort to legislate the industry for both work hours as well as rest duration and also serves as a method to manage fatigue at workplace but does not address the disruption to circadian system.

For managing the fatigue risk in healthcare, there should be an overarching legislative framework specific to healthcare sector that drives and calls for change. Without legislation there are barriers in enforcement of fatigue management practices in the healthcare sector, where there is known resistance to change because of historical precedence. Having legislation for healthcare provides a liability regime, so that the employers as well as employees conform and comply with the regulations and noncompliance can be dealt with in a more effective and transparent manner.

2.7 Healthcare System in Singapore

Singapore has a modern comprehensive healthcare system that integrates public and private initiatives. The public healthcare system comprises a network of polyclinics that are linked to tertiary care hospitals. The tertiary health care system in Singapore has 8 public hospitals which includes 6 general hospitals and 2 speciality hospitals. The tertiary care hospitals have inpatient, outpatient services and 24-hour emergency departments (Ministry of Health, 2013).

2.7.1 Healthcare Delivery by Nurses in Surgical Intensive Care Unit (SICU)

Surgical Intensive Care Unit (SICU) is based in a tertiary hospital and is operational 24/7. SICU is primarily designed for patients who need high level of care and monitoring immediately after surgery. SICU patients are managed collaboratively by a team of specialised physicians and nurses trained in critical care and other paramedical health professionals. Skilled and timely nursing care plays a significant role in determining outcomes for patients (Tai & Ng, 2001). When patients are stable, they are moved to the lower dependency general ward.

In general, patients in SICU are sedated and connected to ventilators and machines that breathe for them or support them. Most patients have a whole lot of cords attached to them such as electrode wires, infusion lines, cords to monitoring machines. Each patient has a dedicated nurse who cannot leave unless another relieves her or him. The nurses' duties involve providing bedside nursing care based on their basic assessment and advice by the treating physician. Nurses carry out procedures such as setting up an infusion pump or wound draining, administer medications to delegated patients within scope of practice, perform and assist with cardio pulmonary resuscitation in the event of an emergency, maintain accurate and up to date documentation related to the patient such as fluid charts, vital signs, medications given and other significant event. They perform specimen collection to send to laboratory for testing. Nurses also help in maintaining patient hygiene such as brushing teeth, cleaning body, changing clothes and frequent change of posture. Nurses manage some aspects of discharge and administrative work related to the patients such as arranging for investigations. They could also be involved in communicating with the families and visitors. Aside from the nursing roles, nurses are expected to adhere to hospital policies to prevent infection and work as an effective team member for quality and safe healthcare.

Nursing as an occupation has rotating shift work in order to ensure continuity of patient care. From an operational perspective, work rosters for the SICU nurses are created primarily with the objective of meeting the requirements of patient care on a continuous basis. It is critical to patient safety that SICU nurses perform their primary tasks correctly such as the right drug in the correct dosage to the right patient. Any incorrect assumptions or errors in performance of primary duties can lead to serious error in patient care.

The SICU identified for this study has approximately 80 health care professionals, a significant majority of these professionals are nurses who work in shifts and are assigned roles that involve patient care in SICU primarily. The SICU staff also includes nursing managers, nurse administrators as well as paramedical staff such as physiotherapist, pain and trauma staff. Nurses in SICU work in a "5 days work and 2 days off" pattern and they are routinely rostered to a rotating shift that includes morning, afternoon and night shift within the 7 day period. Criteria such as skills of the nurses, number of nurses per shift, unexpected contingencies in demands are often the primary driving factors that define the roster pattern in the SICU. The nature of nursing work remains the same throughout the day however, the workload varies at different times of the day. As a general rule, most elective surgeries are planned during the day hours, hence this cascades to more new admissions during the day than at night.

The patients in SICU have medical signs and symptoms that are dynamic and can change over time. The primary aspects of nursing care requires significant amount of cognitive presence and quick responsiveness for good patient outcomes. Shift work related fatigue can influence the vigilance and cognition required for performance of nursing tasks in SICU. Hence this study was conducted in SICU nurses.

2.7.2 Legislation Applicable to SICU Nurses in Singapore

All workplaces including the hospitals in Singapore come under the Workplace Safety and Health Regulations (Ministry of Manpower, 2014b). The working hours of the nurses doing rotating shift work in the hospital are pegged at a maximum of 42 hours per week. The shift work hours ranged from 38 hours per week for permanent night shift work to 40 hours per week for rotating shift workers averaged over 2-3 week roster. There are variations in terms of the magnitude of "on call allowances" and "shift premiums", between the hospitals. This variation was dependant on the type of Health Services Employees Union collective agreement that the hospital had for its nursing staff (Healthcare Services Employees Union, 2010). While the collective agreement is not a legislation it is a contract between the employers and employees and has legal value in providing a framework for reference related to shift work conditions.

2.8 Gap Analysis and Hypothesis Formulation

Section 2.1 presents a summary of the knowledge and understanding of the circadian rhythm and how its disruption due to shift work leads to fatigue. This provides the scientific foundation into designing of appropriate fatigue countermeasure strategies. It also demonstrates a need for translational studies in operational settings such that workers in workplaces gain benefit from this science.

Section 2.2 delves into the relevance and criticality of addressing fatigue to manage its impact on Workplace Safety and Workplace Health. There is a need to address fatigue in every workplace setting where fatigue risk is identified. Shift work in its various forms such as extended work hours, over time, working at night, working at odd hours exist in healthcare. It is also a safety critical domain that has been lagging behind the equivalent safety critical sectors. Healthcare sectors has therefore been chosen as a test bed for this research.

Section 2.3 illustrates the validity of the choice of the healthcare sector as this test-bed. Fatigue is a persistent problem in the healthcare sector and managing fatigue through scientific means often gets curtailed by beliefs and attitudes of the healthcare workers accustomed to working long hours as a vocational tradition notwithstanding the demonstrable dire consequences of such indulgence with rationale. Fatigue risk in the healthcare sector is a high likelihood and high consequences situation and based on risk assessment paradigms there is an opportunity to focus efforts on this sector.

This section also illustrates how fatigue in this industry impacts Workplace Safety and Health of healthcare workers but also impacts public safety and health in terms of managing adverse impacts on patients.

Section 2.4 summarizes the tools for fatigue assessment. In the formulation of the methodology of this research, each of these tools were assessed for the suitability of application in a field setting for healthcare sector and the appropriate tools were chosen. Fatigue needed to be assessed to be able to see how this changed with the application of intervention and hence these tools were used.

Section 2.5 explores Situation Awareness (SA) and its dimensions. Fatigue impacts various aspects of cognitive performance which are important for SA, while fatigue is difficult to measure, SA can be assessed with subjective and objective measures. Fatigue and SA have been studied in the context of extreme fatigue such as total sleep deprivation or sustained military operations but the impact of circadian disruption and shift work induced fatigue on Situation Awareness has not been studied before. This research attempts to study that association.

Section 2.6 explains how the basic science of fatigue is used to develop the translational operational Fatigue Risk Management System for healthcare. This tool is generic in its applicability since it spells out the key principles to consider rather than the specific interventions. The specific fatigue risk assessment tools, fatigue interventions and fatigue monitoring are specific to the industry. So though FRMS is now beginning to be used in the aerospace sector, the principles of FRMS invites its usage in any workplace setting, as long as the relevant fatigue risk assessment and interventions are chosen based on specific findings and operational needs of that sector. The usage of this holistic and comprehensive translational methodology to manage fatigue is new to the healthcare sector which has only been guided by the prescriptive hours of work and the application of this strategy to healthcare sector is novel to this research.

Section 2.7 provides an overview of the healthcare sector in Singapore and why the impact of shift work is most profound on nurses. This is also why this study has chosen nurses as subjects. Furthermore, nurses in a critical care setting have been chosen since the likelihood and consequences of fatigue risk were highest in this space.

Based on this background, the objectives and hypotheses of this research are formulated. The novelty of this research lies in translation of FRMS principles to a novel sector of application i.e., the healthcare sector. The fatigue assessment tools that have been used for the risk assessment and monitoring of fatigue have been specifically identified based on their applicability and validity of use in the healthcare setting.

Chapter 3 Methodology

3.1 Overview of Study Design

The study was conducted at the Surgical Intensive Care Unit (SICU) of a tertiary care hospital in Singapore. Institutional Review Board approval was obtained through the hospital prior to the conduct of the study. The data collection was focussed on the nurses in the SICU who were doing rotating shift work. The study was designed to be conducted in a naturalistic or field setting. This was done to ensure the ecological validity of the measured data. This was because the working patterns of the nurses and fatigue at work were the main areas of interest in this research. Additionally, the results obtained from the preliminary studies and Pre FRMS phase informed the development of a fatigue risk management strategy for the SICU. Post FRMS phase was conducted to assesses the effect of FRMS on fatigue and situation awareness.

The study design was structured to be conducted over a period of 1 year and 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). As depicted in Figure 9, each phase leads to the next phase and is a sequential prospective protocol.

Figure 9 Outline of the study phases

3.2 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.

Research approaches that were used during this phase included interviews and consultation with domain experts such as senior nurses of SICU regarding work rosters, nursing tasks in SICU, fatigue survey with questionnaire, work site walkthrough and work observational study.

The operational considerations related to the conduct of research in the SICU without significantly impacting the primary role of the nurses was discussed and finalised with the SICU management during this phase. The main operational considerations for testing in SICU were that the participation of the nurses in the study should did not impact patient safety. The tests should not be intrusive to the nurse's primary role and the test time and duration do not affect SICU operational requirements. Furthermore, testing procedures had to adhere to the overarching health and safety recommendations within the SICU.

3.2.1 Study 1 - Analysis of Shift Work Patterns in SICU Nurses

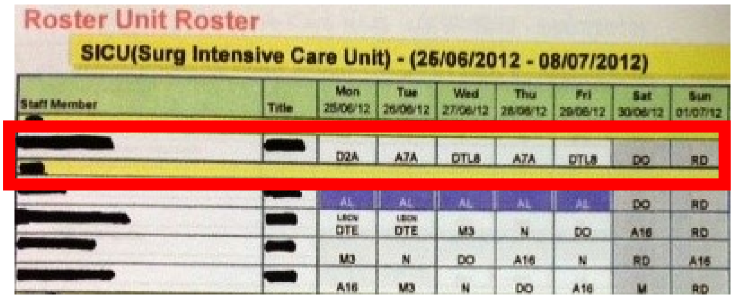
Fatigue risk of SICU nurses was analysed by using their work roster information for a d*efined* 7 day period as standalone input information. The aim of this analysis was to describe the shift work patterns of the SICU and to perform a fatigue risk assessment of the work roster of each SICU nurse for a defined 7 day period.

In recent years, studies in healthcare sector, especially post graduate trainee doctors in hospital, have provided an insight about the effects of the shiftwork in relation to the work patterns. Gander et al. (2010) adapted the AMA's fatigue risk assessment for analysis of work patterns of trainee doctors and reported that despite the prescribed limits to work of 72 hours of work per week, doctors continued to experience fatigue and have reported problems in maintaining work life balance. Similar approach was used to assess the work patterns of SICU nurses using their work roster. The AMA's 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).

Methodology

This is a cross-sectional analysis of the work patterns of SICU nurses for a 7 day period. The work roster of nurses was obtained from the SICU management with the necessary approvals for this study. The instruments were used in the analysis were SICU work roster of the nurses for a 7 day period, Risk Assessment Guide (based on 7 day period) from the Australian Medical Association's (AMA) National Code of Practice – Hours of work, shift work and rostering for Hospital doctors (Appendix VIII) and Roster Legend which is an explanatory table listing the details of the roster codes used in SICU (Table 6).

SICU Work roster: The work roster is the list of staff members and the duty periods that they are assigned to work for a defined period of time. An example of work roster used for this analysis is provided in Figure 10. Each subject is listed in the first column and their work roster for the 7 day period is read off each row as highlighted by the red outline. The illustration is a snapshot of the roster and the names of the staff members have been deleted to conceal their identity and protect their privacy.



Roster Unit Roster

SICU(Surg Intensive Care Unit) - (25/06/2012 - 08/07/2012)

Staff Member	Title	Mon 25/06/12	Tue 26/06/12	Wed 27/06/12	Thu 28/06/12	Fri 29/06/12	Sat 30/06/12	Sun 01/07/12
[redacted]	[redacted]	D2A	A7A	DTL8	A7A	DTL8	DO	RD
[redacted]	[redacted]	AL	AL	AL	AL	AL	DO	RD
[redacted]	[redacted]	LBCN DTE	LBCN DTE	M3	N	DO	A16	RD
[redacted]	[redacted]	M3	N	DO	A16	N	RD	A16
[redacted]	[redacted]	A16	M3	N	DO	A16	M	RD

Figure 10 Sample of the SICU work roster.

Risk Assessment Guide: The AMA fatigue risk assessment matrix has been adapted for use in the assessment of the work roster of SICU nurses. It is included in Appendix VIII. It is a multidimensional tool. Each risk factor is scored for the low, significant or high risk with 0, 1 and 2 points respectively. Each risk factor and the corresponding numerical value help to quantify fatigue risk and identify the attributes that contribute greatest to the fatigue risk.

For this study, certain assumptions were made about the 11 risk factors and these are elaborated in Table 5.

Table 5 Risk factor and corresponding assumption

Risk Factor No	Assumption
1	Hours worked from Monday to Sunday for a defined time period were calculated by adding the hours worked each shift for each of the days and was calculated from the start time to end time of shift. The same 7 day period was used for all nurses in SICU
2	Shift length was the maximum shift length that was noted in any shift in the 7 day work period
3	Scheduled shift hours, the assumption for this analysis was that the shift hours were as per schedule
4	Breaks include the meal breaks and rest breaks. SICU nurses take 1 full meal and rest break during their shift except the 12 hour shift nurses who take 2 breaks
5	The assumption for this analysis was overtime was less than 10 hours
6	SICU nurses do not have on-call duties with the exception of Nurse Clinicians who are rostered for on call duties for specific duties on a certain shift - DTL8
7	Night shift was defined as any shift that required the nurse to work through the night until the next morning
8	Rest opportunity in between shifts was calculated by looking at the hours of rest opportunity in between the consecutive work shifts
9	Shift rotation was scored based on the pattern noted for the 7 day work period
10	Roster changes – the assumption for this analysis was that a) there are changes to the roster and b) the roster changes are unpredictable
11	Maximum sleep opportunity was calculated based on the hours available for rest in between duty periods

For this analysis, scores of 11 were categorised as low risk (LR), scores of 11 - 22 were significant risk and scores of 22 - 33 were high risk.

Roster Legend: The SICU work roster has roster codes which are based on different start and end times as well as codes for days off, training and leave. For this analysis, the roster legend is limited to the roster codes that were noted in the defined 7 day study period.

The basic roster code is as follows: M stands for morning shift, D stands for Day shift, HD stands for Half day shift, A stands for Afternoon shift and N stands for night shift. Each of the shift types are further sub coded with a numerical value based on Start and End time for example; A6 is afternoon shift from 1300-2130 while A16 is afternoon shift from 1230-2130. There are additional roster sub codes for new graduate nurses on orientation (OR), graduate program (GP), Supervised Practice (SP) and Nurse

Training and Orientation (NTO). For example A16GP is Afternoon shift from 1230-2130 for a new nurse on graduate program.

It was noted that in SICU, there are 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. These codes are listed in Table 6 with the details of work time and hours. Rest break of 1 hour to 1.5 hours is integrated into the shift timing. For all the shifts, the rest break is 1 hour with the exception of D12 and N12 which are day and night shifts of twelve and half hours. D12 nurses have 2 breaks totaling 1.5 hours and N12 nurses have a single 1.5 hour break during their shift.

Table 6 Summary of the roster codes with the start time and end time (SICU, 2012)

*Staff are not operationally ready for the entire day despite the time limits. ***Rest break is inclusive*

Roster Code	Shift Start and End Time	Shift Duration**
A16	1230 -2130	9.00
A16GP	**1230 -2130**	**9.00**
A6	1300-2130	8.30
D12	**0700-1930**	**12.30**
D6NTO	0830-1800	9.30
DTL8 (Training leave, On call)	**0800-1700**	**9.00**
M	0700-1430	7.30
M1	**0700-1500**	**8.00**
M2	0700-1530	8.30
M3	**0700-1600**	**9.00**
M3GP	0700-1600	9.00
M3OR	**0700-1600**	**9.00**
M7	0700-1630	9.30
N	**2100-0730**	**10.30**
N12	1900-0730	12.30
Family care leave (FCL)*	**0800-1700**	**9.00**
Medical Certificate Leave (MC)*	0800-1700	9.00
Hospitalisation Leave (HL)*	**0800-1700**	**9.00**
NPL	No Pay Leave	
RD	**Rest day**	
OD	Off Day	
AL	**Annual Leave**	
OST	Overseas Training	
ML	**Maternity Leave**	

Work roster of SICU nurses for a defined 7 day period was used for this study. Personal identification data such as name, age, gender and ethnicity was not part of the analysis. Staff organization category was used for identifying subjects for inclusion in the analysis. The inclusion and exclusion criteria for the rosters is listed in Table 7.

Table 7 Inclusion and exclusion criteria for work roster analysis

Inclusion criteria	1) Roster of nurses working rotating shift pattern in the defined 7 day period 2) Roster of nurses who were involved in the direct care of patients during their shift
Exclusion criteria	1) Roster of nurses who were on regular day shifts (8AM to 5 PM) for the period of observation 2) Roster of nurses who were performing administrative duties (nurse managers and administrators) who were not involved in direct patient care 3) Other staff from pain team, trauma services etc.

Subject ID was assigned for each eligible work roster. The 7 day work roster for each subject was entered into an Excel spreadsheet for the analysis. Appendix IX b shows the Excel spreadsheet and the details of the analysis parameters that were considered for each work roster. The risk assessment and analysis was done as per the AMA fatigue risk assessment guidelines (Appendix VIII), for the multiple dimensions of risk factors such as hours worked, shift length, scheduled shift hours, number of breaks during the shift, overtime, number of on-call days, no of days of night shift work, rest opportunity between shifts, nature of shift rotation and provision for maximum sleep opportunity based on roster information. Total risk score was calculated based on the aggregate of scores for the items scored as Low risk (LR), Significant risk (SR) and High risk (HR). Results of the analysis are discussed in Chapter 4, Section 4.1.1.

3.2.2 Study 2 – Survey of the Work and Rest Patterns in SICU

The nurses in SICU are rostered to work a wide range of shift patterns and their work roster does not show a consistent cyclical pattern. To study the staff demographic profile as well as collect subjective information about their current work and rest patterns, a fatigue questionnaire survey was conducted. The objective of the survey was to evaluate the fatigue risk in the SICU based on the subjective reporting of the work patterns and sleep patterns by the SICU staff and perform a fatigue scan about the relationship between the different aspects of work patterns and fatigue related outcomes.

Methodology

A cross sectional survey was conducted for all the SICU nursing staff, using a questionnaire that was developed for assessment of fatigue risk and work patterns in Junior doctors (Gander et al., 2007). The questionnaire was adapted for use in the SICU nurses. The questionnaire was revised and finalised after initial pilot tests and consultation with Subject Matter Experts that included senior nurses at SICU. This was done to ensure that the questions were relevant for the operational context of SICU nursing work as well as to confirm that all questions could be interpreted by the participants, as intended. The final survey questionnaire contained the following main parameters: Demographic profile such as age, gender, work experience and general health status of SICU nurses; social profile such as smoking, drinking habits as well as use of caffeine, commute time from home to work and study commitments; general work patterns such as working time, shift patterns; fatigue related outcomes such as general sleep profile such as sleep and rest patterns, estimation of sleepiness using the ESS and subjective rating of fatigue using the SP 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. Sample of the 5 page fatigue questionnaire is provided in the Appendix VII.

Participation in the survey was anonymous and voluntary. An initial briefing was done at the SICU for all staff to provide an overview of the survey. The distribution of the survey forms was done through the SICU managers. A survey drop box was placed in the SICU management office and respondents were requested to return the completed forms to the drop box within a 2 week timeframe. Upon the receipt of the completed forms, all the responses were double entered to verify for data accuracy and subsequent analysis.

The results of the survey are in Chapter 4, Section 4.1.2.

3.2.3 Study 3 – Identification of Task for SA Analysis

The nurses of the SICU perform a whole range of patient care activity during their work shift. For the purpose of situation awareness assessment, it was important to identify a safety critical task that the nurses perform routinely during the course of their work.

Methodology

On site work observation was done for each working shift to list the tasks that nurses performed in the course of patient care. A list of key tasks were identified, which included monitoring the patients signs and symptoms such as heart rate, respiration rate, blood pressure, temperature etc., and updating the patients' medical records (paper as well as electronic), checking the doctor's instruction, maintaining close communication with the physicians and nurse managers, reviewing the handover information from the previous shift or to next shift nurse, administering the medications and assisting in investigations and medical procedures. The task list was reviewed by the SICU nursing managers and nurse clinicians and a focus groups discussion was conducted to finally select the task that was met the criteria.

The main criteria for the selection of the task for SA assessment were that the identified task should be consistent for all nurses who were participants in the study, task should be performed in all shifts, i.e., morning, afternoon and night, task should be safety critical therefore incorrect performance of the task has adverse patient safety implications, task should involve the use of cognitive functions such as perception, attention, communication etc., this was important because fatigue affects cognitive functions before causing physical impairment and 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. Task analysis was conducted and a schematic task analysis is provided in Appendix XII. The SA probes of the SART questionnaire were customized based on this task. SART questionnaire is provided in Appendix IV.

The results of the Phase 1 - Preliminary studies are discussed in Chapter 4, Section 4.1. Analysis of results of the Phase 1 - Preliminary studies was conducted before proceeding to the Phase 2 - Pre FRMS. The protocol for the implementation of Pre FRMS phase and interventions for FRMS was finalised based on the results obtained from the preliminary studies.

3.3 Phase 2 – Pre FRMS

Pre FRMS phase formed the baseline data collection phase. Subjective global sleepiness was assessed using the ESS at the start of Pre FRMS 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.

Participant recruitment for the study protocol for the Pre FRMS phase was based on the inclusion and exclusion criteria as shown in Table 8.

Table 8 Inclusion and exclusion Criteria for participants for Pre FRMS phase

Inclusion criteria	1) Nurses working rotating shift pattern in SICU 2) Nurses who were involved in the direct care of patients during their shift. 3) Nurses who were in good general health and not on any long term medications
Exclusion criteria	1) Nurses who had medical condition(s), sleep disorder(s) or were on medications. 2) Nurses who were pregnant 3) Nurses who were on regular day shifts 4) Nurses who were performing administrative duties and were not involved in direct contact with patients

A pre-recruitment questionnaire was administered to all participants with a query regarding medical declaration to ensure that they were healthy and not on any long term regular medications prior to recruitment in the research.

Fatigue is a common complaint for many types of medical problems. In such situations, a person may feel tired easily while doing routine tasks and needs more rest and sleep. This may affect their performance at work. Medical conditions that may present with fatigue include anaemia, infections, depression, cancer, disorders of metabolism and diabetes (Dittner, Wessley, & Brown, 2004). It is therefore reasonable to exclude medical causes when dealing with fatigue.

Pregnancy in nurses is a special condition and is also an exclusion criterion for this research because shift work impacts on the health of nurses during pregnancy. It is likely that the working patterns of nurses during pregnancy are modified from an occupational safety and health perspective to meet the nurses' physiological needs.

After the application of inclusion and exclusion criteria, participants that met the requirements were given a briefing of the test battery and study procedure. Volunteers were sought to participate in the research. Prior to the recruitment into the study all participants gave written informed consent.

3.3.1 Test Battery

Based on the literature review for fatigue and situation awareness evaluation measures, a battery of tests were selected for this study. The test battery is shown in

Table 9 Test battery used for SICU nurses

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

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

Table 9.

The tests chosen are validated for research on shift work and fatigue in a field setting (International Civil Aviation Organisation, 2012; Queensland Government, 2009). 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.

3.3.2 Procedure

Participants were briefed about the experiment protocol and were provided the test kit and the written checklist of study procedures. The test kit was issued to the participants on the day of recruitment into the study. The test kit was collected from the participants after completion of study period. 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. Figure 11 outlines the study protocol. The test procedure for the Pre FRMS and Post FRMS phase was the same.

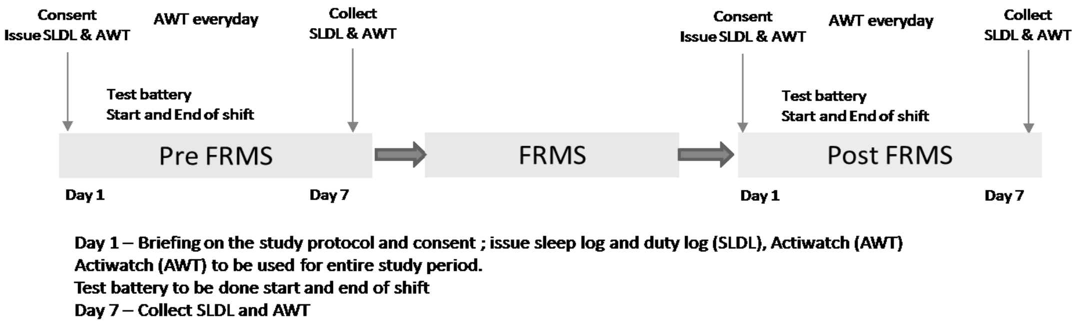


Figure 11 Study protocol

Briefing was done on the Day 1 and subjects were issued actiwatch and a diary containing Sleep log (SL), Duty Log (DL), SP fatigue checklist, KSS, ESS, and SART. The SL and DL as well as actiwatch were to be used for the entire period of monitoring. 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. If all the 3 shift types were covered within the 7 day period, Actiwatch and diary were collected on Day 7. If any one shift type was not covered, the study period was extended to include the missing shift type. 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. Hence for the purposes of monitoring in Pre FRMS and Post FRMS phase, the shift types were considered based on shift duration of 8 hours exclusive of breaks during the shift.

The test kit issued to the participants included a diary with a sheet for Sleep Log and Duty Log, SP Fatigue Checklist , KSS and SART is shown is in Appendix I and an Actiwatch (shown in Figure 12).

Figure 12 Actiwatch (Philips, 2013)

Actiwatch 2 made by Respironics Inc. was used for the study (Philips, 2103). The actiwatch was to be worn continuously for the period of monitoring except when they were working with the patients during the shifts in compliance with the SICU infection control procedures.

Actiwatch battery was charged prior to issuance to the participants. A fully charged actiwatch could collect data for up to 30 days without requiring a recharge. Also full charge ensured that there was no data loss due to loss of battery power. Each actiwatch was activated with a unique identification number and date of birth of the participant. Participants were advised to wear the watch snugly and securely on either wrist and were advised not to remove it except for when taking a shower or going for a swim. Also participants were advised not to exchange actiwatches with each other.

After activation, the actiwatch was issued to the participants for a period of 7 days, with a provision to extend if required. All participants were advised to record the periods when actiwatch was not worn in the comments section in their Sleep Log. Participants were advised to wear the actiwatch on completion of their shift and keep it on for the entire duration until the beginning of the next shift period. The actiwatch was collected after the period of monitoring. Data was downloaded to the Actiwatch companion software program to generate an Actogram for analysis (Appendix II).

Psychomotor Vigilance Task (PVT) was conducted using the Deary Leiwald Reaction Time (DLRT) test that was configured for a 5 minute PVT. DLRT is a free to download computerised reaction time test developed by Centre for Cognitive Ageing and Cognitive Epidemiology (CCACE), University of Edinburgh, UK (Deary, Liewald, & Nissan, 2011). The DLRT test can be configured with various inter stimulus intervals and test duration.

PVT was performed using a laptop that was placed in a nursing manager's office in SICU. The place for the placement of the test was selected so as to provide the least disruption to the participant during the performance of the test.

The test required the participant to press any key of the laptop as quickly as possible each time they noted a cross appearing in the box on the computer screen as shown in Figure 13 and Figure 14.

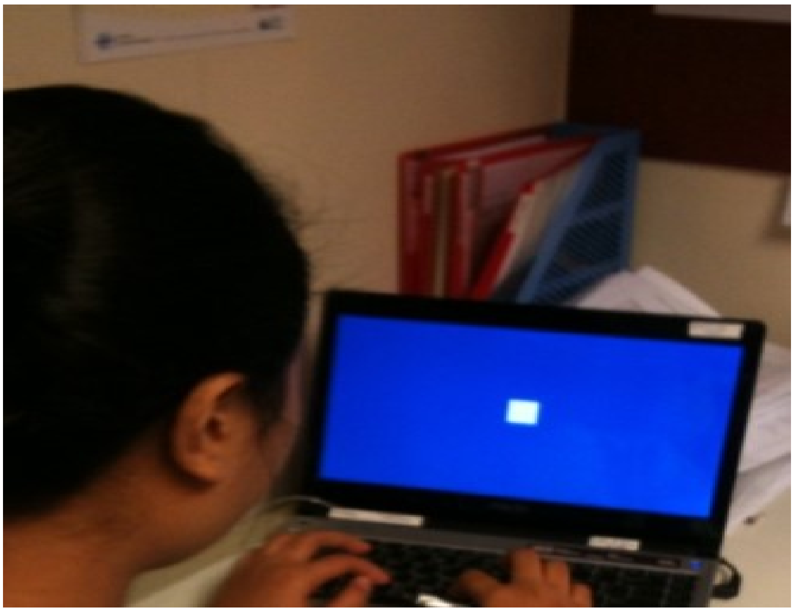


Figure 13 Nurse doing performance test

All participants were given a practice demonstration and a hands-on session. Participants were told not to press the key down continuously but to press and release the key whenever they see the cross appearing, using the index finger of their preferred hand. The interval between each presenting stimulus varied and was determined by the computer software. Participants underwent 8 practice test responses to familiarize themselves before starting the actual test on the first day.

For the actual test session, participants were presented with 120 reaction time events with varying inter-stimulus intervals. The PVT took 5 minutes to complete. The response time for each test was captured along with a time stamp into an Excel spreadsheet.

The test was to be done at the start and end of shift period for each of the morning, afternoon and night shifts.

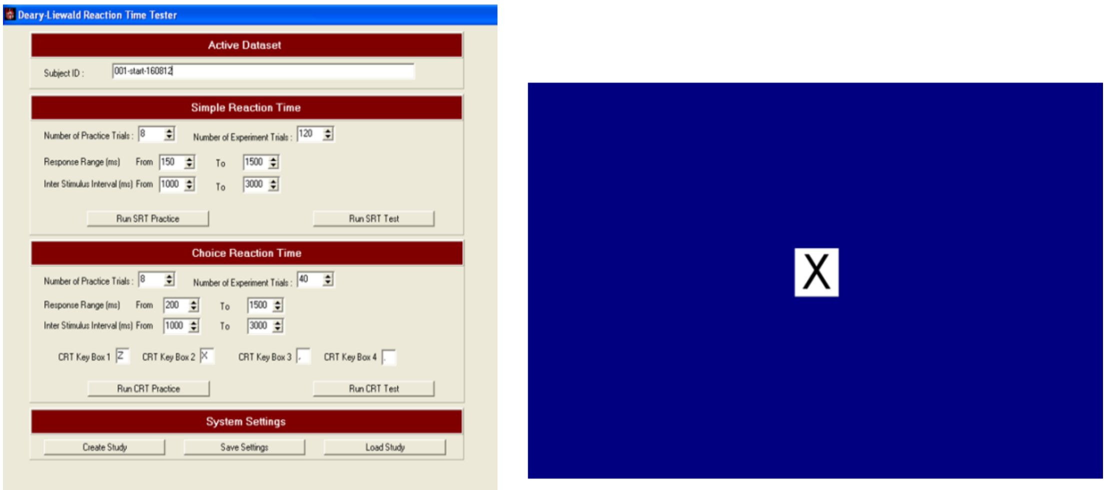


Figure 14 Screen shots of Vigilance test

Sleep Log provided the subjective recordings of the sleep duration for the entire period of monitoring. For the purpose of this study, the sleep duration for the morning, afternoon and night shift days were noted. The subjective sleep durations were compared with that of the objective sleep durations as noted by the actigraphy recordings. Duty log showed the subjective recordings of the duty periods for each shift and this was compared with the duty roster that was available at SICU Manager's office.

Epworth Sleepiness Scale was used for this study to assess global levels of sleepiness (Appendix III). Permission to use the ESS was obtained from MAPI Research Trust. ESS score was done once at the start of Pre FRMS phase and start of Post FRMS phase. Situation Awareness Rating (SART) was done by the nurses after preparation and administration of medication for any one patient under their care at the start and end of shift (Appendix IV).

The main concerns regarding the experiment procedure that were identified in Phase 1 Preliminary studies and mitigated in the Pre FRMS phase were related to SICU infection control procedures and time required to complete the tests.

SICU infection control procedures required that the nurse could not wear jewellery or watch on their hands during duty periods to minimise cross infection. Hence, wearing an actiwatch would be a risk to overall infection control management. Alternative approaches were considered and it was concluded that actiwatch is to be worn for monitoring of sleep duration only after the end of the shift. The slight change in protocol did not impact the variable to be measured but had impact on the data collection process. The administrative process required careful monitoring and regular reminders to the participants to put on their actiwatch when duty period ends. A pilot test was conducted to confirm the feasibility of the experiment protocol.

The time when the test battery could be used without compromising work requirements was another consideration that was identified, studied and mitigated through an appropriate procedure. Time required to perform the test was measured to be 15 minutes. Table 10 lists the time taken for each test.

Table 10 Test battery and time to complete

Test Battery to be done at start and end of shift	**Time to complete the test battery (in minutes)**
Samn Perelli Fatigue Checklist	1
Karolinska Sleepiness Scale	1
Sleep Log and Duty Log	2
Actiwatch	1
SART	5
PVT	5
Total Duration	15

Workplace walkthrough survey was conducted for the staff rest area to assess for sleep environment such as provision of nap zones and nap environment. Pre FRMS results are described in Chapter 4 Results, Section 4.2 and the results tables are in Appendix XI.

3.4 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 are elaborated in Chapter 4 Results, Section 4.3 and include the following key features: modification of work roster and recommendations for rostering; provision of nap time for night shifts and nap zone with good sleep hygiene; alertness recommendations such as strategic caffeine consumption and fatigue management training for all SICU nurses. These recommendations were discussed and implemented as far as practicable with the support of the SICU management.

3.4.1 FRMS Interventions

The main FRMS interventions in the SICU setting include supporting SICU management in fatigue risk management and providing them with recommendations to better plan shift roster to reduce fatigue risk. The AMA risk assessment guidelines were useful in identifying the fatigue risk factors within the rosters (this is later demonstrated in Phase 1 Preliminary Study 1). For such intervention, the AMA guidelines and recommendations were used to design work rosters for Post FRMS phase. This process also needs to accommodate modifications of Post FRMS roster due to last moment roster changes driven by operational considerations and the recommended roster cannot always be used for the Post FRMS participant. However, the rearrangement of work roster does help to substitute high fatigue score shift patterns with lower fatigue score shift patterns.

The SICU staff were given nap time for night shift up to 90 minute duration. Nap zones were identified and nap zone had provision of foldaway beds. Sleep environment recommendations for nap zone were put in place and these include measures for darkened room and minimal disruptions. Caffeine in the form of coffee is a fatigue countermeasure. Caffeinated beverages available for staff at SICU pantry is an effective method.

A fatigue management training program on sleep physiology, fatigue recognition and personal coping strategies for fatigue management developed and offered to all SICU staff to promote awareness influences self-management of fatigue risk. The content of the FRMS training is presented in Appendix X. The fatigue management training was evaluated by all the participants and a feedback form was given to them. A copy of the form is provided in Appendix V.

Feedback was also obtained regarding the effectiveness and relevance of the FRMS interventions from the participants by using the Post FRMS feedback form (Appendix VI) at the end of the Post FRMS phase. Results of the feedback about FRMS intervention are provided in the Chapter 4 Results, Section 4.3.

3.5 Phase 4 - Post FRMS

Post FRMS data collection procedure was similar to the Pre FRMS data collection process as highlighted earlier in Section 3.3.1 and 3.3.2. The test battery was administered and data collection for estimation of fatigue, sleepiness, SA and performance was done for each shift pattern – morning, afternoon and night shift. Post

FRMS data was obtained and analysed. Results of the Post FRMS phase are described in Chapter 4, Section 4.4. The analysis and comparison of results of Pre FRMS and Post FRMS phase are discussed in Chapter 5, Section 5.2. The post FRMS results tables are in Appendix XI.

3.6 Variables

For between shift variation - Shift patterns served as the main independent variable (morning, afternoon and night shift). Information about the shift pattern was obtained from the duty log and work rosters. The dependant variables for fatigue and sleepiness were fatigue scores (SP Fatigue Checklist), response time (Vigilance task) and sleepiness scores (KSS). The dependant variables for situation awareness were the situation awareness scores (SART).

For within shift variation - The shift timing served as the independent variable (comparison made at start and end of shift). The dependant variables for fatigue and sleepiness were fatigue scores (SP Fatigue Checklist), response time (Vigilance task) and sleepiness scores (KSS). The dependant variables for situation awareness were the situation awareness scores (SART).

3.7 Means to Test Hypotheses

The focus of this research is to study the impact of fatigue on SA of healthcare worker performing safety critical tasks at different shifts, before and after applying a comprehensive FRMS. The objectives as stated in Chapter 1, their corresponding hypotheses and the means to test the hypotheses are summarised in Table 11.

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Table 11 Primary and secondary objectives and hypotheses

Objective (O)	**Hypothesis (H)**	**Method for testing the hypothesis**
Primary Objectives		
O[1] **To study the relationship between fatigue and situation awareness in rotating shift workers.**	**H[1]:** SA decreases with increase in fatigue and vice versa.	Fatigue and SA scores obtained from each shift were compared within a shift i.e., between start and end of shift as well as between shifts i.e., between morning, afternoon and night shift to study the relationship.
O[2]: **To customize and evaluate an appropriate fatigue risk management system (FRMS).**	**H[2]:** Implementation of FRMS reduces fatigue and improves SA in SICU nurses	Pre FRMS fatigue and SA scores were compared with Post FRMS fatigue and SA scores.
Secondary Objectives		
O[3]: **To assess if fatigue in a healthcare worker varies within a shift i.e., between start of shift and end of shift.**	**H[3]:** In a healthcare worker, fatigue is higher at the end of the shift as compared to start of the shift.	Fatigue scores obtained from each shift were compared within shift i.e., between start and end of shift.
O[4]: **To assess if the situation awareness of a healthcare worker varies within a shift i.e., between start of shift and end of shift.**	**H[4]**: In a healthcare worker, SA is lower at the end of the shift as compared to the beginning of the shift.	SART scores obtained from each shift were compared within a shift i.e., between start and end of shift.
O[5]**: To assess if fatigue of a healthcare worker varies between different shifts when doing rotating shift work**	**H[5]:** In a healthcare worker doing rotating shift work that includes morning, afternoon and night shift, fatigue varies across different shifts.	Fatigue scores that were obtained from each shift were compared between each of the rotating shifts - morning, afternoon and night shifts.
O[6]: **To assess if SA of a healthcare worker varies between different shifts when doing rotating shift work**	**H[6]:** In a healthcare worker doing rotating shift work that includes morning, afternoon and night shifts, situation awareness varies across different shifts.	In all the participants, SART scores that were obtained from each shift were compared between each of the rotating shifts - morning, afternoon and night shifts.

The exploratory objectives of the study analyse the sleep duration of SICU nurses. This was measured using sleep log and actigraphy.

Chapter 4 Results

This section summarizes the results of the preliminary studies. Roster analysis and fatigue survey results were limited to qualitative and simple quantitative analyses as these were conducted primarily to support the methodology of the Pre FRMS phase and FRMS interventions.

Statistical analysis was done for fatigue scores (SP Fatigue Checklist), sleepiness scores (KSS), response time (Vigilance task), situation awareness scores (SART) and mean subjective and objective sleep duration for Pre FRMS phase and for Post FRMS phase. The Pre and Post FRMS scores for each of the variables were compared to study the impact of FRMS. The data points for Pre and Post FRMS phase are shown in Table 12.

Table 12 Overview of data points for Pre FRMS and Post FRMS

Phase	Nurses doing rotating shift		
Pre FRMS	Morning Start / End	Afternoon Start / End	Night Start / End
FRMS			
Post FRMS	Morning Start / End	Afternoon Start / End	Night Start / End

The dependant variables for the three groups of shift patterns were compared using Analysis of Variance to test if there was any difference between the three groups. Based on the outcome of ANOVA, when the results suggested that there were differences between the three groups, further resolution was secured between pairs of groups to explore differences using appropriate tests such as t- tests. Additionally for the Post FRMS phase, subjective feedback of the participants was obtained for each of the key interventions with regards to the effectiveness of the intervention and relevance on a 7 point scale with bipolar descriptors and these were analysed. A copy of the Post FRMS feedback form is in Appendix VI.

During the FRMS phase, FRMS training was conducted and the FRMS training feedback was analysed. A copy of the FRMS training feedback form is in Appendix V.

The results and analysis tables of the Pre FRMS and Post FRMS are provided in Appendix XI.

4.1 Phase I - Preliminary Studies

The results obtained from the preliminary studies in SICU informed the experiment procedure in Phase 2 – Pre FRMS and Phase 3 - FRMS. Survey results and roster analysis were useful in the development of recommendations for FRMS for SICU. Roster analysis provided information about shift work patterns used in SICU. 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. This information was used subsequently for the development of FRMS recommendations for SICU.

Fatigue survey provided information about the demographics and work rest patterns as perceived by the SICU staff.

Administration of medication was identified as a task for SA assessment. SA probes for the task of medication administration were developed in consultation with the nurses.

4.1.1 Study 1 - Analysis of Shift Work Patterns in SICU Nurses

After the application of the inclusion and exclusion criteria, the total number of subjects considered for the roster analysis was 68 out of 81 (85%) SICU staff. Of these 68 subjects who met the inclusion criteria, nurses on leave or “off duty” for 5 days or more for the defined period of observation were further excluded (n=17). Thus the final sample size for the analysis was 51 nurses (inclusion rate - 75% of the total eligible work rosters).

The shift work patterns of the SICU nurses showed a great variability due to the different start and end times as well as the number of night shifts and rest days. 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 as shown in Table 6 .

There was no identical roster pattern noted in the 51 rosters included in this analysis (Appendix IX a). The rosters examined did not have a predictable work pattern. This was consistently noted to be a high risk factor across all rosters as defined by the AMA Fatigue Risk Assessment Matrix (Appendix VIII).

The calculated AMA scores of the 51 SICU roster is shown in Appendix IX a.

The key results are summarized in Table 13

Table 13 Key results of work roster analysis

Parameter				
	n	% (Denominator =68)		
Rosters Analysed	51	75		
	n	% (Denominator =51)		
Night shifts in 7 day period	35	68.6		
	n	% (Denominator =35)		
2 or more nights in 7 days	23	65.7		
	n	% (Denominator =23)		
Consecutive nights in 7 days	19	82.6		
Rest days in 7 day	n	%		
1 day	1	2		
2 days	38	78		
3 days	6	12		
4 days	4	8		
Afternoon Morning pattern	n	% (Denominator =51)		
Yes	29	56.8		
No	22	43.1		
Distribution of nights shifts	n	Average AMA score		
0	16	15.6		
1	12	16.9		
2	17	17.8		
3	6	18.3		
Hours worked per week	n	%		
Less than 40	8	16		
40 -50	42	82		
More than 50	1	2		
Parameter	Mean	Standard Deviation	Minimum	Maximum
Total hours worked (hours)	43.46	5.75	25	55
AMA scores (score)	16.98	1.30	14	21
Rest days (days)	2.25	0.62	1	4
Night shift work (nights)	1.25	1.03	0	3

The mean duration worked in the shift from start time to end time for the 7 day period was 43.46 hours as show in Table 13. 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 as shown in Figure 15.

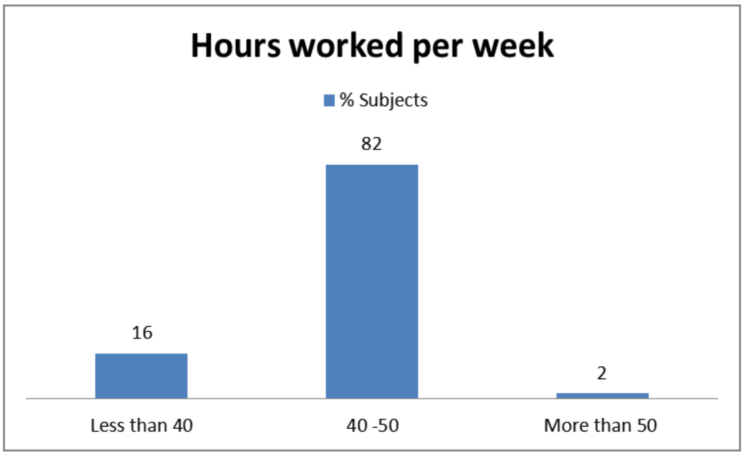


Figure 15 Weekly working hours

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. The number of breaks per shift was 1-2 for the all 51 rosters (100%) and was scored 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 as noted in Table 13.

Based on the AMA risk assessment analysis, the distribution of the risk scores show that the value of AMA risk scores lie between the minimum value of 14 and maximum value of 21. These scores were in the significant risk zone. The frequency distribution of the scores is shown in Figure 16.

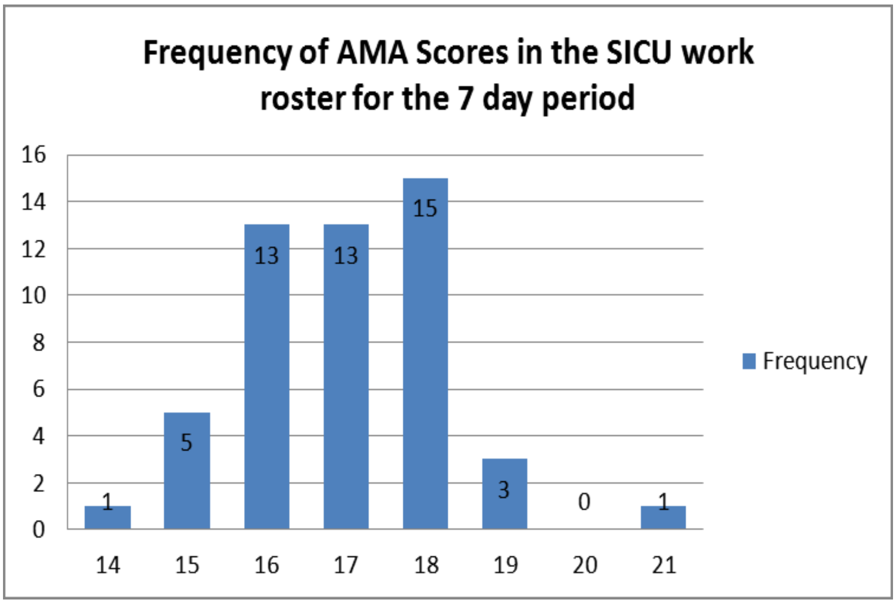


Figure 16 Distribution of the AMA Scores

The mean fatigue risk score was 16.98 (n=51) noted in Table 13, with 29.4% scoring 18 and 25.5 % scoring 16 and 17 respectively. The 51 individual roster pattern and their fatigue risk scores are provided in the Appendix XI b.

Examination of the scores at the extreme range showed that for the roster with minimum fatigue risk score of 14, the roster was only afternoon shifts with no night shifts and there was adequate off duty rest time (> 2 days) while the roster with the maximum fatigue risk score of 21 had been rostered for 55 hours per week, worked 2 night shifts on consecutive days, had 1 day off duty in the study period and was rostered to a backward rotating afternoon morning shift.

Off duty rest opportunity ranged from a minimum of 1 to maximum of 4 days with an overall mean of 2.25 days. 98% of the subjects had off duty days for 2 or more days as depicted in Figure 17. It was noted that the roster with only 1 day rest in the 7 day study period also had the highest fatigue risk score of 21.

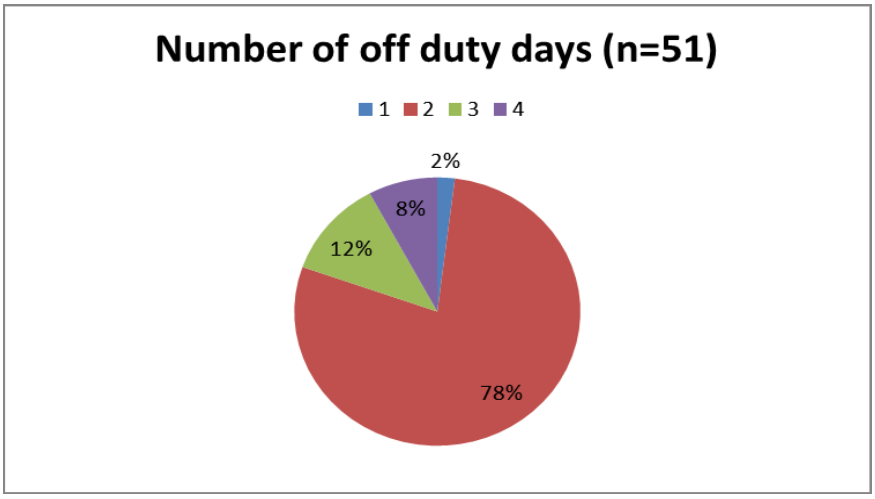


Figure 17 Off duty days in the 7 day period.

Scatter plot of the AMA scores against the number of rest days show a negative association. The higher the number of off duty days, the lower the AMA risk scores. This is graphically represented in Figure 18.

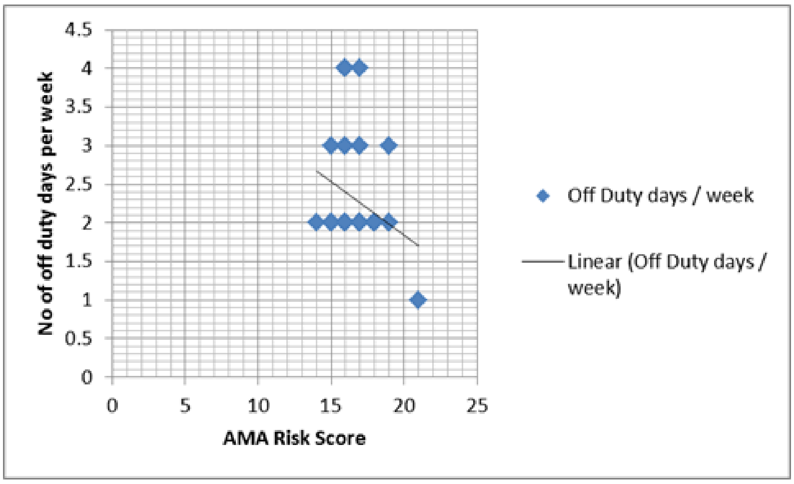


Figure 18 Scatter plot of AMA scores against number of off duty days per week

The number of night shifts in the 7 day period of study ranged from 0 to 3 nights as shown in Figure 19. 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 as shown in Table 13.

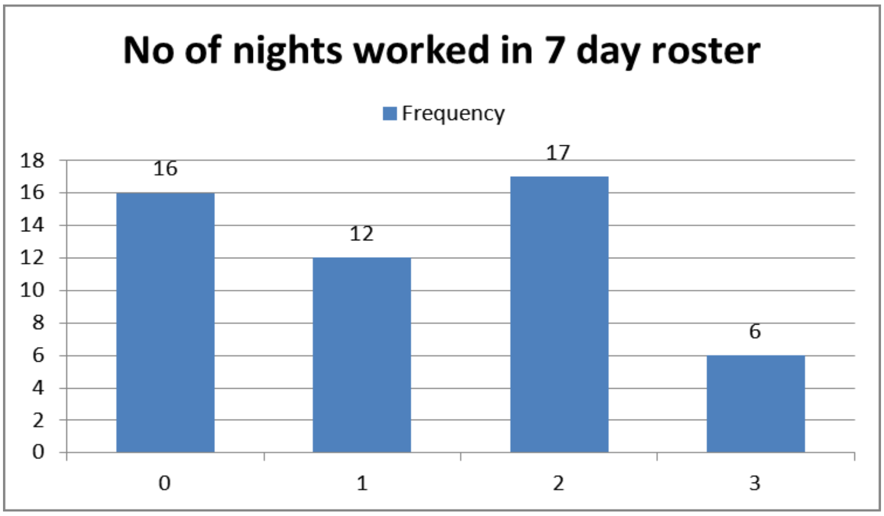


Figure 19 Number of night shifts per week

Scatter plots of the AMA scores against the number of night shifts worked per week show a positive association. The higher the number of night shift per week, the greater the AMA risk scores as shown in Figure 20. AMA scores increase from 15.6 for no night shift to 18.3 for 3 night shifts as shown in Table 13.

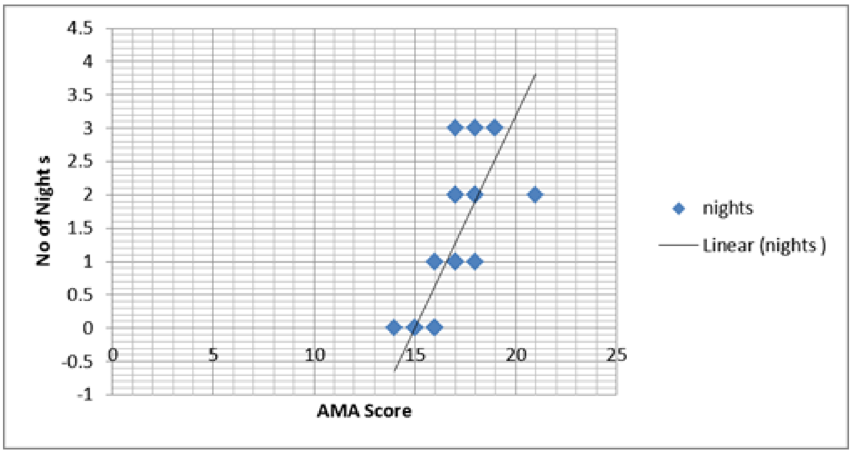


Figure 20 Scatter plot of AMA scores against number of night shifts per 7 days

For work roster changes – the points assigned were 3 (very high) for all nurses based on prior knowledge of working environment in the SICU and personal communication with the nurse manager at SICU (Tan, 2013). Unanticipated schedule changes occur frequently even 48 hours prior to start of shift. However, when staff was reassigned, affected staff was consulted and agreement was sought before implementing change in the roster. While that agreement could be a good human resource management practice, it does not alter the fatigue risk associated with sudden roster changes.

The AMA code was originally designed for use in hospital doctors. In the current analysis, the AMA's Code of Practice was adapted for analysing the roster of SICU nurses. Aside from professional responsibilities, there are differences in the work requirements for nurses and doctors. One such example is that nurses are not routinely assigned "on call duties" with the exception of nurse clinicians. Hence there are certain aspects of the AMA code that do not universally apply to all the staff nurses in SICU. For "on call duties" – 1 point was assigned for all nurses except nurse clinicians who were on DLT8 day shift.

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.

Based on these findings, recommendations for FRMS roster changes were formulated and the recommendations are described in the Section 4.3 FRMS.

4.1.2 Study 2 - Survey of the Work and Rest Patterns in SICU

59 questionnaires returned represent a response rate of 73.7% (denominator is based on the SICU nursing staff strength of 80 at the time of survey).

The survey results are shown in Table 14.

Table 14 Survey results

Demographic Profile		
Parameter	n	%
Age (n=59)		
21 -30	38	64
31 - 40	12	20
41 - 50	5	9
>51	4	7
Gender (n=59)		
Male	2	3
Female	57	97
Nursing experience (n=59)		
< 3 years	16	27
3-5 years	18	30
6- 10 years	8	14
> 10 years	17	29
Declared medical conditions *		
Headaches/Migraine	8	-
GI problems	7	-
Sleep disorders	3	-
High blood pressure	2	-
Others	6	-

Social Profile		
Parameter	n	%
Studying (n=59)		
Yes	8	14
No	51	86
Commute time (n=59)		
< 1 hour	49	83
1-2 hours	10	17
Smoking history (n=59)		
Yes	1	2
No	58	98
Alcohol history (n=58)		
Yes	12	21
No	46	79
Beer	5	-
Wine	5	-
Spirits	2	-
Caffeinated drinks (n=58)		
Yes	42	72
No	16	28
Coffee*	29	-
Tea*	25	-
Coke*	13	-
< 2 cups / day	34	81
2-5 cups / day	8	19

General Sleep Profile		
Parameter	n	%
How often get enough sleep? (n=58)		
Never	0	0
Rarely	10	17
Sometimes	29	50
Often	14	24
Always	5	9
How often wake up refreshed? (n=56)		
Never	3	5
Rarely	11	20
Sometimes	30	53
Often	10	18
Always	2	4
Do you snore loudly? (n=54)		
Never	22	41
Rarely	18	33
Sometimes	11	20
Often	1	2
Always	2	4
Do you move a lot? (n=51)		
Never	2	4
Rarely	13	25
Sometimes	26	51
Often	6	12
Always	4	8
Do you use sleeping pills? (n=53)		
Never	45	85
Rarely	5	9
Sometimes	2	4
Often	1	2
Always	0	0
Sleep duration in last 7 days (n=52)		
<5 hours	3	6
5 to 6 hours	28	54
6 to 7 hours	13	25
7 to 8 hours	7	13
>8 hours	1	2
Normal sleep duration (n=54)		
<5 hours	2	4
5 to 6 hours	14	26
6 to 7 hours	11	21
7 to 8 hours	11	21
>8 hours	15	28
Sleep Quality rating (n=52)		
<4	15	29
4 (mid-range)	16	31
>4	21	40

(* multiple responses were noted)

Survey results (continued)

General Sleep Profile (continued)		
Parameter	n	%
Difficulty staying awake during work (n=58)		
Yes	32	55
Rarely	13	
Sometimes	17	
No	26	45
Epworth Sleepiness Scale (n=54)		
Less than and equal to 10	38	69
More than 10	17	31

Work Pattern Profile		
Parameter	n	%
Shift pattern (n=57)		
day shift only	1	2
night shift only	1	2
Rotating shift	55	96
Duration under current roster (n=46)		
<1 year	6	13
1-5 years	24	52
6-10 years	11	24
>10 years	5	11
Was last week a typical work week (n=57)		
Yes	45	79
No	12	21
Hours per shift (in the Last 7 days) (n=57)		
<8 hours	6	10
8 to 10 hours	41	72
>10 hours	10	18
Night shift (in the last 7 days) (n=57)		
Yes	47	82
No	10	18
No of nights (in the last 7 days) (n=46)		
1	10	13
2	26	56
3	6	22
4	4	9
Hours worked this week (n=47)		
<40	11	20
40	28	52
>40	15	15
Hours worked last week (n=31)		
<40	6	17
40	16	46
>40	13	37
Overtime this week (n=46)		
Yes	26	57
No	20	43

Work Pattern Profile (continued)		
Parameter	n	%
Overtime last week (n=32)		
Yes	17	53
No	15	47
Made error you think is due to fatigue? (n=58)		
Yes	16	28
No	42	72
Got any prior education on fatigue? (n=58)		
Yes	9	16
No	49	84
Interest to participate in fatigue management training (n=58)		
Yes	43	74
No	15	26

Fatigue score (Night shift staff only)			
	Night 1 N=15	***Night 2*** N=14	***Night 3*** N=10
< 5	13	8	1
5	2	3	3
> 5	0	3	6

Demographic Profile: 84% of the staff was between the ages of 21 to 40 years and only 16% are more than 40 years. 97% of the respondents were females. 57% of respondents had work experience as a nurse for less than 5 years; 14% had between 5 -10 years of work experience and 29% had more than 10 years of work experience.

There were a range of designations within the unit, based on the roles and responsibilities such as staff nurse, enrolled nurse, registered nurse, nurse clinicians as well as nurse manager. Amongst the respondents, 75 % were staff nurses (n = 43 out of 57).

General health status query revealed that 64% did not declare medical conditions in their medical declaration. Of the respondents who declared they had a medical condition, migraine and headaches were the commonest problems that were reported followed by gastrointestinal problems.

Social Profile: 14% of the respondents indicated that they are currently studying/ on a training program. Of the 14% who studied, the average study hours per week were about 11.1 hours (Range 2 hours – 20 hours). This query was to assess the extent of academic and training demands that are superimposed on the work requirements.

Commute time refers to how long it takes to get to work from home and vice versa. Longer commute times indicate that the person has to travel longer distance to reach work and hence may require more time to prepare to start from home and similarly at the end of shift, takes more time to return home.

This has a particular significance for workers who start morning shifts as well as those that need to get home after coming off the night shift. In the survey, 83% responded that it takes less than 1 hour to get to work and 17% take between 1-2 hours to commute to work from home as shown in Table 14.

Only 1 out of 58 respondents indicated a positive smoking history and the person smoked ~10 cigarettes per day. 21 % of the SICU staff responded yes to consumption of alcohol and 100% of them indicted that they usually drink only on social occasions. Beer and wine were the common drinks consumed. 72 % responded that they consumed various caffeinated beverages. The common caffeinated beverages were coffee and tea. 81 % indicated that they consumed less than 2 cups / cans of caffeinated beverages per day.

General Sleep Profile: In response to the questions – How often do you get enough sleep and how often do you wake up feeling refreshed (with the answer choices being never, rarely, sometimes, often and always) – 17 % of respondents reported that they never or rarely get enough sleep and 25 % indicated that they never or rarely wake up feeling refreshed as indicated in Figure 21.

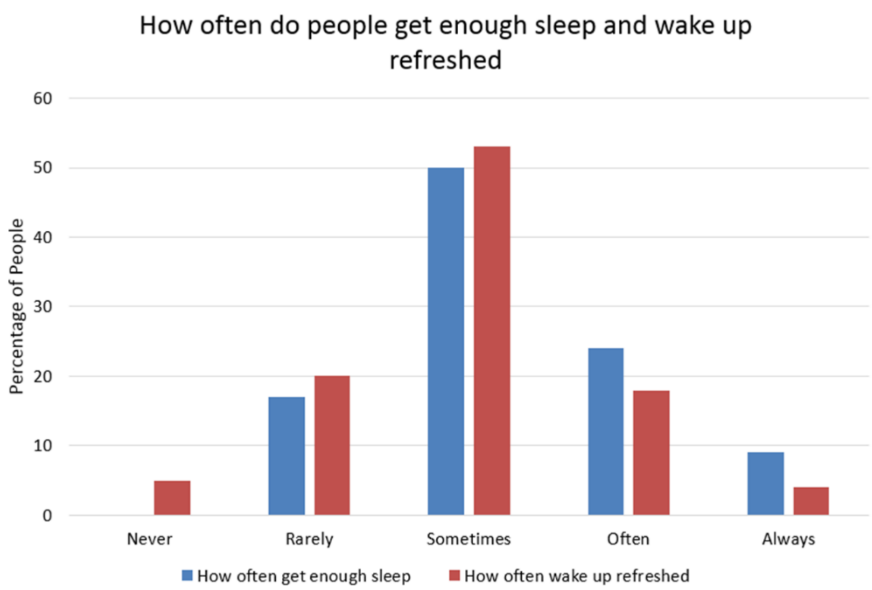


Figure 21 Response for how often people get enough sleep & wake up refreshed

In response to the questions about their sleeping and snoring, excessive movement as well as use of sleeping pills – 6 % respondents indicated that they often or always snored, 20 % indicated that they often or always moved a lot during sleep and 2 % indicated that they often use sleeping pills.

Normal sleep duration was based on the sleep duration on their days off, when the wake up was without an alarm. 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. The responses from the survey about the sleep duration for the past 7 days comparing the sleep durations on the working day and off /rest day are shown in Figure 22. The responses were categorized such that people who reported sleeping 5-6 hours were averaged to 6.5 hours and were grouped under 6 hours. Similarly those reporting 8-10 hours of sleep were averaged to 9 hours and grouped under 9 hours and so forth.

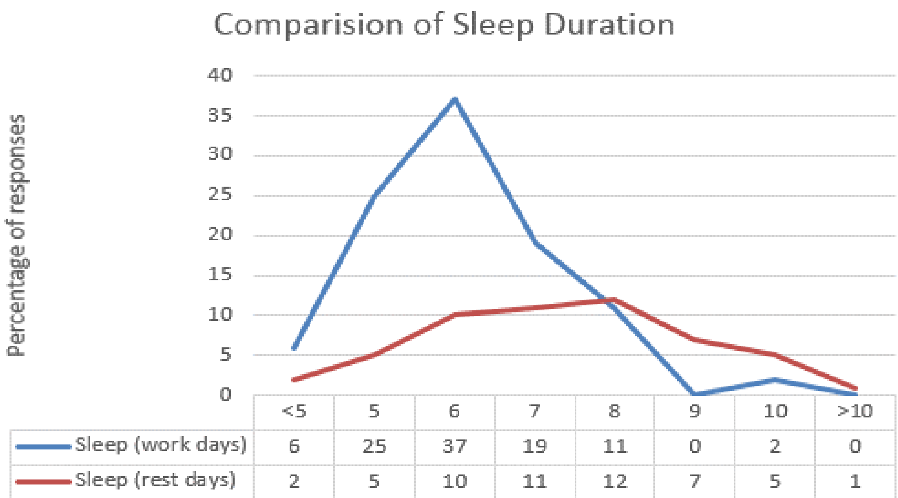


Figure 22 Sleep duration of SICU staff on work days and rest days

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 as shown in Figure 23. However, the mean score for the sleep quality in the past 7 days was 4.16 (minimum of 2 and maximum of 7).

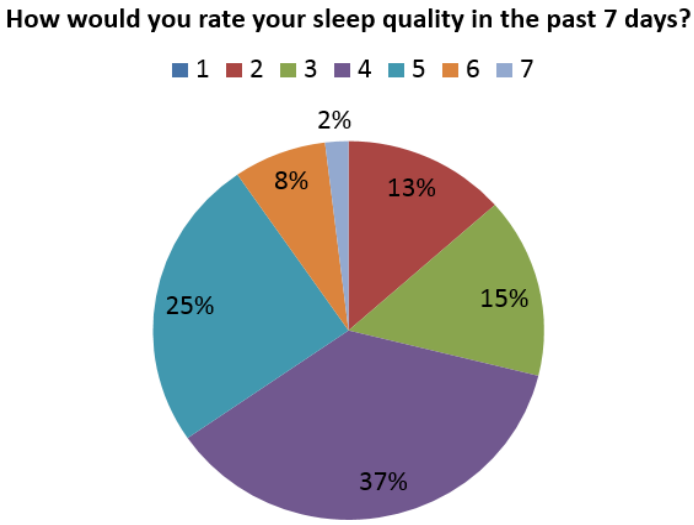


Figure 23 Percentage of responses for sleep quality in the past 7 days

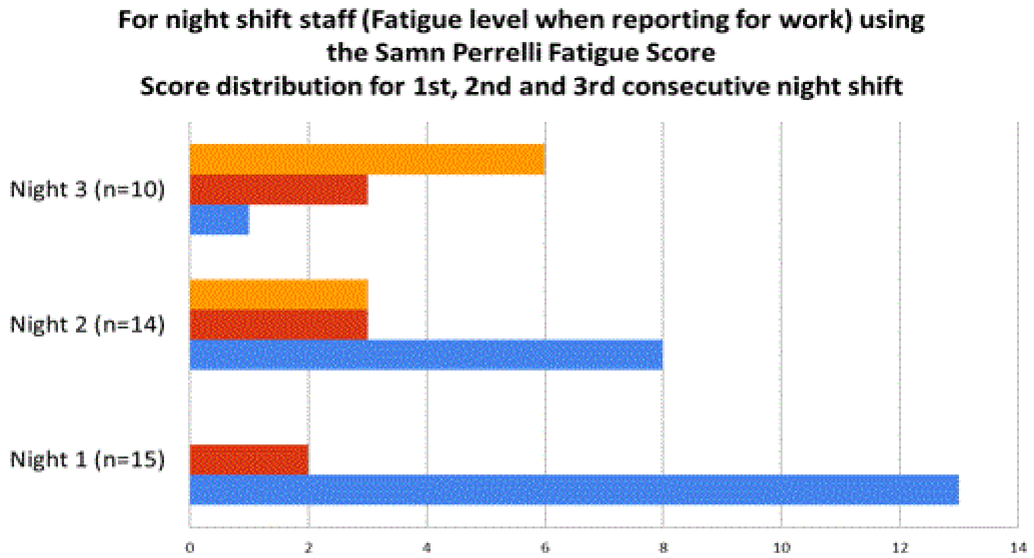
55% of the nurses responded "Yes" to the question – Do you ever have difficulty staying awake during working hours? Of those who responded "Yes" (n=30), 43 % and 57 % indicated that they rarely and sometimes have difficulty staying awake during working hours respectively. The commonest shift when they are most likely have difficulty staying awake is the night shift followed by the morning shift.

Daytime sleepiness was measured on the Epworth Sleepiness Scale (ESS). ESS is clinical test for day time sleepiness. Scores of more than 10 are considered to be indicative of excessive sleepiness. 31 % of the respondents had ESS of more than 10.

Daytime sleepiness is an indicator of cumulative sleep debt. While the scores more than 10 are not clinically significant, these give an indication of cumulative sleep debt in SICU nurses.

Work Pattern Profile: This section of the survey was intended to find out the actual work patterns of the respondents. 96 % of the SICU staff described their work pattern as rotating shifts. Shift timings varied between the morning, afternoon and night shifts with different start and end times.

There was a specific question in the survey for the staff rostered to do night shift to give an indicative fatigue score for each night shift, when rostered for three consecutive nights. Generally, in the SICU staff on rotating shift, night duties are rostered for a maximum of 2 consecutive nights, however on certain occasions due to operational requirements, staff may be rostered for 3 consecutive nights. Samn Perelli (SP) Fatigue score was used to understand the subjective fatigue level for first, second and if applicable third night shift.



	Night 1 (n=15)	Night 2 (n=14)	Night 3 (n=10)
>5	0	3	6
5	2	3	3
<5	13	8	1

Figure 24 Distribution of SP Fatigue Scores in night shift staff over 3 consecutive nights

The responses from the respondents show that with each consecutive night shift the mean fatigue score increases. For the first night, the mean score was 3.1, for the second night the mean score was 4.1 and for the third night, the mean score was 5.5. The distribution of the SP score over the three consecutive night shifts is shown in Figure 24.

On the first night none of the respondents indicated a score of > 5, however on day 2 – 21.4 % and day 3 – 60 % indicated a score of > 5. This suggests that subjective fatigue levels as indicated by SP Fatigue score increases with each consecutive night shift.

Consecutive shifts particularly night shift are associated with excessive fatigue and longer recovery times. On average it was reported that accident risks increase over successive night shifts i.e, 6% higher on the second night shift and 17% higher on third night shift (Rogers, 2008).

It was noted that a 65 % of the SICU staff have been working under the current shift roster for varying duration up to 5 years. 11 % staff reported working under the current shift roster for more than 10 years.

In response to the question “Was last week a typical working week for you?” 79% responded “Yes” and 21 % responded “No”. Those who responded “No” provided reasons such as being on course, sickness, holiday and other family commitments as reasons for the working week being unusual.

Work hours in SICU are usually 40 hours per week; however the work hours are averaged over a 2 week period such that it does not exceed 80 hours over 2 weeks. Working hours per shift in the SICU rotating shift system has considerable variation as seen in the roster analysis. 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.

Working overtime is not uncommon in the nursing profession. Overtime work and rotating shift work can be a lethal combination. Frequent overtime can be associated with difficulties with maximizing on the rest opportunities and thus leading to reduced sleep time and greater fatigue. In a study in hospital staff nurses collected on 11, 387 shifts, nurses left work at the end of their scheduled shift less than once every six shift.

82 % had done a night shift duty during the 7 day period and the number of night shifts that they did ranged from 1 to 4 days. The distribution of the night duty is shown in Figure 25. Of those who responded, majority of the SICU staff (56 %, n=26) indicated that they worked 2 night shifts over the 7 day period.

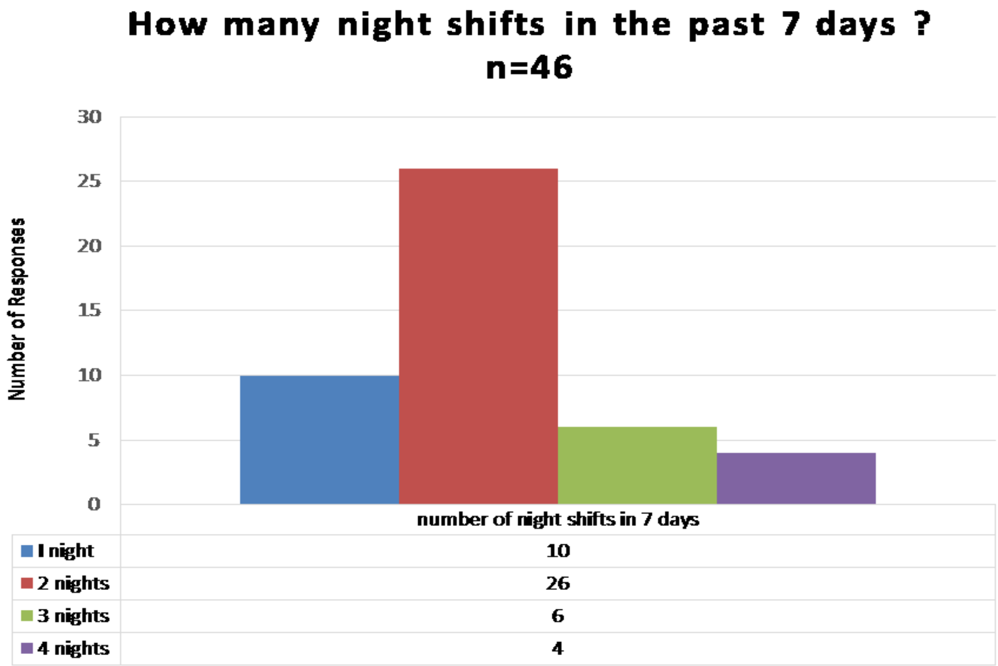


Figure 25 Number of night shifts over a 7 day period

Distribution of the weekly working hours during survey show that majority of the staff are rostered to 40 hours per week for the two weeks (last 7 days and the week before). There were variations to the working hours over the period of 2 weeks but overall, a large majority worked 40 hours per week as shown in Figure 26.

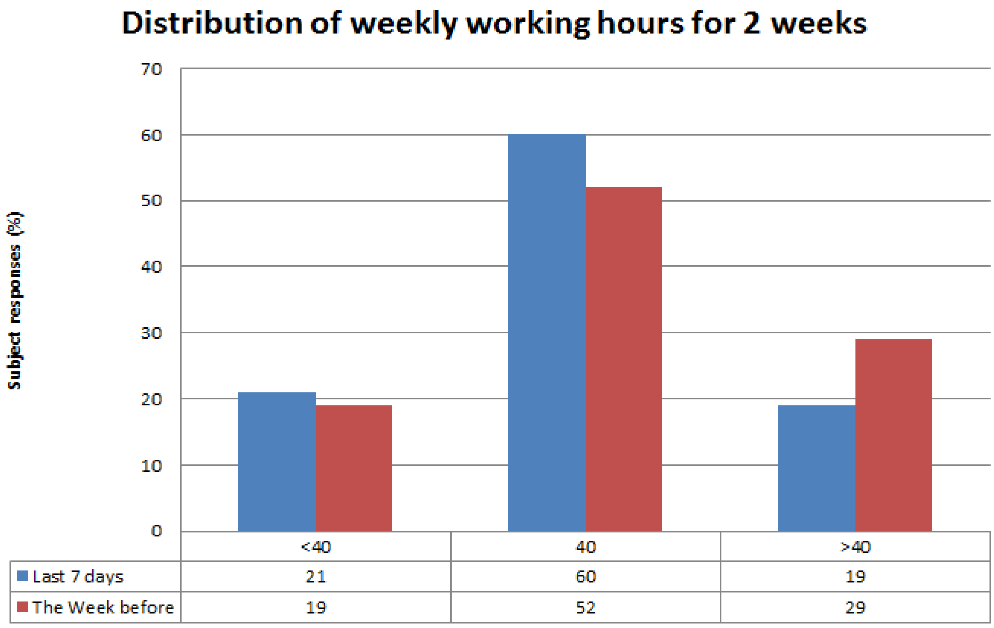


Figure 26 Distribution of weekly working hours over a 2 week period

More than 50 % of the staff indicated that they worked longer than the rostered duty in the preceding 2 weeks. Figure 27 shows the distribution of the work beyond rostered hours. 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”.

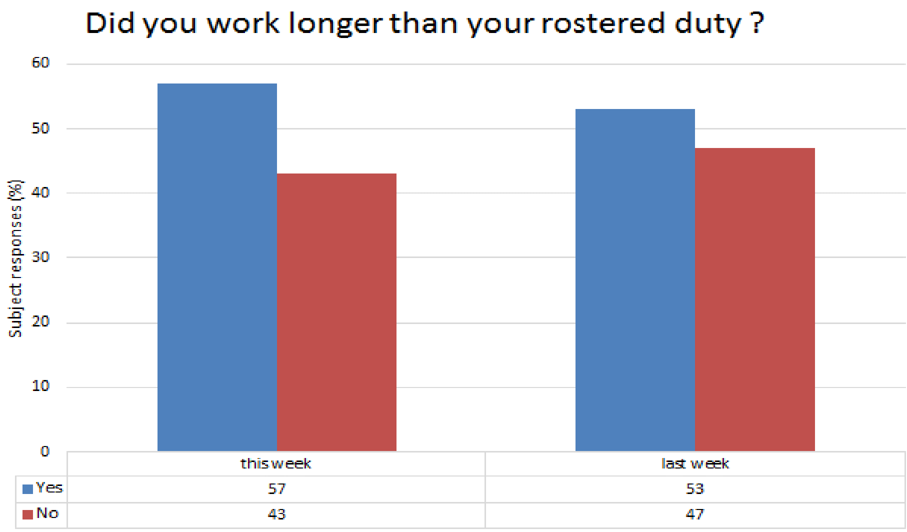


Figure 27 Working beyond the rostered hours over the 2 week period

In response to the question "Have you ever made an error that you consider was due to fatigue?" 28 % (n=16) responded yes as shown in Figure 28. Previous studies in nurses have observed a relationship between sleep in prior 24 hours and risk of making an error. It is estimated that there is a 3.4 % chance of error when a nurse obtains 6 or fewer hours of sleep in prior 24 hours. This translates to a probability of 34 events a day in an average teaching hospital with 1000 nursing shifts per day (Rogers, 2008).

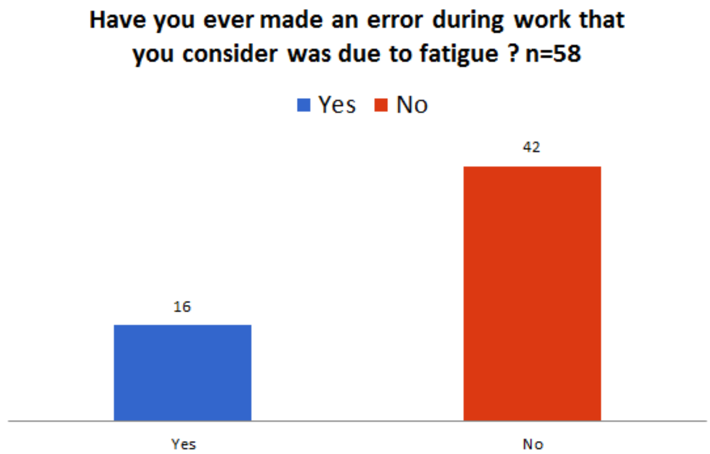


Figure 28 Number of responses for "error at work attributed to fatigue"

84 % of the SICU staff did not ever get any education on personal strategies for coping with the effects of shiftwork, fatigue and inadequate sleep. However, 74 % of those surveyed responded yes to the question "Would you be interested to participate in a workshop to learn about fatigue and fatigue management?"

Staff also provided some valuable comments regarding their experiences about shiftwork. The comments provide valuable insights into the subjective perception of shift patterns. One such notable comment is "can be very tiring to work morning shift after an afternoon shift". It was also observed during the study of work roster that the rest opportunity in between shifts for morning shift followed by afternoon shift was minimal (9.5 hours) as compared to other shift patterns. This is therefore a potential shift pattern of concern for fatigue. The feedback relates to the following key dimensions of shift work: shift duration, shift patterns, overtime work, breaks, performance errors and mood. Table 15 summarises the comments.

Some nurses have given feedback suggesting 12 hour shifts are better. However most authorities do not recommend the use of 12 hours shift unless there are sufficient rest breaks and assurance that overtime will not be added. A 12 hour shift system increases the risk of fatigue and if there are staff shortages, there is a potential danger of asking an already fatigued nurse to cover extra duties.

Table 15 Comments by the SICU staff related to shift work and fatigue

No.	Comments
1	Can be very tiring to work morning shift after an afternoon shift
2	After working for afternoon shift and you do morning the next day you cannot sleep well
3	Working rotating shift is tiring. Sometimes we get our day Off and rest day after post night. When the ward is very busy had to work overtime. If patient come in late when nearly at the end of the shift have to stay back almost one and half hours & sometime very sick patient had to stay back 2 hrs.
4	Shifting work is very tiring & sometimes all your days you are in your workplace is often on Day off / Rest Day is after our night shift then after we do our day (AM) shift. We seldom go to social occasion which we need. We rather do 12 hours shift at least we can spend a good quality time in our family.
5	Make the shift regular, such as all day shift for one week, then all afternoon shift for next week
6	I suggest 12 hour shift is better because we usually extend our duty hours with no pay when we are busy and day offs are usually given post night duty for one day
7	In ICU 12 hour duty is better because 1) reports are long - passing report will potentially cause mistake especially if you need to pass report 3 times per day and 2) many staff- roster setting may be easier
8	I think 12 hours shift is better since we are able to have longer days of off days.
9	Everyday changing of shift (ex. From afternoon to morning shift) got difficulty of sleeping on my part
10	Shift work affects my sleep and diet and takes a toll on my health.
11	Seniors get sicker patients; end up staying later than actual shift & therefore actual working hrs. much more allocated shift hours
12	Fatigue and stressed when not able to go for break (meal time) and go home in time when work situation was too busy/occupied
13	I have made a serious medication error during my night shift around 3-4 am. I read doctor's description wrongly and administered the wrong dosage. I think it's mostly due to fatigue.
14	It's quite tough to work with frequently changing shift
15	Most of morning shifts feel a bit tired to wake up since there might be difficulty to sleep early at night
16	When fatigue, becomes not so alert, reaction time is delayed and sometimes get easily impatient with difficult patients/relatives

4.1.3 Study 3 – Identification of Task for SA Analysis

The SA assessment method for this study was identified to be Situation Assessment Rating Technique (SART) based on the literature review. SART has 10 rating queries which were modified for SICU for the task of "administering medication".

Task analysis for medication administration was conducted. The task analysis is shown in Appendix XII. SART probes specific to the administration of medication were developed. Senior nurses of SICU were consulted to refine the SART probes for the context of use and each item was clearly defined for clarity. The SART scale used for this study is provided in the Appendix IV.

4.2 Phase 2 Pre FRMS

Pre FRMS phase formed the baseline data collection phase. Subjective global sleepiness was assessed using the ESS at the start of Pre FRMS phase. Data collection included a battery of tests for the estimation of fatigue, sleepiness, SA and performance during each shift type – morning, afternoon and night shift and at the start and end of shift.

Coding was used in the results analysis is described in Table 16.

Table 16 Coding used in results analysis

Descriptor	*Codes*
Phase	Pre FRMS or "Before" – B Post FRMS or "After" - A
Shift type	Morning –M / Afternoon- A / Night –N
Data point	Start – 0/ End – 1
Variable	SP/SA/ KSS/ RT

Example: BM1SP refers to Pre FRMS, End of morning shift, Samn Perelli Fatigue Score

Participants Profile:

Participants for the Pre FRMS were all females, with mean age of 26.7 years (Range 21 - 48 years). All the subjects were in good general health as determined by the medical declaration and were free of medical disorders and were not on any prescribed medications during the period of their involvement in the study. All the participants performed nursing duties during the course of their work at SICU.

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. A total of 28 participants completed all the phases of the study (Pre FRMS, FRMS and Post FRMS) and data from these subjects was used for the comparative analysis of the Pre and Post FRMS phase.

8 participants from Pre FRMS phase did not proceed to the Post FRMS phase. The main reasons for participant attrition during the post FRMS were: on long leave (n=4); resigned from job (n=1); reassigned to another unit (n=1) and withdrew participation after completing Pre FRMS (n=2). The two participants, who withdrew from the study, cited not being interested to continue in the research as reason for withdrawal.

Table 17 summarizes the Pre FRMS results for the morning, afternoon and night shifts for fatigue, SA, sleepiness and response time on vigilance task. The Post FRMS results for the different dependant variables were compared using statistical analysis tools and the results tables are in Appendix XI.

Table 17 Pre FRMS results

Pre FRMS Mean fatigue scores with SP checklist			
Shift	**Mean**	**Variance**	**No of observations**
All			
B0SP (Start)	**3.45**	**1.79**	**88**
B1SP (End)	**4.83**	**1.51**	**77**
Morning			
BM0SP (Start)	**3.77**	**1.71**	**31**
BM1SP (End)	**4.82**	**1.61**	**29**
Afternoon			
BA0SP (Start)	**3.17**	**1.93**	**29**
BA1SP (End)	**4.81**	**1.61**	**27**
Night			
BN0SP (Start)	**3.23**	**1.38**	**26**
BN1SP (End)	**5.34**	**0.87**	**23**

Pre FRMS Mean SA scores with SART			
Shift	**Mean**	**Variance**	**No of observations**
All			
B0SA (Start)	**22.68**	**43.86**	**63**
B1SA (End)	**22.03**	**44.48**	**63**
Morning			
BM0SA (Start)	**23.38**	**36.04**	**21**
BM1SA (End)	**22.61**	**40.54**	**21**
Afternoon			
BA0SA (Start)	**21.38**	**45.34**	**21**
BA1SA (End)	**21.33**	**45.23**	**21**
Night			
BN0SA (Start)	**23.28**	**51.91**	**21**
BN1SA (End)	**22.14**	**51.22**	**21**

Pre FRMS Mean sleepiness scores with KSS			
Shift	**Mean**	**Variance**	**No of observations**
All			
B0KSS (Start)	**3.79**	**2.59**	**86**
B1KSS (End)	**5.49**	**3.27**	**77**
Morning			
BM0KSS (Start)	**4.43**	**2.87**	**30**
BM1KSS (End)	**5.25**	**3.75**	**28**
Afternoon			
BA0KSS (Start)	**3.46**	**2.53**	**30**
BA1KSS (End)	**5.07**	**3.19**	**26**
Night			
BN0KSS (Start)	**3.42**	**1.77**	**26**
BN1KSS (End)	**6.26**	**2.20**	**23**

Pre FRMS Mean RT on vigilance task			
Shift	**Mean**	**Variance**	**No of observations**
All			
B0RT (Start)	**344.86**	**3273.84**	**75**
B1RT (End)	**386.11**	**6260.05**	**79**
Morning			
BM0RT (Start)	**360.58**	**4219.21**	**24**
BM1RT (End)	**387.75**	**8405.47**	**29**
Afternoon			
BA0RT (Start)	**338.07**	**2551.99**	**28**
BA1RT(End)	**373.14**	**3734.82**	**27**
Night			
BN0RT (Start)	**336.73**	**3071.74**	**23**
BN1RT (End)	**399.26**	**6692.38**	**23**

Pre FRMS Mean sleep duration (in hours)	**Morning (hours)**	**Afternoon (hours)**	**Night (hours)**
Subjective (Sleep Log)	**8 (8)**	**7h 44min (7.73)**	**5h 43min (5.72)**
Objective (Actigraphy)	**9h 1 min (9.02)**	**8h 18 min (8.3)**	**5 h 54min (5.9)**

Fatigue Scores:

Data was pooled from all subjects who participated in this study. SP fatigue scores at the start of each of the three shifts (morning, afternoon and night) were pooled together. This was compared with the fatigue scores at the end of all three shifts for all subjects pooled together using the F test Two sample for variances. The mean fatigue score at the start of shift was 3.45. The mean fatigue score at the end of shift was higher with a mean of 4.83. While there is a difference between the means, this difference is not statistically significant.

The fatigue levels at the start of shift across the three shifts were compared using ANOVA. The mean fatigue score was 3.77 at the start of the morning shift and exceeds the mean fatigue score of 3.17 at the start of the afternoon shift and the mean fatigue score of 3.23 at start of the night shift. The difference is not statistically significant.

The fatigue levels at the end of shift across the three shifts were compared using ANOVA. The fatigue score at the end of the three shifts were 4.48 for end of morning shift, 4.81 for end of afternoon shift and 5.34 for end of night shift. The difference is significant and therefore paired comparisons were made to assess between which pairs of groups the difference lie.

Pairwise comparison of fatigue scores were done for end of morning versus end of afternoon shift , end of afternoon versus end of night shift and end of morning versus end of night shift. No statistically significant difference was noted between SP scores between ends of morning versus afternoon shifts and for ends of afternoon versus night shift, however significant difference was noted for end of the morning shift versus end of the night shift.

Fatigue levels were compared at the start and end of shift for morning, afternoon and night. The mean fatigue levels at the start and end of morning shift were 3.77 and 4.48 respectively. The difference is statistically significant with $p<0.05$. The mean fatigue levels at the start and end of afternoon shift were 3.17 and 4.81 respectively and for start and end of night shift were 3.23 and 5.34 respectively. The mean fatigue threshold from the safety critical perspective was breached only at the end of the night shift i.e., more than 5.

Situation Awareness scores:

The Situation Awareness scores were compared at the start and end of shifts using t - test. The mean score was 22.68 at the start of shift and the mean score was 22.03 at the end of shift. The difference between the means is not statistically significant.

The SA levels at the start of shift across the three shifts were compared using ANOVA. The SA score at the start of the three shifts were 23.38 for morning shift, 21.38 for afternoon shift and 23.28 for night shift. The difference in mean scores is not statistically significant.

Similarly the SA levels at the end of shift across the three shifts were compared using ANOVA. The SA score at the end of the three shifts were 22.6 for end of morning shift, 21.3 for end of afternoon shift and 22.1 for end of night shift. The difference in mean scores is not statistically significant.

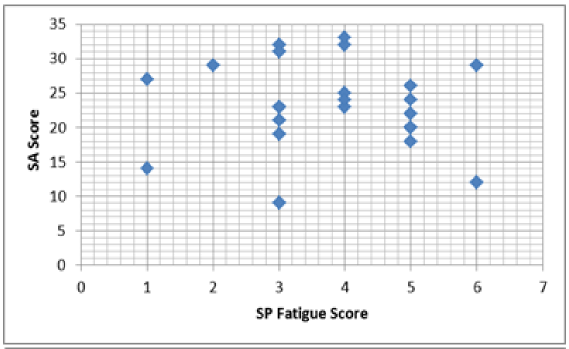
The SA scores at the start of the morning shift had a mean value of 23.38 and dropped to 22.61 at the end of the morning shift; this difference was not found to be statistically significant. The SA scores at the start of the afternoon shift had a mean value of 21.38 and dropped to 21.33 at the end of the afternoon shift; this difference was not found to be statistically significant. The SA scores at the start of the night shift had a mean value of 23.28 and dropped to 22.14 at the end of the night shift; this difference was not found to be statistically significant.

The lowest SA score was noted at the end of the night shift which was also the time when the Fatigue score was recorded to be the highest.

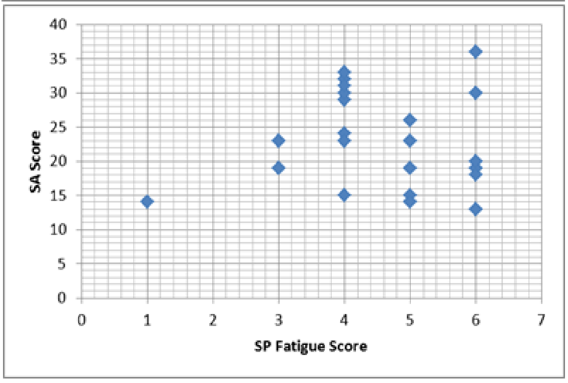
<u>Correlation between Fatigue score and SA score:</u>

Correlation between fatigue and SA scores for start and end of morning, afternoon and night shift in the Pre FRMS phase was explored as shown in Figure 29, Figure 30 and Figure 31 .

	BM0SP	*BM0SA*
BM0SP	1	
BM0SA	-0.072606551	1



	BM1SP	*BM1SA*
BM1SP	1	
BM1SA	0.048484	1



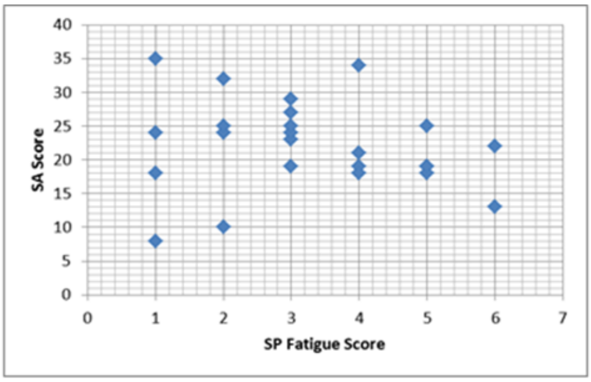
Correlation between Fatigue score and Situation Awareness score at the start (BM0) and end (BM1) of the morning shift in the Pre FRMS phase

Figure 29 Scatterplot of Fatigue and SA scores for morning shift in Pre FRMS phase

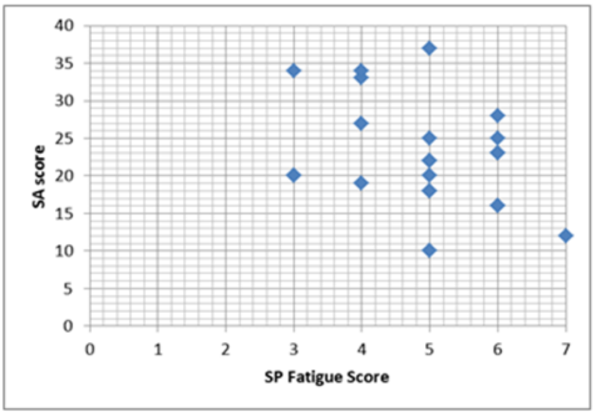
No significant correlation was noted between fatigue and SA scores at the start and end of morning shift.

Very weak negative correlation was noted between fatigue and SA scores at the start (-0.14) and end (-0.3) of afternoon shift. These do not appear to be significant.

	BA0SP	*BA0SA*
BA0SP	1	
BA0SA	-0.14387	1



	BA1SP	*BA1SA*
BA1SP	1	
BA1SA	-0.3633	1



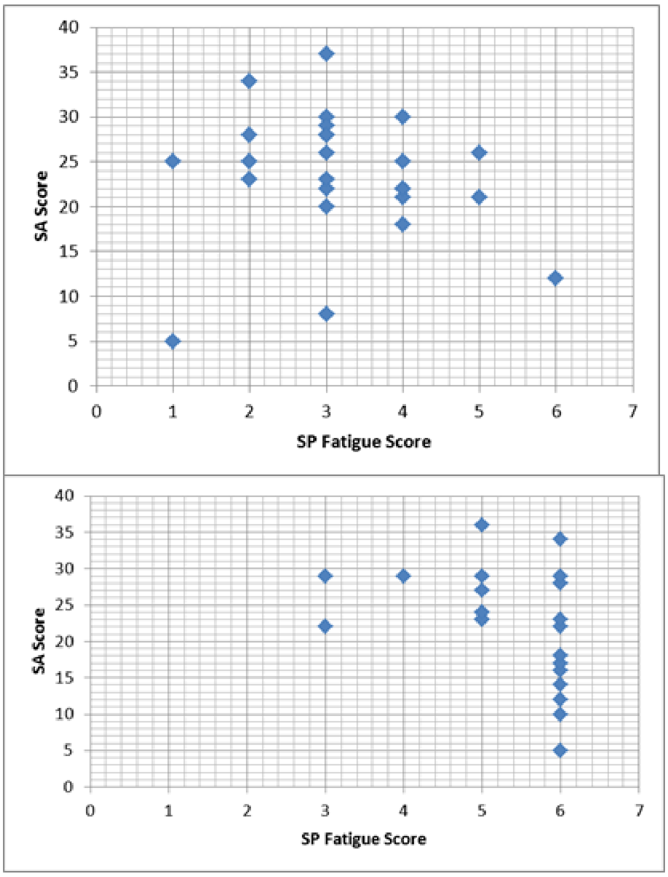
Correlation between Fatigue score and Situation Awareness score at the start (BA0) and end (BA1) of the afternoon shift in the Pre FRMS phase

Figure 30 Scatterplot of Fatigue and SA Score for afternoon shift in Pre FRMS phase

Very weak negative correlation was noted between fatigue and SA scores at the start (-0.09) and end (-0.3) of night shift. These do not appear to be significant.

	BN0SP	*BN0SA*
BN0SP	1	
BN0SA	-0.09454	1

	BN1SP	*BN1SA*
BN1SP	1	
BN1SA	-0.38862	1



Correlation between Fatigue score and Situation Awareness score at the start (BN0) and end (BN1) of the night shift in the Pre FRMS phase

Figure 31 Scatterplot of Fatigue and SA scores for night shift in Pre FRMS phase

<u>Sleepiness Scores</u>:

The sleepiness scores were pooled for all three shifts and compared at the start and end of shifts. The mean score was 3.79 at the start of shift and the mean score was 5.49 at the end of shift. The difference between the means is not statistically significant.

The mean KSS scores for the start of morning shift was 4.43. The mean KSS scores for the start of afternoon shift and night shift was 3.46 and 3.42 respectively. The difference was noted to be significant and therefore paired comparisons were made to assess between which pairs of groups the difference lie.

The mean KSS scores at the start of morning shift were significantly more than the mean KSS scores at the start of afternoon shift. Similarly, the mean KSS scores at the start of the morning shift were significantly more than the mean KSS scores at the start of night shift. However, no significant difference was noted between the mean KSS score between the start of the afternoon shift and the start of night shift.

The mean KSS scores for the end of morning shift was 5.25. The mean KSS scores for the start of afternoon shift was 5.07 and night shift was 6.26. The highest sleepiness scores were noted at the night shift. The difference was noted to be significant and therefore paired comparisons were made between ends of morning versus afternoon shift, ends of morning versus night shift and ends of afternoon versus night, to assess between which pairs of groups the difference lie.

No significant difference was noted between ends of morning versus afternoon shift. However the mean KSS scores showed a significant difference between ends of morning versus night shift as well as for ends of afternoon versus night shift.

The KSS scores at the start of the morning shift had a mean value of 4.43 and increased to 5.25 at the end of the morning shift; this difference was found to be statistically significant. The KSS scores at the start of the afternoon shift had a mean value of 3.46 and increased to 5.07 at the end of the afternoon shift; this difference was found to be statistically significant. The KSS scores at the start of the night shift had a mean value of 3.45 and increased to 6.27 at the end of the night shift.

Response time (RT) on the Vigilance task:

RT data for the three shifts were pooled and analysed. The mean RT at the start of shifts was 344.86 milliseconds and it increased to 386.11 milliseconds at the end of shifts. Significant difference was noted between mean RT values at start and end of all shifts. RT was compared between start of morning, afternoon and night shift as well as between end of morning, afternoon and night shift. No statistically significant differences were found in the RT values in both situations. However, the highest mean RT was noted for the end of night shift at 399.26 milliseconds, followed by the end of morning shift at 387.75. Mean RT in milliseconds at start of morning shift was 360.58 and increased to 386.11 at the end of the morning shift. The differences between the RT values were not significant. Mean RT in milliseconds at start of afternoon shift was 338.0 and increased to 373.14 at the end of the afternoon shift. The differences between the RT values were significant. The RT at the start of the night shift had a mean value of 336.73 and increased to 399.26 at the end of the night shift. The differences between the RT values were significant.

Sleep Duration:

The objective sleep duration was recorded by actigraphy and the subjective sleep duration was recorded by the participant in the sleep diary. Both subjective sleep and objective sleep duration records show that the maximum mean sleep duration was after the morning shift as shown in Table 17 . Post night shift, mean sleep duration was less than 6 hours.

Epworth Sleepiness Scale Scores (ESS):

ESS score was used to measure a general level of daytime sleepiness at the beginning of the Pre FRMS phase. ESS scores of up to 10 are considered to be within normal range. It was noted that in the Pre FRMS phase 58.8% (n=20) of the participants had scores $\leq$ 10 while 41.2% (n=14) of participants had scores more than 10.

4.3 Phase 3 FRMS

Data obtained from the three preliminary studies and Pre FRMS phase were used to develop the fatigue risk management recommendations for SICU.

Six main recommendations were proposed to reduce the fatigue risk of the work rosters based on work roster analysis (Phase 1- Preliminary Study 1). 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.

The first recommendation was to increase the frequency of breaks. The current practice in SICU was to have a single one hour meal and rest break during the shift (Tan, 2013). Based on AMA fatigue risk assessment, one break is scored as significant risk (2 points). By fragmenting the breaks to three shorter periods that aggregate to one hour, the risk could be reduced further to low risk (1 point).

The second recommendation was to limit the night shifts to two nights per week. It was noted that those who did not work night shifts in the 7 day period had an average AMA score of 15.6 which increased to 16.9 for 1 night shift, 17.8 for 2 night shifts and 18.3 for 3 night shifts. While no night shift is the best solution purely in terms of fatigue minimization, it does not support operational considerations. SICU requires its nurses to work at least 2 night shifts per week which is a significant risk (2 points). It was recommended that the night shifts were limited to two per week to distribute the risk equally over the two week roster.

The third recommendation was to provide a rest opportunity of at least 24 hours after five days of continuous work. Majority of the rosters examined, provided adequate rest opportunity over the seven day period (more than two days per week). Incidentally, the highest AMA score of 21 (bordering on high risk)) had only one rest day in the week. It is recommended that the "5 day on and 2 days off" work pattern be followed as far as practicable. At least 24 hours of rest must be provided after five days of continuous work to keep the fatigue risk in the moderate range.

The fourth recommendation was to eliminate or minimise the afternoon followed by morning shift. The shift pattern of "afternoon shift followed by morning shift", was noted to limit the rest opportunity to less than 10 hours. Between shift end time of A6/A16 - 2130 hours and shift start time of all M shifts- 0700 hours, gap in between shifts was noted to be 9.5 hours. This indicates less than optimal rest opportunity after discounting commute time and time required for other domestic matters. This contributed to significant risk (2 points). Eliminating or minimizing the "Afternoon Morning" shift pattern would benefit by addressing both the rest opportunity before shift as well as backward rotation pattern. Alternative option was to provide a rest day following an "Afternoon Morning" shift pattern; however this did not address the fatigue associated with the afternoon shift as such.

The fifth recommendation was to adopt forward shift rotation as far as practicable. There was no stable direction or speed of rotation noted in the rosters examined, with the exception of a few rosters. This contributed to a high risk (3 points). Having a forward rotation will help to reduce the risk from high to significant or low risk. Also it was noted that “afternoon shift followed by morning shift” was a backward rotation pattern. It was recommended to minimise the rostering of this particular pattern.

The sixth and final recommendation was to introduce a degree of predictability in roster schedules. SICU roster changes were highly unpredictable and hence this contributed to a high risk (3 points). Introducing a degree of predictability in the roster could facilitate in reduction of risk to significant risk. The SICU roster was flexible to the demands of the operations and that traded off with stability.

Recommendations about work place 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 couches which the nurses could use during their shifts to take rest. During the night shifts these couches were used to take naps.

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 –were to define 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. Some nurses could not sleep at work and preferred not to take a nap.

Nurses were advised to consider taking a nap at home prior to night shift ideally in the post lunch period to help them maintain alertness during working hours at night.

Alertness recommendations

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.

Fatigue education and fatigue self-management recommendations

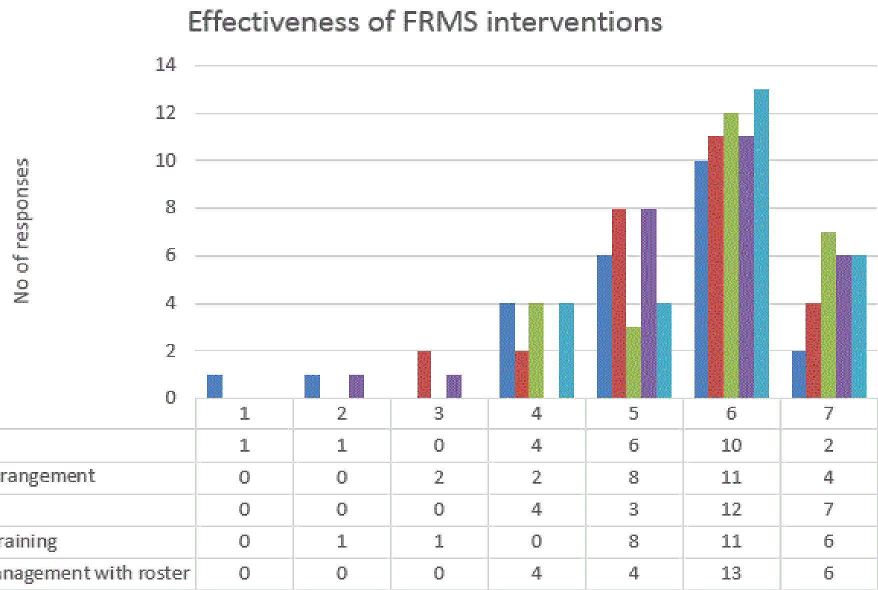
Fatigue management training module was developed for the SICU nurses. The training module covered information about sleep physiology and hygiene measures, fatigue recognition, alertness management recommendations and fatigue self-management skills. The module was delivered as a workshop of 2 hours duration. A total of eight training sessions with open session for discussion were conducted at SICU. The training session was open to all staff and management of SICU and not just the study participants. The contents of the slides used for the fatigue management training are provided in Appendix X.

The sleep physiology and fatigue management training was evaluated by all the participants and a feedback form was given to them. A copy of the form is provided in Appendix V.

Based on the above recommendations, interventions were done in SICU during the FRMS phase. The interventions are detailed in Section 3.4.

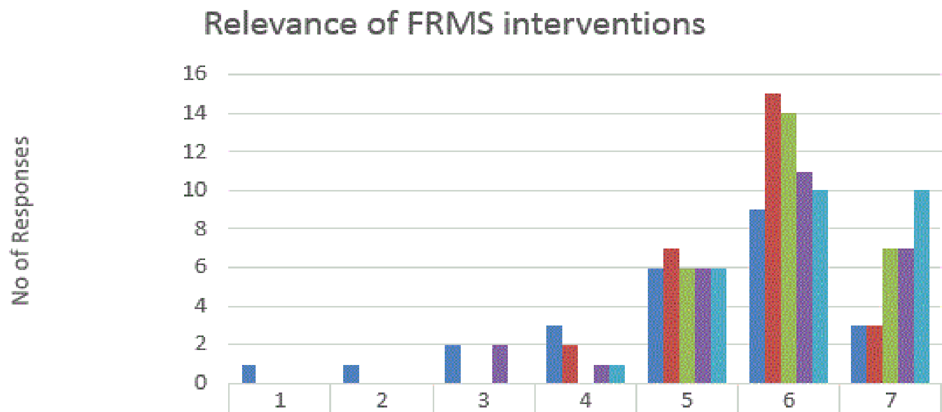
Five key interventions were evaluated. These are provision and use of caffeine as a fatigue countermeasure, rearrangement of roster to substitute high fatigue score shift patterns with lower fatigue shift score patterns, provision of nap time for night shift and provision of place to sleep, education in fatigue recognition and strategies for managing fatigue and finally assisting SICU management in fatigue risk management and giving them tools to better plan shift rosters to reduce fatigue risk.

The results of the FRMS evaluation are shown in Figure 32 and Figure 33. The results show that a median score of 6 for both effectiveness and relevance across all interventions.



	1	2	3	4	5	6	7
Caffiene	1	1	0	4	6	10	2
Roster arrangement	0	0	2	2	8	11	4
Nap	0	0	0	4	3	12	7
Fatigue training	0	1	1	0	8	11	6
Assist management with roster	0	0	0	4	4	13	6

Figure 32 Feedback about effectiveness of FRMS interventions



	1	2	3	4	5	6	7
Caffeine	1	1	2	3	6	9	3
Roster arrangement	0	0	0	2	7	15	3
Nap	0	0	0	0	6	14	7
Fatigue training	0	0	2	1	6	11	7
Assist management with roster	0	0	0	1	6	10	10

Figure 33 Feedback about the relevance of FRMS interventions

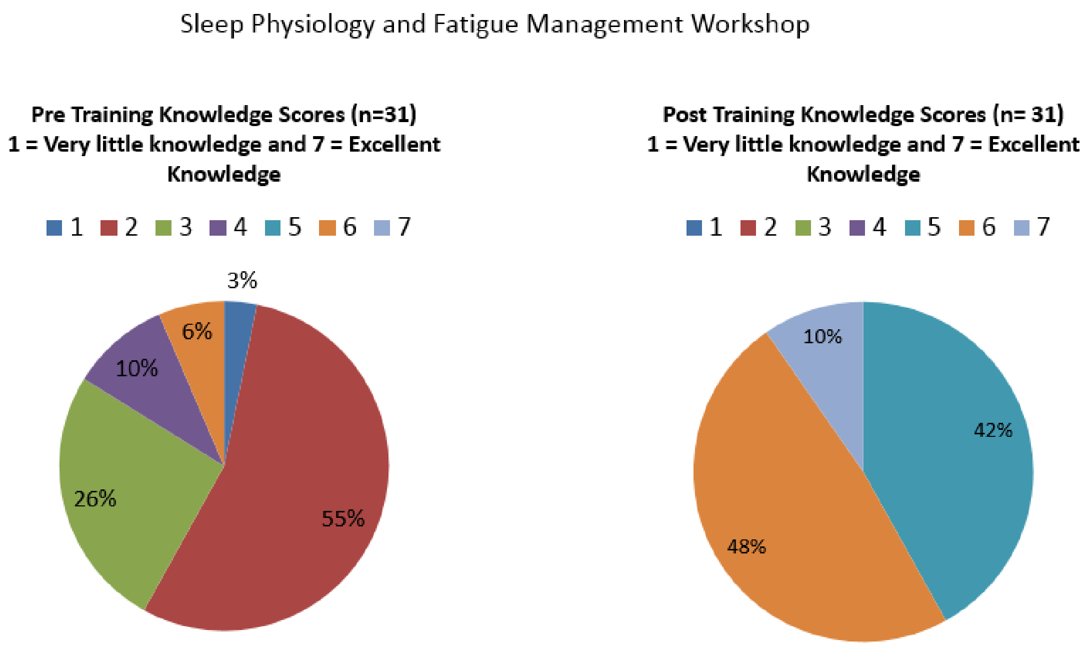


Figure 34 Participant feedback before and after fatigue management training

The evaluation of FRMS training survey show that 58% of the participants scored 6 and 7 after workshop as compared to 6 % before the workshop as shown in Figure 34.

4.4 Phase 4 Post FRMS

28 participants who enrolled in the Pre FRMS phase completed the Post FRMS phase. Table 18 shows the Post FRMS results. The Post FRMS results for the different dependant variables were compared using statistical analysis tools and the results tables are in Appendix XI.

Table 18 Post FRMS results

Post FRMS Mean fatigue scores with SP checklist			
Shift	**Mean**	**Variance**	**No of observations**
All			
A0SP (Start)	**2.93**	**1.55**	**72**
A1SP (End)	**4.2**	**2.30**	**70**
Morning			
AM0SP (Start)	**3.30**	**1.66**	**26**
AM1SP (End)	**3.96**	**1.95**	**26**
Afternoon			
AA0SP (Start)	**2.6**	**1.66**	**25**
AA1SP (End)	**3.56**	**2.52**	**23**
Night			
AN0SP (Start)	**2.85**	**1.12**	**21**
AN1SP (End)	**5.19**	**1.16**	**21**

Post FRMS Mean SA scores with SART			
Shift	**Mean**	**Variance**	**No of observations**
All			
A0SA (Start)	**23.74**	**45.03**	**63**
A1SA (End)	**23.52**	**46.09**	**63**
Morning			
AM0SA (Start)	**23.86**	**52.50**	**22**
AM1SA (End)	**22.68**	**51.17**	**22**
Afternoon			
AA0SA (Start)	**23.38**	**48.04**	**21**
AA1SA (End)	**23.38**	**52.74**	**21**
Night			
AN0SA (Start)	**24**	**38.10**	**20**
AN1SA (End)	**24.6**	**36.25**	**20**

Post FRMS Mean sleepiness scores with KSS			
Shift	**Mean**	**Variance**	**No of observations**
All			
A0KSS (Start)	**3.51**	**3.06**	**70**
A1KSS (End)	**4.94**	**4.11**	**69**
Morning			
AM0KSS (Start)	**4.22**	**4.48**	**27**
AM1KSS (End)	**4.77**	**4.02**	**27**
Afternoon			
AA0KSS (Start)	**3.13**	**1.75**	**23**
AA1KSS (End)	**3.85**	**3.42**	**21**
Night			
AN0KSS (Start)	**3**	**1.78**	**20**
AN1KSS (End)	**6.23**	**2.29**	**21**

Post FRMS Mean RT on vigilance task			
Shift	**Mean**	**Variance**	**No of observations**
All			
A0RT (Start)	**368.54**	**4141.51**	**61**
A1RT (End)	**395.70**	**5963.94**	**61**
Morning			
AM0RT (Start)	**375.65**	**3053.66**	**20**
AM1RT (End)	**382.86**	**4801.20**	**23**
Afternoon			
AA0RT (Start)	**356.47**	**1493.46**	**21**
AA1RT(End)	**388.73**	**5225.42**	**19**
Night			
AN0RT (Start)	**374.1**	**8209.14**	**20**
AN1RT (End)	**418.21**	**7989.84**	**19**

Post FRMS Mean sleep duration (in hours)	**Morning (hours)**	**Afternoon (hours)**	**Night (hours)**
Subjective	8h 5 min (8.08)	7h 21 min (7.35)	5 h 43 min (5.71)
Objective	9 h 1 min (9.02)	8 h 30 min (8.5)	5h 48 min (5.8)

Fatigue Scores:

For this comparison, the fatigue scores at the start of each of the three shifts were pooled together. SP fatigue scores at the start of each of the three shifts (morning, afternoon and night) were pooled together. This was compared with the fatigue scores at the end of all three shifts for all subjects pooled together using the F test Two sample for variances. The mean fatigue score at the start of shift was 2.93. The mean fatigue score at the end of shift was higher with a mean of 4. There is a difference between the means and this difference almost reaches statistical significance at p = 0.051. Neither mean is above the safety critical level of 5.

The fatigue levels at the start of shift across the three shifts were compared using ANOVA. The mean fatigue score was 3.30 at the start of the morning shift and exceeds the mean fatigue score of 2.6 at the start of the afternoon shift and the fatigue score of 2.85 at start of the night shift. The difference is not statistically significant. The highest fatigue score at the start of the morning shift could be related to the early waking up required being able to report for work at 7 AM in the morning. This observation is consistent for both Pre and Post FRMS.

The fatigue levels at the end of shift across the three shifts were compared using ANOVA. The fatigue score at the end of the three shifts were 3.96 for end of morning shift, 3.56 for end of afternoon shift and 5.19 for end of night shift. The difference was noted to be significant and therefore paired comparisons were made to assess between which pairs of groups the difference lie.

Pairwise comparison of fatigue scores were done for end of morning versus end of afternoon shift, end of afternoon versus end of night shift and end of morning versus end of night shift. No statistically significant difference was noted between SP scores between ends of morning versus afternoon shifts. However significant difference was noted for ends of afternoon versus night shift and end of the morning shift versus end of the night shift. The mean 5.19, at the end of night shift, crosses the safety critical level of 5, suggesting that a significant number of nurses feel fatigue at moderate levels towards the end of night shift.

Fatigue levels were compared at the start and end of shift for morning, afternoon and night. The mean fatigue levels at the start and end of morning shift were 3.30 and 3.96 respectively. The difference is statistically significant with $p<0.05$. The mean fatigue levels at the start and end of afternoon shift were 2.6 and 3.56 respectively and for start and end of night shift were 2.85 and 5.19 respectively. The difference in means for the afternoon shift is statistically significant but not for night shift. The mean fatigue threshold from the safety critical perspective was breached only at the end of the night shift i.e., more than 5.

<u>Situation Awareness scores:</u>

Pooled estimates were done for Situation Awareness scores at the start and end of all shifts using t- test. The mean score was 23.74 at the start of shift and the mean score was 23.52 at the end of shift. The difference between the means is not statistically significant.

The SA levels at the start of shift across the three shifts were compared using ANOVA. The SA score was noted to be the highest for the start of the night shift (24) for night shift and lowest for start of afternoon shift (23.38). The difference in mean scores is not statistically significant.

Similarly the SA levels at the end of shift across the three shifts were compared using ANOVA. The SA score at the end of the three shifts were 22.68 for end of morning shift, 23.38 for end of afternoon shift and 24.6 for end of night shift. The difference in mean scores is not statistically significant.

The SA scores at the start of the morning shift had a mean value of 23.86 and dropped to 22.68 at the end of the morning shift; this difference was not found to be statistically significant. The SA scores at the start of the afternoon shift had a mean value of 23.38 and stayed at 23.38 at the end of the afternoon shift. This suggests that SA did not show much change during the afternoon shift. Similar findings were noted in the Pre FRMS phase between the start and end of afternoon shift.

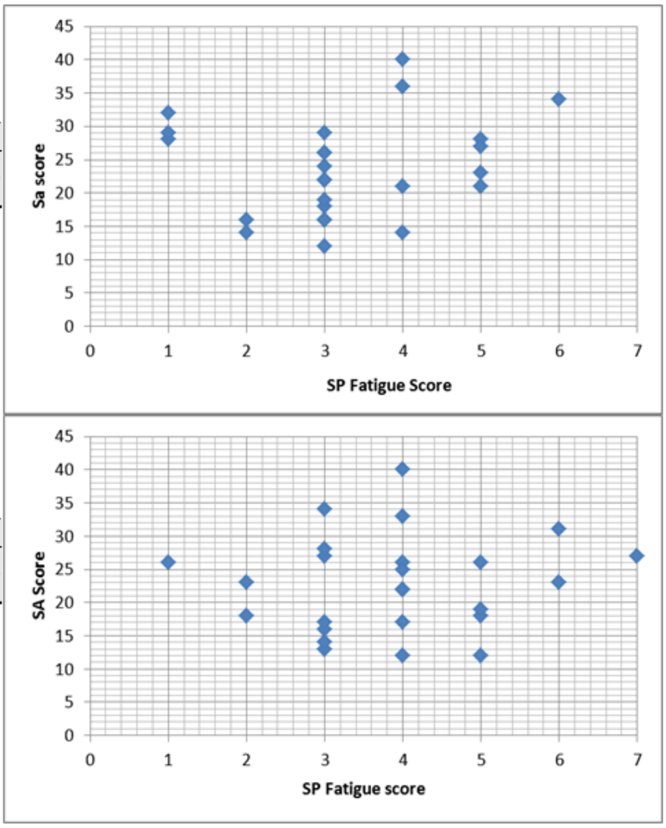
The SA scores at the start of the night shift had a mean value of 24 and increased to 24.6 at the end of the night shift; this difference was not found to be statistically significant. The highest Situation Awareness score was noted at the end of the night shift.

Correlation between fatigue and SA score

The following figures (Figure 35, Figure 36 and Figure 37) show the correlation between fatigue and SA scores for start and end of morning, afternoon and night shift in the Post FRMS phase.

	AM0SP	*AM0SA*
AM0SP	1	
AM0SA	0.160942	1

	AM1SP	*AM1SA*
AM1SP	1	
AM1SA	0.097675	1



Correlation between Fatigue score and Situation Awareness score at the start (AM0) and end (AM1) of the morning shift in the Post FRMS phase

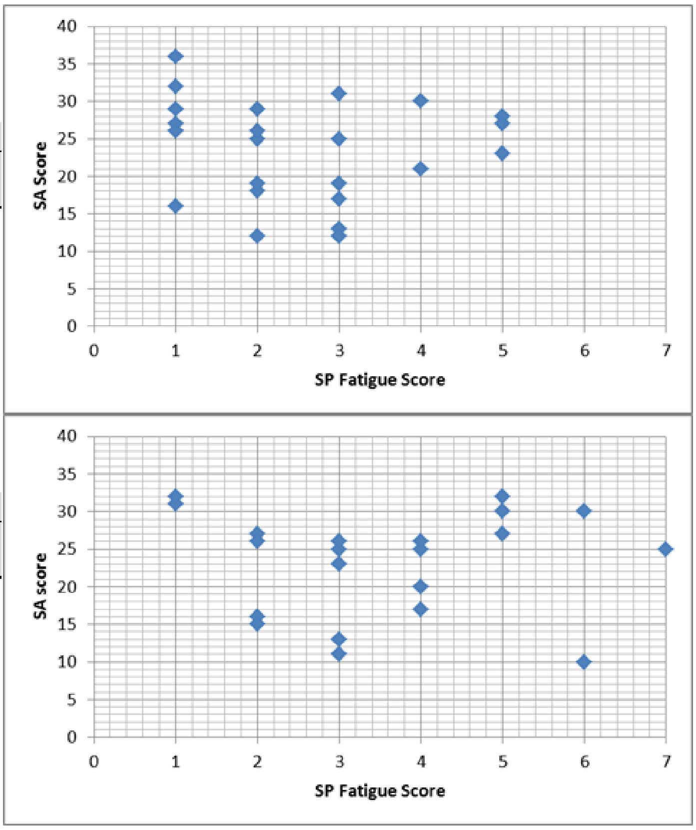
Figure 35 Scatterplot of Fatigue and SA score for morning shift in Post FRMS phase

Very poor positive correlation was noted for fatigue and SA scores at the start (0.16) and end (0.09) of morning shift.

Very poor negative correlation was noted for fatigue and SA scores at the start and end of afternoon shift.

	AA0SP	AA0SA
AA0SP	1	
AA0SA	-0.09434	1

	AA1SP	AA1SA
AA1SP	1	
AA1SA	-0.00991	1

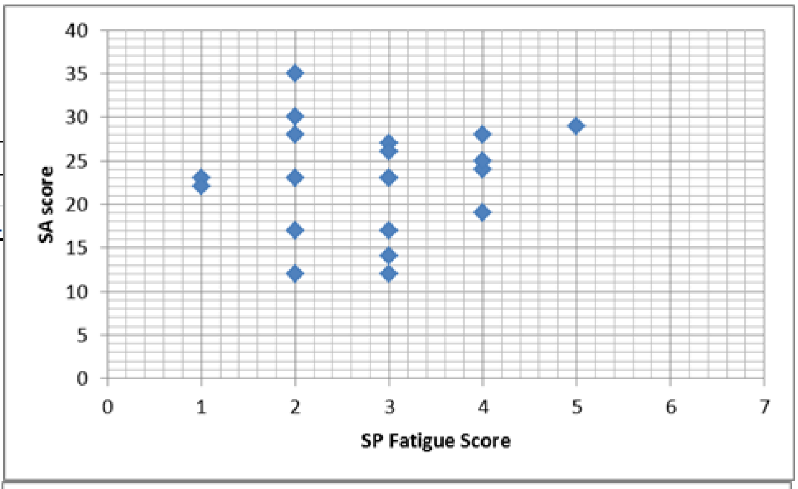


Correlation between Fatigue score and Situation Awareness score at the start (AA0) and end (AA1) of the afternoon shift in the Post FRMS phase

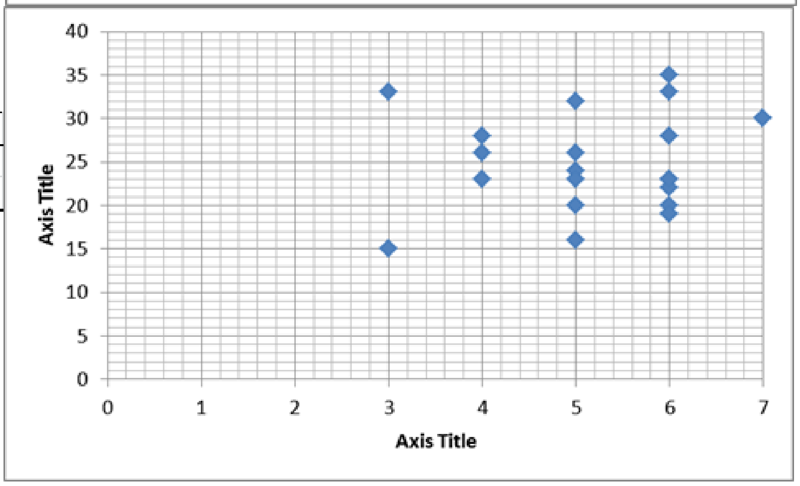
Figure 36 Scatterplot of Fatigue and SA scores for afternoon shift in Post FRMS phase

Very poor correlation was noted for fatigue and SA scores at the start and end of night shift.

	AN0SP	*AN0SA*
AN0SP	1	
AN0SA	0.084146	1



	AN1SP	*AN1SA*
AN1SP	1	
AN1SA	0.128653	1



Correlation between Fatigue score and Situation Awareness score at the start (AN0) and end (AN1) of the night shift in the Post FRMS phase

Figure 37 Scatterplot of Fatigue and SA scores for night shift in Post FRMS phase

<u>Sleepiness scores:</u>

Mean KSS score at the start of morning shift was 4.22 and it increased to 4.77 at the end of the shift. This difference was not found to be statistically significant. Mean KSS score at the start of afternoon shift was 3.13 and it increased to 3.85 at the end of the shift. This difference was not found to be statistically significant. Mean KSS score at the start of night shift was 3 and it increased to 6.23 at the end of the shift. The mean sleepiness score at end of night shift is twice that at start.

The mean KSS score was noted to be highest for start of the morning shift and lowest for start of night shift. The difference was statistically significant.

Pairwise comparison of KSS sleepiness scores at the start of morning versus start of afternoon shift and start of morning versus start of night shift show a statistically significant difference. No statistically significant difference was noted for the start of the afternoon shift versus start of night shift.

The mean KSS score was noted to be highest for end of the night shift and lowest for end of afternoon shift. The difference between the KSS was statistically significant.

Pairwise comparison of Sleepiness scores for end of morning versus end of afternoon shift and for end of morning versus end of night shift show a statistically significant difference.

Response time (RT) on the Vigilance task:

RT data for the three shifts were pooled and analysed. The mean RT at the start of shifts was 368.54 milliseconds and it increased to 395.70 milliseconds at the end of shifts. No statistically significant differences were found in the RT scores in both situations.

RT was compared between start of morning, afternoon and night shift as well as between end of morning, afternoon and night shift. No statistically significant differences were found in the RT values in both situations. However, the highest mean RT was noted for the end of night shift at 399.26 milliseconds, followed by the end of morning shift at 387.75.

Mean RT in milliseconds at start of morning shift was 375.65 and increased to 382.86 at the end of the morning shift. The differences between the RT values were not significant. Mean RT in milliseconds at start of afternoon shift was 356.47 and increased to 388.73 at the end of the afternoon shift. The differences between the RT values were significant. The RT at the start of the night shift had a mean value of 374.1 and increased to 418.21 at the end of the night shift. The differences between the RT values do not show clear statistical significance.

Sleep Duration:

Post FRMS Mean sleep duration was recorded for morning, afternoon and night shift and was included in Table 18. The maximum sleep duration was noted to be after the morning shift and the least sleep duration was noted after the night shift. Post night shift the sleep duration was less than 6 hours.

Epworth Sleepiness Scale Scores (ESS):

ESS score was used to measure a general level of daytime sleepiness at the beginning of the Post FRMS phase. ESS scores of up to 10 are considered to be within normal range. It was noted that in the Post FRMS phase 70% (n=19) of the participants had scores $\leq$ 10 while 30% (n=8) of participants had scores more than 10.

4.5 Comparison of Pre FRMS and Post FRMS results

Comparison of fatigue scores at the start of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=86 for pre FRMS and n=72 for post FRMS. The mean fatigue score of 3.45 at pre FRMS stage is reduced to a mean fatigue score of 2.93 at post FRMS stage; this translates to 15.07% reduction in fatigue scores. This difference is statistically significant ($p<0.05$).

Comparison of fatigue scores at the end of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=79 for pre FRMS and n=70 for post FRMS. The mean fatigue score of 4.83 at pre FRMS stage is reduced to a mean fatigue score of 4.2 at post FRMS stage; this translates to 13.04% reduction in fatigue scores. This difference is statistically significant ($p<0.05$).

Comparison of SA scores at the start of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=63 for both pre FRMS and post FRMS. The mean SA score of 22.68 at pre FRMS stage increased to a mean SA score of 23.74 at post FRMS stage; this translates to 4.67% improvement in SA scores. This difference was not statistically significant ($p<0.05$).

Comparison of SA scores at the end of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=63 for both pre FRMS and post FRMS. The mean SA score of 22.03 at pre FRMS stage increased to a mean SA score of 23.52 at post FRMS stage; this translates to 6.76% improvement in SA scores. This difference was not statistically significant ($p<0.05$).

Comparison of KSS scores at the start of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=86 for pre FRMS and n= 70 for post FRMS. The mean KSS score of 3.79 at pre FRMS phase decreased to a mean KSS score of 3.51 at post FRMS phase; this translates to 7.39% reduction in KSS scores. This difference was not statistically significant ($p<0.05$).

Comparison of KSS scores at the end of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=77 for pre FRMS and n= 69 for post-FRMS. The mean KSS score of 5.49 at pre FRMS phase decreased to a mean KSS score of 4.94 at post FRMS phase; this translates to 10.02% reduction in KSS scores. This difference was statistically significant (p<0.05).

Comparison of RT at the start of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=75 for Pre FRMS and n= 61 for post-FRMS. The mean RT of 344.86 at pre FRMS phase increased to a mean RT of 368.54 at post FRMS phase; this translates to 6.87% increase in RT. This difference was statistically significant (p<0.05).

Comparison of RT at the end of shift in the Pre FRMS and Post FRMS

All three shifts were included in this analysis. Observations were for n=79 for Pre FRMS and n= 61 for post-FRMS. The mean RT of 386.11 at end of pre FRMS phase increased to a mean RT of 395.70 at end of post FRMS phase; this translates to 2.48% increase in RT. This difference was not statistically significant (p<0.05).

Chapter 5 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, assess the fatigue risk using appropriate methods and measures.

FRMS was developed though an 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.

5.1 Phase 1 – Preliminary Studies

5.1.1. Study 1 - Analysis of Shift Work Patterns in SICU Nurses

SICU nurses who were rostered for rotating shift were scheduled for 40 hours work per week. The nurses working hours are guided by the overarching but generic Ministry of Manpower regulations on hours of work and rest days (Ministry of Manpower, 2013) as well as their employment terms based on collective agreement by the Union (Healthcare Services Employees Union, 2010).

The roster analysis shows that average working hours over a 7 day period is 43.5 hours. From a practical perspective in SICU, working hours are operationally aggregated over the 2 week period so that it does not exceed the 80 hours limit over 2 weeks. While this is an operationally sustainable Human Resources management approach to practical needs, the impact on fatigue and performance remains significant if there is a need for an individual to work long hours in a particular week, while not exceeding the 80 hours a fortnight limit. In summary, this approach helps mitigate cumulative fatigue risk but its effect on acute fatigue over any single week remains debatable. Further, the interpretation of 40 hours a week being equal to 80 hours a fortnight is an extrapolation that is not necessarily a recommended best practice.

From the AMA analysis of the individual rosters of SICU nurses, it was observed that the fatigue risk was in the low to significant range (Appendix VIII). The major contributors to the fatigue risk were noted to be number of night shifts in the 7 day period, duration of rest opportunity in between shifts, number of breaks during shifts, nature of shift rotation and unpredictable changes to roster. Recommendations based on above finding were to increase the frequency of breaks, limit the night shifts to two per week, provide adequate rest opportunity in between shifts, address the shift rotation and the afternoon followed by morning shift pattern and introduce some predictability in the roster schedules. These recommendations have been elaborated in Section 4.3.

Frequent short rests breaks help in prevention of fatigue. Nurses often sacrifice their rest break and meal break to provide patient care. Studies show that hospital staff nurses were completely free of their patient care responsibilities during their break for less than half of the shifts they worked (Rogers, 2008). In 10 % of the shifts, nurses reported having no opportunity to sit down for a break or meal period (Rogers, Hwang, & Scott, 2004). Providing short break during the shift improves performance and also helps mitigate fatigue (Rogers, 2008; Rosekind et al., 1994).

Recommendation was made to avoid scheduling nurses for more than 2 consecutive nights. Conventionally in SICU, night shifts are followed by a second night shift and or a rest day. However it was noted that this may not always be the case. Some nurses were scheduled for third and fourth consecutive night shift due to sudden operational requirement increasing the risk of fatigue. Night shifts can increase mental fatigue and confusion as well as decreased arousal and activity levels. This combined with sleep deprivation can lead to a greater risk of fatigue (Gander, 2003a).

It was noted that the SICU already had in place the "5 day on and 2 day off" pattern but on closer examination of the unit's roster during this analysis, it was noted that while the rostering principle was adopted, there was a variability in how it was actually put into practice. In some rosters there were up to 4 off days and in one extreme example, there was only one day off after 6 days on continuous work and the roster also had 2 night shifts. At least 24 hours of rest must be provided after 5 days of continuous work to keep the fatigue risk in the moderate range (Australian Medical Association Ltd, 2005)

Recovery periods between the shifts helps in recuperation from the sleep deprivation. Recommendation was made to consider a rest break or off day after "afternoon morning" shift pattern as this was shown to have inadequate rest opportunity in between shifts and it was a backward rotation pattern. The rest opportunity was below the recommended minimum level of 10 hours (Australian Medical Association Ltd, 2005).

It was recommended to minimise sudden changes in roster and to provide a notice period of at least 24 hours prior to roster change. In SICU rosters were planned based on staff preferences and availability, this made the task of rostering even more complex. Flexibility in rostering was preferred by the nurses and to some degrees also by the management to facilitate work life balance. However the flexibility in rostering also traded off predictability of rosters and impacted on the fatigue risk. In effects the rosters did not have any specific pattern in terms of nature of shift rotation or speed of rotation. This was difficult to resolve. However recommendations were made to avoid backward rotation patterns as far as practicable.

A large number of women in SICU are women. This is perhaps reflective of nursing as a profession where there are more women take up nursing as profession compared to men. In this context, there is some evidence of gender differences in level of fatigue and higher risk of fatigue in women arising from their dual role of contributing to work force while also being responsible for their family and domestic work (ILO, 2011) . ILO (2011) statistics show that in general shift work is greater in men than women worldwide across all sectors, however globally women still bear the main responsibilities for household and childcare irrespective of their engagement with the work sector.

The thesis used the AMA fatigue assessment tool, determining that its prediction about rosters is dependent on assumptions used to score the roster data. The AMA risk assessment tool is a simple method that can be used in an operational environment to assess fatigue risk of a work roster. It is inexpensive and does not require a large amount of training for everyday use. In comparison, there are commercially available fatigue prediction tools that are expensive and require significant training to adopt and use in routine operational environment. AMA fatigue assessment tool provides an optimal method of fatigue risk assessment for healthcare. Despite some limitations, it provides valuable insight into the work roster and has both diagnostic and predictive value in fatigue risk assessment.

Work rosters are the key documents that generate shiftwork patterns and poorly designed work rosters can lead to fatigue (Leape, 1994). A well designed work roster that can balance the operational demands as well as consider the rest and recovery of the staff helps in setting the scene for the strengthening the safety net in a safety critical system such as healthcare. Addressing the roster is fundamental to addressing the fatigue in an operational unit where there is a need to support 24/7 operations. If the nurses were to continue to have to perform rotating shift work , the recommendation for the rotating shift work have to be aligned to the best practices in rostering.

5.1.2 Other Recommendations and Interventions for FRMS

In addition to the work roster changes, the fatigue risk management program included recommendations and interventions for strategic napping, stimulants such as caffeine for alertness and fatigue education for SICU staff.

Strategic napping helps counter the effects of fatigue during night shift work, it improved alertness and reaction times in early morning periods (Rogers, 2008). In SICU nap break of 90 minutes duration was allowed by rotation for all the night shift staff (up to 15 staff members). The 90 minute duration was allocated to allow for a nap of up to 40 minutes and also accounts for other ancillary activities such as preparation for nap, time taken to fall asleep, allowing for overcoming sleep inertia when they wake up and freshening up before returning to duties.

The nap zone identified for the naps could allow only 3 individuals to nap in the operational unit at any one time. Hence, a nap roster was made to facilitate the nap while also maintaining continuity of care. The nap roster schedules naps for night shift staff by rotation. The nap roster influenced the timing allocated for nap for a certain individual. Nap time that did not coincide with the individuals sleep drive could cause the person to not have a nap or to lie down without being able to sleep despite the nap time and zone provisions. These are the practical problems in the implementation of the nap recommendations that were difficult to resolve for the SICU staff.

Sleep environment is extremely important in order to ensure high efficiency of a nap during rest period. In an operational environment it is essential to ensure good sleep quality for the shift worker during their scheduled nap periods. Scheduling of nap times and design of sleep zones are complementary interventions. This influences the sleep quality perceived by the individuals. The nap zone needs to offer privacy and comfort while decreasing noise, light etc. and other environmental factors that can cause sleep disturbances.

Nap zone was within the SICU staff area and it was possible to hear the sounds of the patient monitors. The SICU is designed for patient care and it was desirable design to hear the patient monitor alarms and beeps for emergency response. This was a distraction for some nurses and they could not take their planned nap despite the allocation of time and place. Alternatives such as earplugs or other noise countering methods were proposed to the nurses for consideration. Studies have shown that napping prior to night shifts, have improved alertness. This aspect was emphasized during the fatigue training for staff reporting for night shift and particularly for those who could not sleep at SICU.

Caffeine is a commonly used fatigue countermeasure and has been extensively studied as an intervention alone as well as in combination with other interventions such as naps, rest breaks and other stimulants (Rogers et al., 2004). In SICU, caffeine was available in the form of caffeinated beverages such as coffee and tea. Information about the appropriate use caffeine as a fatigue countermeasure was provided during the fatigue training. Once consumed, caffeine starts its action within 15–30 minutes and its effects last for up to 3–4 hours. Although tolerance to caffeine can develop, there are improvements in alertness and performance with one or two cups of coffee. SICU staff that did not prefer coffee were advised to follow recommendations that worked best for them.

During the Fatigue management training program, information was provided about sleep physiology, sleep hygiene measures, a variety of strategies for fatigue countermeasures were introduced and SICU staff were encouraged to adopt these recommendations and behavioural changes both during work as well as off duty hours. Fatigue cannot be compartmentalised to work and non-work environments. Both work and non-work related factors can contribute to fatigue. Self-management programmes for fatigue helps in individual being actively engaged to take part in reducing the fatigue risk and its impact on their health and safety. This was emphasized for SICU participants. The content for fatigue management training is provided in Appendix X.

5.1.3 Study 2 - Survey of the Work and Rest Patterns in SICU

The study has observed that, SICU staff comprises of mostly young women (< 40 years), with a large majority being staff nurses having a work experience of less than 5 years. While this study has not explored this aspect, there remains the possibility that nurses self-select out of the SICU work environment as they become more experienced. This could be partly due to the effect of cumulative fatigue and the impact of shift work on their work life balance. This could lead to the loss of experienced nurses in such a safety critical area and needs to be addressed by Human Resources Management team in conjunction with Workplace Safety and Health personnel.

The social profile of the SICU workforce indicates that majority (83%) lives within an hour's radius of the hospital. However the survey did not query about the social commitments of the individuals such as caring for dependents (young children and elderly). Thus it is difficult to comment of the overall non work time commitment of the individual.

General health status query shows that majority of the respondents did not have any medical declaration. Amongst those who declared at least one medical condition, migraine and headaches was the commonest problem. Smoking and alcohol consumption history indicate that both these are not very prevalent amongst the SICU staff. The common caffeinated beverages consumed were coffee and tea and majority consumed up to 2 cups of caffeinated beverages per day.

Summary of sleep patterns indicated that the average sleep duration during a working day is 6.15 hours and for a rest day is 7.4 hours. Sleeping longer on rest days is common and had been reported in other sleep surveys. Nurses in America reported obtaining an average of 84 minutes more sleep on non-work days than work days. They got 6.8 hours on workdays and 8.2 hours on non-work days (Rogers, 2008). The findings from the survey of SICU nurses show similar trends though slightly lower than their American colleagues.

The evidence based recommendations for sleep duration are that nurses need to obtain 7-8 hours sleep per night to protect both the health of their patients and their own health. The sleep duration of SICU nurses falls short of recommendations (Rogers, 2008).

This could at least partly explain why 17 % of respondents reported that they never or rarely get enough sleep and 25 % indicated that they never or rarely wake up feeling refreshed. Sleep quality assessed by a sleep quality rating (1 poor sleep quality and 7 being very good sleep quality) showed a mean score of 4.16.

55 % of the nurses responded that they have difficulty in staying awake during work and this was most likely to happen in the night shift (56 %) followed by the morning shift (33 %). Similar findings were reported in other studies.

31 % of the respondents had an ESS score of more than 10, which indicated excessive day time sleepiness. When this information is viewed in the context of the nature of work that the nurses perform and the minimal error tolerance of the healthcare system, the potential adverse impact on patient safety strikes as a possibility. Traditionally nurses work on their own in many aspects of the work that they do; an example could be the dispensing of medication to a patient. Since patient safety outcome is linked to an individual nurse's alertness and the process does not have a

built in redundancy, the possible slips and lapses that can occur in a nurse who is fighting sleep can lead to adverse outcome and medication dispensing errors.

Summary of the general work patterns based on the responses indicate that majority of the SICU staff surveyed work rotating shifts that include morning, afternoon and night shifts.

The responses to the SP Fatigue checklist score for night shifts showed that with each consecutive night shift the mean fatigue score increases. For the first night, the mean score was 3.1 (SP Score of 3 = okay), for the second night the mean score was 4.1 (SP score of 4= A little tired) and for the third night, the mean score was 5.5 (SP score of 5 = moderately tired). 72 % of the SICU staff responded that they work between 8 to 10 hours per shift in the past 7 days. And a vast majority of them had done a night shift duty during the 7 day period and the number of night shifts worked ranged from 1 to 4 days.

While the SICU work duration limits is 40 hours per week, about a quarter of those surveyed responded that they worked more than 40 hours per week at the time of the survey. Also 50 % reported that they worked longer than the duration that they were rostered. Working overtime has implications on the fatigue levels that the nurses experience as well as their ability to optimize their rest opportunity.

About slightly more than a quarter of respondents reported making an error which they think was likely due to fatigue in the course of their work.

A large majority of the SICU staff reported that had not had any prior education about shiftwork and personal strategies for management of fatigue at workplace and if provided an opportunity would like to learn more. Furthermore the comments of the respondents also provide valuable insight into the subjective perception about shift work duration, patterns and overtime.

Feedback on shift duration suggest that a 12 hour shift pattern gives the nurses more flexibility in planning their rest days including a better work life balance as well as optimal utilization of time on work day. However based on the evidence in the literature – it is observed that a 12 hour shift duration nearly triples the risk of fatigue related accidents and incidents (Gander, 2003a; Rogers, 2008). While 12 hours shift gives a compressed work week it also significantly increases the fatigue risk during the work periods and is not the recommended pattern in view of patient safety.

Afternoon shift followed by morning shift is noted to be a tiring pattern according to the feedback as the rest opportunity is less than 10 hours, this is known as a risk factor as per AMA code (Australian Medical Association Ltd, 2005). Furthermore, the rotation patterns of the shift are noted to impact the duration and quality of sleep. Afternoon shift followed by morning shift is a backward rotation pattern.

Some of the survey comments suggest that based on the workload in the unit, in certain shifts there is a high likelihood of working beyond the scheduled rostered hours and that has an impact on the fatigue risk. Experienced nurses are more likely to work overtime or longer than their rostered hours.

Some nurses have reported in the survey that they are unable to take a break or go for meals breaks during their shifts due to the work commitments.

Respondents have reported in the survey about instances of medication error during night shift as well as slow reaction times – both of these factors have an impact on patient safety. Similar findings about medication errors were reported in other studies involving nurses and risk of making an error was significantly associated with the sleep in prior 24 hours (Rogers, 2008).

There are comments that fatigue causes irritability and this has an impact on dealing with difficult patients and their next of kin (patient's relatives). Sleep deprivation is associated with mood changes and has been reported to occur in healthy individuals of all ages (Pilcher & Huffcutt, 1996).

While the roster analysis provides the input about roster factors, the survey provided information about the existing work and rest patterns and helped to identify the prevalent shift patterns and some information about the work and sleep patterns in the SICU environment. The information from the survey complements the roster analysis and helps to identify problem areas where possible improvements could be made from the subjective perspective.

5.1.4 Study 3– Identification of Task for SA Analysis

"Medication administration" was identified as a safety critical task and medication errors had implications in terms of patient safety. The task of administering medication is routine in the nurses daily work, however it is also prone to errors. It is estimated that a nurse can administer up to 50 medications during her work shift (Mayo & Duncan, 2003). Fontan, Maneglier, Nguyen, Loirat, and Brion (2003) have reported in their study that medication errors can be as high as 1.9 per patient per day in a hospital. Between 10 -18 % of hospital injuries are related to medication errors in the US (Hume, 1999).

5.2 Pre and Post FRMS Comparison and Discussion

5.2.1 Fatigue Scores

Table 19 shows the Pre FRMS and Post FRMS Fatigue scores and trends.

Table 19 Mean fatigue scores trends in Pre FRMS and Post FRMS phase

Pre FRMS Fatigue	Morning	Afternoon	Night	Overall
Start	3.77	3.17	3.23	3.45
End	4.82	4.81	5.34	4.83
Trend (Start vs. End)	↑	↑	↑	↑
Statistical significance	Yes			

Post FRMS Fatigue	Morning	Afternoon	Night	Overall
Start	3.30	2.6	2.85	2.93
End	3.96	3.56	5.19	4.2
Trend (Start vs. End)	↑	↑	↑	↑
Statistical significance	Yes	Yes		Yes

Fatigue	Start of shift	End of shift
Pre FRMS	3.45	4.83
Post FRMS	2.93	4.2
Trend (Pre vs. Post)	↓	↓
Statistical significance	Yes	Yes

Pre 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. The mean fatigue scores at the end of the shift were higher compared to the start of shift for all shifts. However, the differences in scores were not significant except for the morning shift.

The highest mean fatigue score for start of shift was noted for morning shift (3.77) and for end of shift it was noted for night shift (5.34). The highest mean fatigue score at the start of the morning shift could be related to the early wake up required to be able to report for work at 7 a.m. in the morning. Similarly the highest mean fatigue scores seen at the end of shift for night shift could be explained by building sleep pressure in an individual staying awake and working all night when the body naturally prefers to be asleep.

A threshold of above 5 for SP fatigue score is operationally significant and fatigue countermeasures need to be considered (International Civil Aviation Organisation, 2012). This threshold is reached only for the end of night shift. The greatest fatigue risk based on SP score was therefore noted to be at end of night shift and this period was identified as period requiring intervention during the FRMS. Between shifts variation of mean fatigue scores showed statistically significant difference only for the end of morning (4.82) versus end of night shift (5.34).

The 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. In general, the mean fatigue scores at the end of the shift were higher compared to the start of the shift for all shifts.

The differences in mean fatigue scores were noted to be significant for all the shifts except the night shift. Between shifts variation showed statistically significant difference between end of afternoon versus end of night shift as well as end of morning versus end of 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 show that there is a reduction in the mean fatigue scores both at the start and end of shift and the difference was statistically significant.

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.

5.2.2 Situation Awareness (SA) Scores

Pre 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 20. 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. Between shifts, mean SA scores also did not show any statistically significant difference.

Table 20 Mean SA score trends in Pre FRMS and Post FRMS phase

Pre FRMS SA	Morning	Afternoon	Night	Overall
Start	23.38	21.38	23.28	22.68
End	22.61	21.38	22.14	22.03
Trend (Start vs. End)	↓	↔	↓	↓
Statistical significance				

Post FRMS SA	Morning	Afternoon	Night	Overall
Start	23.86	23.38	24	23.74
End	22.68	23.38	24.6	23.52
Trend (Start vs. End)	↓	↔	↑	↓
Statistical significance				

SA	Start of shift	End of shift
Pre FRMS	22.68	22.03
Post FRMS	23.74	23.52
Trend (Pre vs. Post)	↑	↑
Statistical significance		

Post FRMS mean SA scores were also compared between morning, afternoon and night shifts as well as at the start and end of each type of shift. 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. Between shifts, mean SA scores also did not show any statistically significant difference. 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.

Based on these observations, it can be concluded that SA 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.

5.2.3 Sleepiness Scores

Pre 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 21. The mean KSS scores at the end of the shift were greater compared to the start of shift for all three shifts. The differences in mean KSS scores were statistically significant for morning and afternoon shift. Between shifts, mean KSS scores showed significant differences between start of morning and afternoon shifts, start of morning and night shift, end of morning and night shift and end of afternoon and night shift.

Table 21 Mean KSS score trends in Pre FRMS and Post FRMS phase

Pre FRMS KSS	Morning	Afternoon	Night	Overall
Start	4.43	3.46	3.42	3.79
End	5.25	5.07	6.26	5.49
Trend (Start vs. End)	↑	↑	↑	↑
Statistical significance	Yes	Yes		

Post FRMS KSS	Morning	Afternoon	Night	Overall
Start	4.22	3.13	3	3.51
End	4.72	3.85	6.23	4.94
Trend (Start vs. End)	↑	↑	↑	↑
Statistical significance				

KSS	Start of shift	End of shift
Pre FRMS	3.79	5.49
Post FRMS	3.51	4.94
Trend (Pre vs. Post)	↓	↓
Statistical significance		Yes

Similarly Post FRMS mean KSS scores were compared. The mean KSS scores at the end of shift were greater compared to the start of the shift for all three shifts. The differences in mean KSS scores were not statistically significant in any of the shifts. Between shifts, mean KSS scores showed statistically significant difference between both the start and end of morning and afternoon shift as well as start and end of morning and night shift. It is noted from these observations that mean KSS 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. 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.

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.

As is noted, fatigue scores and sleepiness scores show 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.

5.2.4 Response Time (RT) on Vigilance Task

Pre 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 22. 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. Between shifts mean RT did not show any statistically significant difference during the Pre FRMS phase.

Table 22 Mean RT trends in Pre FRMS and Post FRMS phase

Pre FRMS RT	Morning	Afternoon	Night	Overall
Start	360.58	338.07	336.73	344.86
End	387.75	373.14	399.26	386.11
Trend (Start vs. End)	↑	↑	↑	↑
Statistical significance		Yes	Yes	Yes

Post FRMS RT	Morning	Afternoon	Night	Overall
Start	375.65	356.47	374.1	368.54
End	382.86	388.73	418.21	395.70
Trend (Start vs. End)	↑	↑	↑	↑
Statistical significance		Yes		Yes

RT	Start of shift	End of shift
Pre FRMS	344.86	386.11
Post FRMS	368.54	395.70
Trend (Pre vs. Post)	↑	↑
Statistical significance	Yes	

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. The mean RT at the end of shift were greater compared to the start of shift for all three shifts. However the differences in mean RT were statistically significant for afternoon shift only. Between shifts mean RT did not show any statistically significant difference during the Post FRMS phase. Overall, mean response time on vigilance task was increased in Post FRMS phase as compared to Pre FRMS phase. It was also noted that the difference in the mean RT for the overall start of shift was statistically significant as shown in Table 22.

This observation of increased mean RT 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.

5.2.5 Sleep Duration

Sleep duration was assessed as an exploratory objective. Overall mean sleep duration was varied between the morning, afternoon and night shift days in both the Pre FRMS and Post FRMS phase. Mean duration of sleep after the night shift is recorded to be the least as compared to the morning and afternoon shift during the Pre FRMS phase as shown Table 23. This is an expected observation and could be related to the limitations associated with sleeping in the day time hours and due to the disruptions in the circadian sleep wake cycle. Sleep after night shift in day hours is shorter and fragmented.

Table 23 Mean sleep duration in Pre FRMS and Post FRMS phase

Pre FRMS Mean Sleep Duration	Morning	Afternoon	Night
Subjective (Sleep Log)	8h	7h 44m	5h 43m
Objective (Actiwatch)	9h 1m	8h 18m	5h 54m

Post FRMS Mean Sleep Duration	Morning	Afternoon	Night
Subjective (Sleep Log)	8h 5m	7h 21m	5h 43m
Objective (Actiwatch)	9h 1min	8h 30m	5h 48m

In the Pre FRMS phase, objective sleep duration was noted to be more than subjective sleep duration by approximately 1 hour for morning shift, approximately 30 minutes for afternoon shift and approximately 10 minutes for night shift. However, no significant differences were noted between the reported mean sleep duration and the sleep duration measured by the actiwatch for all the shifts.

For the Post FRMS phase, the findings were very similar to that of Pre FRMS phase. Though objective sleep duration was noted to be more than subjective sleep, no statistically significant differences were found between the reported mean sleep duration and the mean sleep duration measured by the actiwatch for all shifts. Objective sleep duration was noted to be more than subjective sleep duration by approximately 1 hour for morning shift, approximately 1 hour 10 minutes for afternoon shift and approximately 5 minutes for night shift.

Prior studies have shown that objective measurements may actually be lower than those typically reported subjectively. Rogers (2008) reported that in a study of middle aged residents of San Diego, mean objective sleep duration obtained from wrist actigraphy was approximately 6.22 hours and subjective sleep duration was approximately 7 hours. Similar results are reported in studies done in airline pilots (Gander, 2003a).

The reported mean sleep duration was noted to be consistently lower than the actigraphy sleep duration in SICU nurses. The reason for the difference could be related to how the nurses maintained their sleep log. While they were encouraged to fill in the diaries after every sleep period to minimise recall bias, it was noted that some nurses completed their sleep logs at irregular intervals. This might have contributed to the recording sleep duration based on memory, introducing recall bias. The other contributory factor could be that actigraphy records inactivity rather than sleep. Nurses could be lying on bed to sleep without movement in preparation for sleeping and this duration is captured by actigraphy as objective sleep duration. The time to fall asleep was not assessed in this analysis.

The results on the comparison of sleep duration shows that sleep duration after night shift is less than 6 hours, which is approximately 2 hours less than sleep duration obtained during morning shift. This finding is consistent with findings from other studies which show that night shift workers obtain 1-4 hours less sleep than normal when they were working at night (Rogers, 2008).

Comparison of the subjective and objective data across all shifts shows that sleep duration did not change significantly in the Post FRMS as compared to the Pre FRMS phase. The sleep quality of these sleep periods could not be assessed objectively. This brings attention to the fact that many work related and non-work related factors influence sleep duration. Work roster modification and fatigue management training were the organizational FRMS interventions to provide sleep opportunity for SICU nurses and to enable them to self- manage fatigue in the Post FRMS phase. It could not be assessed whether the sleep opportunity was utilized optimally by the nurses during the FRMS and Post FRMS phase.

While it may be expected that roster planning and fatigue management education could contribute to the improvements in sleep duration, it is important to recognize that it was dependant on the individual to adopt the FRMS interventions to mitigate fatigue. Individual sleep habits and individual non work factors play an important role in the amount of sleep that the individual actually obtains.

Subjective data from sleep log has potential for use for quick fatigue scan in a workplace environment. Sleep duration could be used as a simple fatigue check and fatigue monitoring tool at workplace for groups of individuals such as in SICU. For example, if individuals report having obtained less than 5 hours of sleep or disturbed sleep at the start of shift, fatigue risk management plan could be activated to reduce the risk. Similar findings are reported in field studies in aviation (Signal et al., 2005).

Naps were taken by nurses especially before the night shift at home as well as during the night shift at work in the staff room. The naps were reported in the sleep log that was issued to the nurses. The naps and nap duration at night shift could not be recorded objectively by the actigraphy as nurses were not wearing actiwatch during the duty period. As seen in the Figure 38, 52 % took naps at work in Pre FRMS phase and that increased to 61 % at the Post FRMS phase. The Pre FRMS mean nap duration were 79 minutes (work) and 102.5 minutes (home) and the Post FRMS mean nap duration were 82.2 minutes (work) and 102.8 minutes (home). While frequency of naps has increased slightly, nap durations have remained similar in the Pre FRMS and Post FRMS phase.

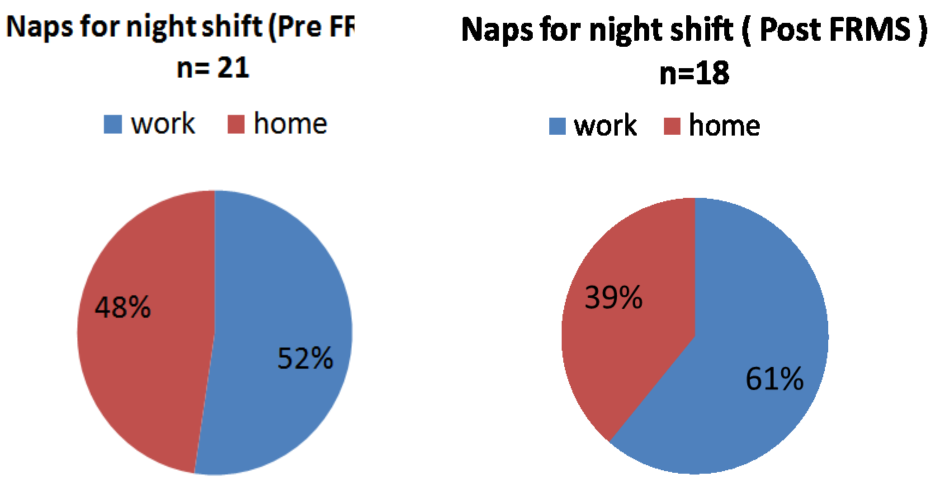


Figure 38 Nap duration in the Pre FRMS and Post FRMS phase

This research has explored some dimensions of shift work primarily from a work perspective, it has not focussed on the non-work contributors of fatigue. Leisure habits such as watching late night television and social commitments and activities often take up the time made available for sleeping. Providing adequate sleep opportunity through changes to work roster and providing nap opportunity are useful practices but do not guarantee optimisation of rest time for sleeping. This observation is important for fatigue risk management from an operational perspective.

A successful FRMS would require commitment from the nurses to own and share responsibility to mitigate fatigue risk for their own health and safety and for patient safety. This aspect was facilitated through the self-management of fatigue risk by providing FRMS training to all the participants. This training included creating an awareness of the significance of fatigue and fatigue management modalities to create buy-in and provide tools that could be used by the nurses.

Chapter 6 Conclusions

6.1 Contributions

The purpose of this study was to investigate the relationship between fatigue due to shift work and SA during the performance of nursing work and the effects of FRMS on fatigue and SA in the SICU. The healthcare sector was chosen for this study in view of this sector being involved in 24/7 operations where fatigue leading to human error in safety critical tasks is known to impact both patient safety and workplace safety and health of healthcare workers (Barger et al., 2006; Gander et al., 2007; Harrington, 2001; Rogers, 2008). Nurses are known to be involved in shift work for the entire career and were identified as personnel who would benefit most from a Fatigue Risk Management System. SICU nurses were chosen for this research due to the safety critical nature of the tasks in the intensive care. Further, the profile of the participants also considered the guidance provided by the Health and Safety team at the hospital.

The study investigated the extent to which fatigue was related to work rest patterns both by subjective methods as well as objective methods; multiple measures of fatigue measurement and assessment tools were used in SICU setting for nurses as described in Sections 2.4, 3.2 and 3.3. Previous studies were primarily cross sectional and/or looked at only certain dimensions of shift work in nursing environment (Gander et al., 2010; Gander et al., 2000; Rogers et al., 2004).

This study analysed the work roster of nurses to identify aspects of the roster that can be modified to reduce fatigue risk and help in recommendation for FRMS interventions. 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.

This thesis supports previous findings that rotating shift work in nurses contributes to fatigue. References. The study shows the reduction in measures of fatigue (fatigue scores and sleepiness scores) and improvements in SA scores after the FRMS interventions.

The study shows an association between fatigue and situation awareness of nurses performing nursing tasks. It was observed that when fatigue increased, SA decreased. After the implementation of the fatigue risk management interventions and recommendations, there was evidence of reduction in fatigue and increase in SA.

It is noted that the participants managed shift work better with less perceived fatigue and sleepiness and enhanced 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.

28 nurses completed the entire study out of the 36 who started off having fulfilled the inclusion and exclusion criteria set out at the start of the Phase 2 Pre FRMS phase, this represented almost 80% of the nurses who participated in the Pre FRMS phase. Given that this study had a rigorous methodology that required each nurse to complete 28 sets of observations spread out over a period of time to be able to complete the participation in the entire study, the completion rate of 80% reflected a commendable and enthusiastic participation of the nurses in the study process, largely driven by their appreciation of the operational significance of the study that was being undertaken.

FRMS, by its very definition, relies on scientific evidence as applied to the data that emerges in a particular sector. While the overarching principles of FRMS are the same and can be applied for any workplace, the finer details are likely to differ depending on the specifics of fatigue in that workplace.

The key theoretical contribution of this study is the Healthcare FRMS model that was developed and tested in this thesis. Healthcare FRMS model has four main phases for fatigue recognition, fatigue assessment, fatigue mitigation and fatigue monitoring. The four stages of Healthcare FRMS model are translated and tested in the equivalent four phases (Preliminary Phase, Pre FRMS phase, FRMS phase and Post FRMS phase) of this research and the impact of Healthcare FRMS has been demonstrated to be operationally and statistically significant.

The FRMS operational model for healthcare can be adopted to other work sectors such as construction, manufacturing, marine sector etc. The conceptual framework of

Healthcare FRMS model (Recognise, Assess, Mitigate and Monitor) will enable a structured approach to risk assessment and subsequent fatigue mitigation. However since each sector would have a different fatigue exposure based on the nature of the shift work – the fatigue risk profile and hence the method of fatigue monitoring and fatigue mitigation may vary between sectors.

The customisation of FRMS for SICU nurses is the operational contribution of this work. In this research the specific assessment tools used for fatigue recognition, assessment and monitoring in healthcare sector were reviewed and selected based on their validity and applicability in operational field environment. While these tools have been studied independently, their integrated application in a comprehensive framework for the healthcare sector has not been carried out previously.

The Healthcare FRMS model in this research and the identified tools could be used for other healthcare professionals such as doctors, emergency department workers and ambulance paramedical staff.

In many operational safety critical industries such as aviation, maritime, rail, trucking and military– fatigue management programs have been developed to reduce errors and improve performance. However limited information is published about the effectiveness and relevance of these programs. This thesis also describes the efficacy of the FRMS as a whole without attempting to analyse the various individual components.

The translational value of the FRMS model developed and tested in this research is currently being applied to other sectors of work in Singapore and New Zealand where shift work is carried out in a safety critical environment.

6.2 Limitations

This research is based on findings from actual operational environment. The key limitations of this research were:

Limited duration of observation: This study relied on data that was collected over two short periods of time (8 – 10 weeks). The Pre FRMS and Post FRMS data was each collected over 6 - 8 weeks such that each rotating shift worker in this study had the rotation cover all the shift schedules that they are required to work through. The data collection was limited by the number of actiwatches that were available for the participants at any one time. At any one time, between five to seven participants were recruited into the study. Though the outcomes were compared for each worker working each shift type, it is recognized that these were cross-sectional snapshots rather than long term prospective cohorts that were observed over longer timeframes. While the latter may be ideal, it does involve considerable costs as well as inconvenience to the workers involved in safety critical tasks in healthcare and patient management.

Situation Awareness assessment using subjective methods: This research study could be further enhanced if objective techniques such as SAGAT was used to assess situation awareness. Objective SA data could further augment the objective fatigue data that this study has explored. During the preliminary studies, the use of objective probes was explored. In view of the potential risk to patient safety and privacy concerns in the intensive care unit, objective testing of SA was not used.

Lack of objective strategic nap data: The study participants took strategic naps to counter fatigue. This was captured in the sleep log.

However, this information was not validated from the objective sleep data from the actiwatch because the nurses were not able to wear the actiwatch during their working hours due to safety reasons given that they were dealing with patients in an intensive care setting. Objective data on the nap timings and duration could have further enhanced and validated these findings.

Lack of baseline data: There was no baseline data on fatigue, sleepiness, SA and RT from the participants under optimal sleeping conditions. The Pre FRMS period was used as a baseline from an operational point of view for a unit without an FRMS. The study has been conducted in a field setting where operational constraints made it impossible to control for various external influences and interactions other than the designed FRMS interventions; these were present in both the Pre FRMS phase and Post FRMS phase. Hence a study of this nature can only demonstrate an association between fatigue and SA rather than establish a causal relationship.

Effectiveness of individual FRMS interventions: FRMS interventions included various components. It was not possible to assess which of the interventions was most effective. The interactions of the various interventions could not be isolated and studied within the scope of this research. However, subjective feedback about the effectiveness and relevance of individual components does provide some insight about the effectiveness of FRMS interventions.

Lack of local legislative benchmarks specific to health care sector: Healthcare workers including nurses often work unusual shift patterns and working durations. While this study has been able to explore the working patterns, there were no local benchmarks to compare the data. Hence, where possible, benchmarks for this sector were chosen from the international scientific literature as well as international best practices from allied fields. However, given that every country is different and has different operational considerations, direct application of guidelines and benchmarks may not necessarily be the best approach. However, given that there was no local legislation for this sector, this study has used international guidelines that were available in the Asia- Pacific region for comparison.

6.3 Recommendations for Future Work

Enhanced duration of observation: The construct validity of the results can be further enhanced if there is opportunity to establish a cohort study over a longer period of time to obtain the information over multiple data points for each shift types for each worker.

Situation Awareness assessment using objective methods: A similar research could be further augmented by inserting objective probes to assess situation awareness, especially when the nurse is doing a nursing task. However, such a study will have to be in a less safety critical hospital setting if this must be a field study. Alternatively, the study may have to be considered in a simulated medical environment.

Incorporation of objective strategic nap data: Future studies could consider looking at obtaining objective napping data using actiwatch but acknowledges that this will have to be in a simulated setting or in a field setting that has less patient safety risk.

Baseline data: Future studies may also consider having a baseline study in ideal sleeping conditions for comparison of fatigue and SA to assess the relationship between fatigue and SA more effectively.

Studying the effectiveness of each FRMS intervention: Future studies should account for and consider the effectiveness of each intervention that was implemented for both short term as well as long term monitoring by using appropriate outcomes. Precise control of other variables for study of fatigue is possible only in controlled experiment setting such as in sleep lab and may not be possible in operational environment. But it is also important to recognise that although a controlled lab setting is ideal to help isolate cause effect relationship, the operational setting is valuable because it allows us to obtain additional interactions and environmental factors that may not have been foreseen otherwise. Both settings should be considered for future study.

Comparison with local legislative benchmarks specific to sector when available: Outcome from this study or other similar studies in the future should compare the findings against local benchmarks for the healthcare industry in that country when such benchmarks, guidelines and legislations are made available.

Papers and Reports

Conference Papers

Dara, S., Park, T., Tan, J., Whai, T.W., Helander, M. Analysis of work patterns and fatigue risk associated with rotating shift work in Surgical Intensive Care Unit (SICU) Nurses. Occupational Health and Safety Industry Group (OHSIG 2014), 10- 12 September 2014, Auckland, New Zealand.

Dara, S. Impact of Fatigue on Situation Awareness of Healthcare workers. Occupational Health Peer Review Group/ Australasian Faculty of Occupational and Environmental Medicine (AFOEM) Meeting, 14 June 2014, Mana, New Zealand.

Dara, S. Impact of shift work on Public Health. Academic Seminar: Centre for Public Health Research, Massey University, 22-23 May 2013, Wellington, New Zealand.

Dara, S. Fatigue Measurement and Evaluation at the Workplace. Conference workshop on Fatigue Risk Management System. 6th Singapore Public Health and Occupational Medicine Conference 2011, 24- 26th August 2011, Singapore.

Other related research and academic reports

Dara, S., Ghosh, R., Peng, C.M., Park, T. Impact of fatigue on situation awareness of workers in the marine and logistics and transport sectors and to develop a Fatigue Risk Management System for the two sectors. Grant proposal submitted to Workplace Safety and Health Institute (WSHI) in 2011. The proposal was similar to the PhD research on healthcare workers. WSHI grant was awarded to ST Medical Services Pte Ltd in 2012 for commencement of this work.

Dara, S. (2013) Circadian System: An Overview. Academic Report, Massey University.

Dara, S. (2013) Case Report: Junior Doctors Working hours – Analysis using systems approach. Academic Report, Massey University.

Dara, S. (2013) Work patterns in Surgical Intensive Care Unit (SICU) Nurses. Academic Report, Massey University.

Dara, S. (2013) Impact of Shift work on Public Health. Academic Report, Massey University.

Journal Papers

Dara, S., Tan, J., Park, T., Whai, T.W. (submitted to Singapore Nursing Journal in June 2014) Fatigue risk in nurses performing rotating shift work in an intensive care unit in Singapore: Survey Findings

Dara, S., Tan, J., Park, T., Whai, T.W. (submitted to Singapore Nursing Journal in July 2014) Fatigue risk in nurses performing rotating shift work in an intensive care unit in Singapore: Analysis of Work Rosters

Paper in progress: An operational model for Fatigue Risk Management System: Impact on fatigue and situation awareness in healthcare workers.
Targeted Journals: Applied Ergonomics, Human Factors, Journal of Advanced Nursing, Occupational and Environmental Medicine

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Appendix I Sleep Log and Duty Log, KSS, SP Fatigue Checklist

Fatigue Study CIRB 2011/549/A

Please fill up duty diary

Duty Log

Please circle where appropriate and fill in the information as completely as possible for each day of your duty period

S/No.	Question	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	Type of shift	Day / Night / DO	Day / Night / DO	Day / Night / DO	Day /Night/ DO	Day /Night / DO	Day /Night / DO	Day /Night / DO
2a	Shift start	____:____	____:____	____:____	____:____	____:____	____:____	____:____
2b	Fatigue Checklist	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
2c	Sleepiness Scale	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
3a	How many hours did you sleep in last 24 hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs
3b	How many hours did you sleep in last 48 hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs
3c	How long have you been awake since you woke up today ?	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs
3d	Fatigue Score							
4a	Shift End	____:____	____:____	____:____	____:____	____:____	____:____	____:____
4b	Fatigue Checklist	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
4c	Sleepiness Scale	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
5a	How many hours did you sleep in last 24 hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs
5b	How many hours did you sleep in last 48 hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs
5c	How long have you been awake since you woke up today ?	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs	_____ hrs
5d	Fatigue Score							
6	Workload in the shift	Low/Moderate /High	Low/Moderate /High	Low/Moderate /High	Low/Moderate /High	Low/Moderate /High	Low/Moderate /High	Low/Moderate /High

Fatigue Checklist

1. Fully alert 2. Very lively 3. Okay 4. A little tired 5. Moderately tired 6. Extremely tired 7. Completely exhausted

Sleepiness Scale

1. Extremely alert 2. Very Alert 3. Alert 4. Somewhat alert 5. Neither alert nor sleepy 6. Slightly sleepy 7. Sleepy but not strenuous to stay awake 8. Sleepy somewhat, strenuous to stay awake 9. Very sleepy, great effort to stay awake, fighting sleep

Fatigue Study CIRB 2011/549/A

Sleep Log

Please circle where appropriate and fill in the information as completely as possible for each day

S/No.	Question	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1a	Did you remove the actiwatch for more than 1 hour?	Yes /No If yes, answer 1b	Yes /No If yes, answer 1b	Yes /No If yes, answer 1b	Yes /No If yes, answer 1b	Yes /No If yes, answer 1b	Yes /No If yes, answer 1b	Yes /No If yes, answer 1b
1b	How long did you remove the actiwatch in 24 hour period ?	____ hrs	____ hrs	____ hrs	____ hrs	____ hrs	____ hrs	____ hrs
2a	Naps	Yes /No If yes, answer 2b, 2c	Yes /No If yes, answer 2b, 2c	Yes /No If yes, answer 2b , 2c	Yes /No If yes, answer 2b, 2c	Yes /No If yes, answer 2b, 2c	Yes /No If yes, answer 2b, 2c	Yes /No If yes, answer 2b, 2c
2b	Nap Duration	___ mins	___ mins	___ mins	____ mins	____ mins	____ mins	____ mins
2c	Nap location	Home / Work	Home / Work	Home / Work	Home / Work	Home / Work	Home / Work	Home / Work
3a	Time got into bed to sleep for the day?	____:____	____:____	____:____	____:____	____:____	____:____	____:____
3b	Fatigue Checklist	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
3c	Sleepiness Scale	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
4a	Time woke up from sleep?	____:____	____:____	____:____	____:____	____:____	____:____	____:____
4b	Fatigue Checklist	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
4c	Sleepiness Scale	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
5	Sleep Quality	Poor / Good / Excellent	Poor / Good / Excellent	Poor / Good / Excellent	Poor / Good / Excellent	Poor / Good / Excellent	Poor / Good / Excellent	Poor / Good / Excellent
6	Additional remarks							

Please fill up duty diary

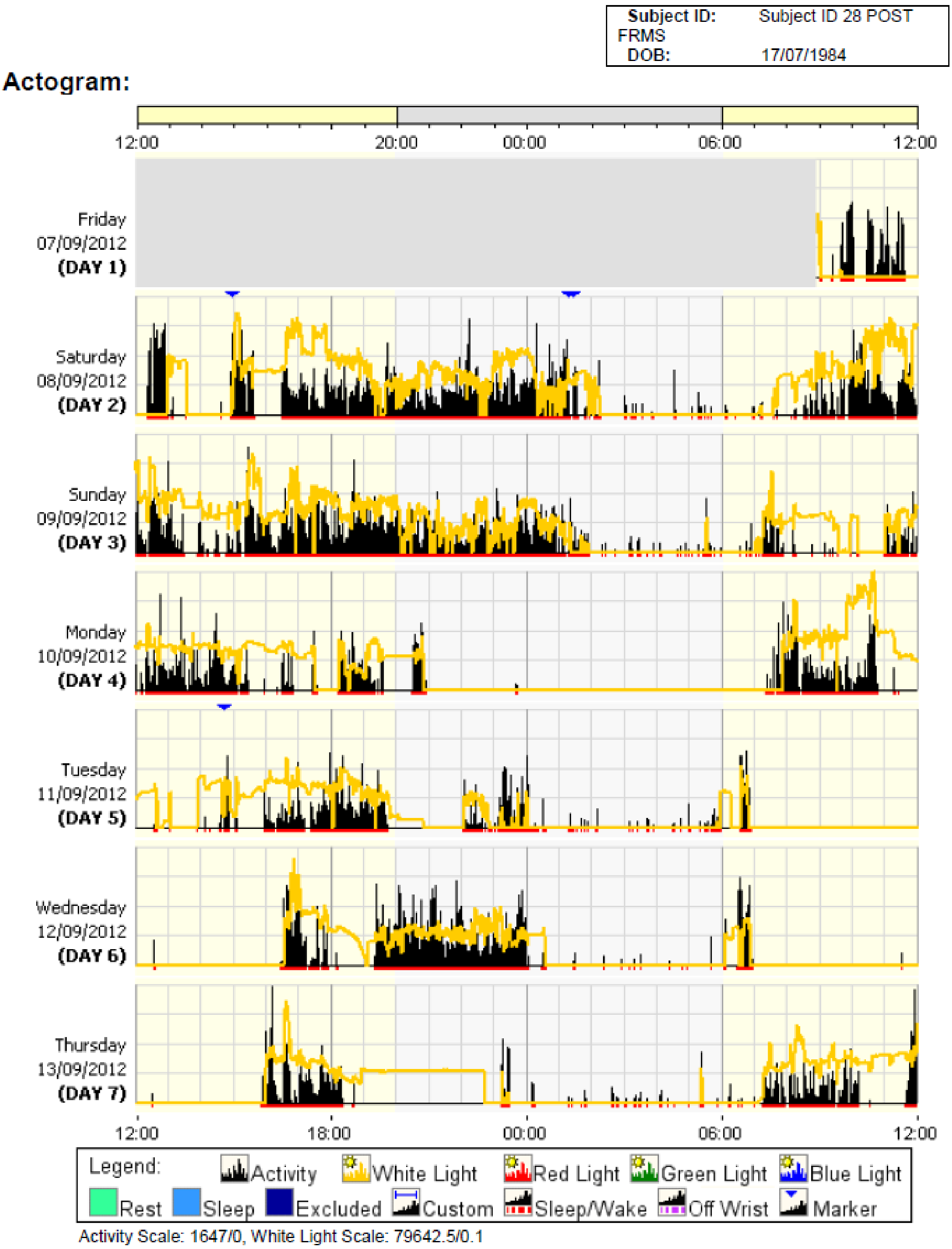
Fatigue Checklist

1. Fully alert 2. Very lively 3. Okay 4. A little tired 5. Moderately tired 6. Extremely tired 7. Completely exhausted

Sleepiness Scale

1. Extremely alert 2. Very Alert 3. Alert 4. Somewhat alert 5. Neither alert nor sleepy 6. Slightly sleepy 7. Sleepy but not strenuous to stay awake 8. Sleepy somewhat, strenuous to stay awake 9. Very sleepy, great effort to stay awake, fighting sleep

Appendix II Actogram



Appendix III Epworth Sleepiness Scale

Participant I/D: ____ Date: __________________

Age (Years): ________________ Sex (Male = M, Female = F): ________

How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life recently. Even if you haven't done some of these things recently, try to figure out how they would have affected you.
Use the following scale to choose the **most appropriate number** for each situation:

0 = no **chance** of dozing

1 = slight **chance** of dozing

2 = moderate **chance** of dozing

3 = high **chance** of dozing

It is important that you answer each item as best as you can.

Situation	**Chance of Dozing (0-3)**
Sitting and reading	________
Watching TV	________
Sitting inactive in a public place (e.g., a theatre or a meeting)	________
As a passenger in a car for an hour without a break	________
Lying down to rest in the afternoon when circumstances permit	________
Sitting and talking to someone	________
Sitting quietly after a lunch without alcohol	________
In a car, stopped for a few minutes in traffic	________

THANK YOU FOR YOUR COOPERATION

Appendix IV SART

SART	DAY 1	
Questions:	Start of Shift time:	End of Shift time:
How changeable is the medication order for this patient? Is the medication order by the doctor likely to change suddenly (High)? Or is it not likely to change (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
How complicated is the preparation of medication? Do you have to calculate dosage of medicine (High) based on the doctor's order? Or is the preparation simple and straightforward (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
How variable is the method of administering this medication? Are there a large number of factors varying (High) such as new route of administration or are there few variables changing (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Are you alert and ready for administering the medication (High) or do you have a low degree of alertness (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Do you have to concentrate a lot to prepare the medicine for (High) or does the medicine preparation require low levels of attention (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Do you have to do many tasks while preparing and administering medication (High) or are you focused on only one medication (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Do you have spare mental capacity to attend to the different aspects of preparing medication (High) or you do not have any spare capacity (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Do you have to do a lot of steps to prepare and administer medication (High) or very little steps to prepare medication (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Is the knowledge regarding patient's medication preparation and administration very routine (High) or is it a new situation (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
Do you have a great deal of experience in preparation of medication (High) or a new method is required in preparation of medication (Low)?	1 2 3 4 5 6 7 Low High	1 2 3 4 5 6 7 Low High
For researcher's scoring only	Score:	Score:

Appendix V FRMS Training Feedback Form

SLEEP PHYSIOLOGY ANF FATIGUE MANAGEMENT WORKSHOP

FEEDBACK FORM

Date:

Name:

Please rate your knowledge on the subject before and after the workshop.

Before: 1 2 3 4 5 6 7

After: 1 2 3 4 5 6 7

1= Very little knowledge

7=Excellent knowledge

Appendix VI Post FRMS Feedback Form

Subject ID: Date:

We hope you have noted various Fatigue Risk Management efforts at your workplace. In this short survey please tell us your personal opinion on the effectiveness and relevance of five of the interventions that have been done to better manage fatigue risk.

For each of the questions, the scale is 1 to 7, where:

1 = Not effective / Not relevant

7 = Very effectiveness/ Very relevant

Please circle the number that you feel is most accurate.

Intervention 1: Provision of CAFFEINE as a fatigue countermeasure through the procurement of coffee machine at your workplace.

Effectiveness: Not Effective 1 2 3 4 5 6 7 Very Effective

Relevance: Not Relevant 1 2 3 4 5 6 7 Very Relevant

Intervention 2: Re-arrangement of roster to substitute high fatigue score shift patterns with lower fatigue score shift patterns.

Effectiveness: Not Effective 1 2 3 4 5 6 7 Very Effective

Relevance: Not Relevant 1 2 3 4 5 6 7 Very Relevant

Intervention 3: Provision of nap time for night shift and provision of place to sleep.

Effectiveness: Not Effective 1 2 3 4 5 6 7 Very Effective

Relevance: Not Relevant 1 2 3 4 5 6 7 Very Relevant

Intervention 4: Education in fatigue recognition and strategies for managing fatigue.

Effectiveness: Not Effective 1 2 3 4 5 6 7 Very Effective

Relevance: Not Relevant 1 2 3 4 5 6 7 Very Relevant

Intervention 5: Assisting management in fatigue risk management and giving them tools to better plan shift rosters to reduce fatigue risk.

Effectiveness: Not Effective 1 2 3 4 5 6 7 Very Effective

Relevance: Not Relevant 1 2 3 4 5 6 7 Very Relevant

Any other feedback / remarks to improve fatigue risk management in your unit for you:

Appendix VII Fatigue Survey

As part of the research about the Impact of Fatigue on Situation Awareness in healthcare, some general information on your lifestyle, health and work history is required. It will take approximately 15 minutes to complete this survey.

All information that you provide will be kept **CONFIDENTIAL** and **ANONYMOUS.**

We would appreciate you filling in as carefully as possible.

Date of survey _______________

Part 1: Participant Profile

1.	What is your age group (in years)? ☐ < 20 ☐ 21 – 30 ☐ 31 – 40 ☐ 41 – 50 ☐ 51 – 60 ☐ ≥ 60
2.	Gender ☐ Male ☐ Female
3.	How long, on average, does it currently take you to get to work from your home every day? ☐ < 1 hour ☐ Between 1 – 2 Hours ☐ > 2 hours
4.	How long have you been working as a nurse (include the total duration both in Singapore as well as overseas)? ☐ Less than 3 years ☐ 3 – 5 years ☐ 6 – 10 years More than 10 years
5.	Current designation / position in the Unit you are working : ____
6	Are you currently studying / on a training program? ☐ Yes. If yes how many hours / week do you study on average ______hrs? ☐ No

7	Do you currently have any of the following? (Please tick) ☐ Diabetes ☐ High Blood pressure ☐ Asthma / Any chronic lung problem ☐ Sleep disorders such as insomnia , sleep apnoea ☐ Stomach or digestive problems such as gastric ulcer ☐ Liver problems ☐ Kidney problems ☐ Heart or circulation problems such as angina ☐ Migraine or headaches ☐ Any other medical condition (please specify) ____________________ ☐ Pregnancy
8	Do you smoke cigarettes? ☐ Yes. How many do you smoke on average per day? _______ cigarettes ☐ No
9	Do you drink caffeinated drinks (e.g., tea, coffee)? ☐ Yes ☐ No If YES, what sorts of caffeinated drinks do you usually consume? ☐ Coffee ☐ Tea ☐ Coke ☐ Red Bull / similar energy drinks ☐ Others (please specify) _________________ How many of these drinks do you have on average per day? ☐ Less that 2 cups/cans per 24 hr. period ☐ 2 – 5 cups/ cans per 24 hr. period ☐ More than 5 cups/ cans per 24 hr. period
10	Do you drink alcohol? ☐ Yes ☐ No If YES, what sort of alcoholic beverages do you usually consume ? Please circle the number of units / week consumed. ☐ Beer (0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / > 7 units / week) ☐ Wine (0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / > 7 units / week) ☐ Spirits (0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / > 7 units / week If YES, please indicate which of the following best describes your drinking habits. ☐ I usually drink only on social occasions ☐ I usually drink only on weekends ☐ I usually drink more than twice weekly ☐ I usually drink on most days

PART 2: GENERAL SLEEP PROFILE

11	How often do you get enough sleep? ☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always
12	How often do you wake up feeling refreshed? ☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always
13	When you are sleeping Do you snore loudly: ☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always Do you move about a lot: ☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always Do you use sleeping pills: ☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always
14	In the last 7 days (not counting today): How much sleep have you had per sleep period? _________ hours How much is your normal * sleep duration per sleep period?_________hours * On day off, when you wake up without alarm, how many hours do you sleep? How would you rate the quality of your sleep in the past 7 days (not counting today)? (Please draw a cross at the point in the scale below , which closely describes the quality of your sleep - 1 is very poor and 7 is very good) (Very poor) 1____ 2______3______4_____5_____6_____7 (Very good)
15	Do you ever have difficulty staying awake during working hours? ☐ Yes – if yes please state ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐ No If YES , Please state the shift (working hours) when this is most likely to happen ____

16	How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation: 0 = Would never dose 1 = Slight chance of dozing 2 = Moderate chance of dozing 3 = High chance of dozing

Situation	Chance of dozing
Sitting and reading	0 / 1 / 2 / 3
Watching TV	0 / 1 / 2 / 3
Sitting, inactive in a public place (e.g. a theatre or a meeting)	0 / 1 / 2 / 3
As a passenger in a car for an hour without a break	0 / 1 / 2 / 3
Lying down to rest in the afternoon when circumstances permit	0 / 1 / 2 / 3
Sitting and talking to someone	0 / 1 / 2 / 3
Sitting quietly after a lunch without alcohol	0 / 1 / 2 / 3
In a car, while stopped for a few minutes in the traffic	0 / 1 / 2 / 3

PART 3: WORK PATTERNS

The following questions refer to your actual work pattern, NOT what you were rostered to work

17	Which of the following describes your work routine: ☐ I work mostly day shifts. Indicate shift timing ____________________ ☐ I work rotating shifts. Please indicate shift timing for each shift and your shift pattern ____ ☐ I work mostly night shifts. Indicate shift timing____________________
18	**For the night shift staff only**, Please indicate your fatigue levels when you report for work. Use the following indicators to score in the list below : 1= Fully alert 2= Very lively 3 = Okay 4 = A little tired 5 = Moderately tired 6 = Extremely tired 7 = Completely exhausted Tick as applicable and circle the appropriate number ☐ Day 1 of night shift 1 / 2 / 3 / 4 / 5 / 6 / 7 ☐ Day 2 of night shift 1 / 2 / 3 / 4 / 5 / 6 / 7 ☐ Day 3 of night shift 1 / 2 / 3 / 4 / 5 / 6 / 7
19	How long have you been working under the current shift roster? ___________weeks / months / years
20	Was last week a typical working week for you? ☐ Yes ☐ No If NO, what was unusual about it? (e.g., on holidays, sick, on light duties etc.) ____
21	In the last 7 days, (not counting today), How many hours did you work **per shift**? ☐ Less than 8 hrs. ☐ Between 8 - 10 hrs. ☐ More than 10 hrs.
22	In the last 7 days (not counting today), did you do any night shift duties? ☐ Yes. If YES, how many night shifts _______? ☐ No

23	Please indicate the total number of hours you have worked: ☐ In the last 7 days (not counting today) _________hours ☐ In the week before, _____________hours
24	Did you work longer than your rostered duty? Indicate the number of days. ☐ In the last 7 days (not counting today) 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 days ☐ In the week before 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 days
25	Have you ever made an error during work that you consider was due to fatigue? ☐ Yes ☐ No
26	Have you ever had any education on personal strategies for coping with the effects of shift work, fatigue and inadequate sleep? ☐ Yes ☐ No
27	Would you be interested to participate in a <u>workshop</u> to learn about fatigue and fatigue management? ☐ Yes ☐ No
28	Please state any other comments you may have about your experience with shift work or fatigue in general. ______________________________ ______________________________ ______________________________ ______________________________

Thank you very much for your time

For questions or clarifications regarding this survey, please contact 98220526.

Appendix VIII AMA Fatigue Risk Assessment Matrix

Calculation of the total risk scores for a 7 day period of the roster (Adapted from Australian Medical Association's National Code of Practice – Hours of Work, Shift work and Rostering for Hospital Doctors)

S. No	Risk factor	Low (1 point)	Significant (2 points)	High (3 points)
1	Hours worked	<50 hours	50 - 70 hours	>70 hours
2	Shift length	All shifts ≤10 hours	Any 1 shift up to 14 hours	Any 2 shift ≥14 hours
3	Scheduled shift hours	As per scheduled shift hours	Any 1 shift longer than scheduled , but < 24 hours	Any shift longer than scheduled , but ≥ 24 hours
4	Breaks	≥ 3	1 - 2	0
5	Overtime	0 -10 hours	>10 hours	>20 hours
6	On call (days)	0-2 days	3-6 days	7 days
7	Night shift	0 -1	2	≥3
8	Rest opportunity in between shifts	Minimum 10 hours break and ≥ 2 days free of work	Minimum 10 hours break and 1 day free of work	< 10 hours break on at least 2 work periods and no full day free of work
9	Shift rotation	Forward rotation and predictable cycle	Forward rotation and changed cycle	No stable direction or speed of rotation
10	Roster changes	No changes without notice	Changes to roster but schedule predictable	Changes to roster , unpredictable schedule
11	Max sleep opportunity	≥2 full nights	≥1 night of sleep	< 1 night of sleep
	Total points	**11**	**22**	**33**

Appendix IX a SICU roster for 7 days with AMA Score

Subject ID	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7	AMA Score
1	**DO**	N12	**DO**	D12	**DO**	**DO**	D12	**17**
2	D12	**DO**	D12	**DO**	D12	D12	**DO**	**16**
3	M2	M2	**DO**	M1	M7	N	**RD**	**16**
4	M3	A16	A16	**DO**	M3	M3	**RD**	**16**
5	N	**DO**	A6	DTL8	M	N	**RD**	**18**
6	**DO**	A6	N	**RD**	M3	A6	M3	**16**
7	M	M	**DO**	**N**	N	**RD**	M	**18**
8	M2	N	N	**DO**	A16	M1	**RD**	**18**
9	A6	M1	N	N	**DO**	**RD**	M	**18**
10	**HL**	**HL**	**A6**	**DO**	**RD**	A6	M3	**16**
11	**DO**	M	**RD**	M2	A6	**MC**	M2	**15**
12	A6	A6	N	N	**DO**	**RD**	A6	**17**
13	M3	**DO**	M3	A16	A16	**RD**	A16	**15**
14	A6	M	**M3**	M3	N	N	**RD**	**21**
15	**AL**	**AL**	**DO**	**RD**	A16	A16	M1	**16**
16	A16	A16	M3	**DO**	**RD**	A16	A16	**16**
17	A6	N	**DO**	M1	**RD**	N	N	**17**
18	N	**DO**	**RD**	A6	A6	M2	N	**18**
19	**DO**	**RD**	M2	A6	A6	N	N	**17**
20	**DO**	M	**RD**	A6	A6	M	N	**17**
21	**DO**	N	**DO**	DTL8	N	N	**RD**	**19**
22	M	A16	A6	M3	**DO**	**RD**	N	**17**
23	A6	M	M3	**DO**	M	N	**RD**	**17**
24	N	**DO**	M	A6	A6	M	**RD**	**18**
25	N	**DO**	M	A6	M7	**RD**	A6	**18**
26	N	**DO**	A6	A6	**FCL**	M2	**RD**	**17**
27	A16	N	**DO**	DTL8	M1	**RD**	A6	**17**
28	N	N	**DO**	**MC**	**RD**	A6	A16	**17**
29	**DO**	A6	**A6**	M1	N	N	**RD**	**18**
30	M	N	N	**DO**	A6	M	**RD**	**18**
31	N	**DO**	**M**	A6	N	**RD**	N	**19**
32	DTL8	DTL8	**DO**	N	N	**RD**	N	**18**
33	A6	A6	N	N	**DO**	M	**RD**	**18**
34	**DO**	M3	A6	M	N	**RD**	M	**17**
35	**AL**	**AL**	N	**DO**	M3	M1	**RD**	**16**
36	**DO**	M	M3	M3	**RD**	N	N	**17**
37	DTL8	DTL8	N	N	**DO**	A6	**RD**	**17**
38	**AL**	**DO**	M	M	M2	A6	**RD**	**16**
39	M	A6	A6	N	N	**DO**	**RD**	**18**
40	N	**DO**	A6	N	**RD**	A16	M2	**18**
41	N	N	**DO**	A6	N	**RD**	A6	**18**
42	**DO**	A6	**A6**	M	**RD**	N	N	**18**
43	A16GP	M3GP	**DO**	M3GP	**RD**	M3GP	M3GP	**15**
44	M3GP	**DO**	M3GP	A16GP	M3GP	**RD**	M3GP	**16**
45	M3GP	M3GP	**DO**	**RD**	A16GP	A16GP	A16GP	**15**
46	M3GP	**DO**	M3GP	A16GP	A16GP	**RD**	A16GP	**15**
47	A16GP	A16GP	**DO**	A16GP	A16GP	**RD**	A16GP	**14**
48	**DO**	A16GP	A16GP	**RD**	M3GP	A16GP	M3GP	**16**
49	**DO**	M3GP	**RD**	M3GP	A16GP	A16GP	M3GP	**16**
50	D6NTO	M3OR	**DO**	M3OR	M3OR	A16	**RD**	**16**
51	M	N	**DO**	M	N	N	**RD**	**19**

Appendix IX b Roster Analysis Sample

SUBJECT	1				REST OPP		
				0.00			
DAY	**ROSTER**	**D**	**B**	**TDW**	**BEF**	**AFT**	**TOTAL BRK B4 SHFT**
1	DO	0.00	0.00	0.00	24		
2	N12 (1900-0730)	12.30	1.15	11.15	19		43
3	DO	0.00	0.00	0.00		16.5	
4	D12 (0700-1930)	12.30	1.15	11.15	7	4.5	23.5
5	DO	0.00	0.00	0.00	24		
6	DO	0.00	0.00	0.00	24		
7	D12 (0700-1930)	12.30	1.15	11.15	7	4.5	59.5
		37.30		33.45			

DAY																									
1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
3	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
4	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
5	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
6	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
7	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

AMA

Risk factor		**LR**	**SR**	**HR**
Hours worked	37.3	1		
Shift length	12 .30		2	
Scheduled shift hours	Y	1		
Breaks	Y		2	
Overtime	N	1		
On call (days)	N	1		
Night shift	Y	1		
Rest opportunity in between shifts	Y	1		
Shift rotation				3
Roster changes	Y			3
Max sleep opportunity	Y	1		
TOTAL		7	4	6
			17	

Screenshot of the Excel Spread sheet used for visualisation and analysis of the AMA risk score for each subject in work roster. The annotation for each of the items is described here: D – Shift Duration (hours), B – Break Duration (hours), TDW- Total Duration Worked exclusive of breaks (hours); REST OPP is Rest opportunity BEF is before start of shift (hours), AFT is after shift (hours) and TOTAL BRK B4 SHFT is total break before next shift (hours) ;AMA is Australian Medical Association (AMA) Risk Factor: LR (low risk) is 1 point, SR(significant risk) is 2 points and HR (high risk) is 3 points. The number 0-24 represent the work day in hours. The "pink" highlighted area represents the working shift and over the 7 day period it depicts the shift rotation pattern as well as opportunity for rest.

Appendix X FRMS Workshop Training Slides

Sleep Physiology & Fatigue Countermeasures

….since there are no simple blood tests for detection of fatigue….

Introduction

- All humans need, on average, just over 8 hours of sleep every 24 hours
- Extended shifts, night shifts and rotating shift work are common in healthcare sector
- Sleep deprived healthcare professionals are susceptible to the effects of fatigue
- Healthcare workers perform duties that require skills that are known to degrade with fatigue

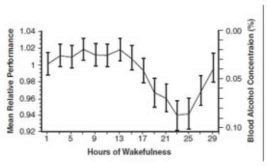
We know that

- Poor sleep quantity and quality can incur sleep debt and fatigue
- Sleep deprivation and cumulative fatigue can lead to
  - Performance decrements during the performance of safety critical tasks such at performing a medical procedure
- Fatigue impacts Safety
  - Lessons from transportation sector (road, rail and aviation), military domains apply very much to the healthcare domain

A person who goes without sleep for 18-20 hours experiences the same effects as if they had 2 to 3 beers ! They are euphoric, punchy, display decreased motor control skills and impaired thinking !

The Fatigue Countermeasures Group, NASA- Ames Research Centre

- A study compared the effects of sleep loss with those of alcohol intoxication on performance during a hand-eye coordination test
- Performance declined over time and rebounded almost to starting levels during the final hours of sleep deprivation
- After 24 hours of sustained wakefulness, performance on the tracking task decreased to a level equivalent to the performance deficit observed at a blood alcohol concentration of 0.10 percent
- The overnight decline and morning recovery of tracking performance illustrate a typical circadian rhythm



Dawson, D.; Reid, K. 1997. Fatigue, alcohol and performance impairment. Nature. 388: 235

Physiology of Sleep

7

What is sleep?

- Cyclical physiological process that alternates with longer periods of wakefulness
- Vital physiological function

8

What is sleep?

- reduced muscle activity
- decreased response to stimulation
- stereotypic postures (in humans, for example, lying down with eyes closed) and
- relatively easy reversibility

9

What is sleep?

- Stages of sleep
  - NREM - Non rapid Eye Movement
  - REM - Rapid Eye Movement
- REM & NREM alternate throughout each sleep period
- REM periods are longer and more regular later in the sleep period
- 25 % of sleep time is spent in REM sleep and about 50 % in spent in NREM stage 2

10

Sleep Stages

NREM sleep

Sleep becomes increasingly deep from stage 1 to stage 4

- **Stage 1** - lightest level of sleep, easily arousable, lasts a few min
- **Stage 2** - Sound sleep lasts 10 - 20 minutes, body functions continue to slow
- **Stage 3** - Initial stages of deep sleep, last 15 - 30 min , muscles completely relaxed, difficult to arouse
- **Stage 4** - Deepest stage of sleep, lasts 15- 30 min, very difficult to arouse

11

Sleep Stages

REM sleep

- Stage at end of each NREM cycle
- Brain active
- Vivid full colour dreaming
- Autonomic response of rapidly moving eyes, fluctuating heart rate, respiratory rate and blood pressure
- Loss of muscle tone
- Very difficult to arouse
- Duration increase with each cycle

12

Functions of sleep

- ? Physiological and psychological restoration
- Restoration of biological processes
- ? Release of Human growth Hormone (NREM Stage 4)
- Energy conservation

13

Sleep Physiology
and
Understanding Fatigue Countermeasures

14

How much sleep ?

- 17-18 hours at birth (~50 % REM)
- 10-12 hours at age 4
- 7-8.5 hours by age 20

15

Quality Vs Quantity

- Getting 8 hrs of disrupted sleep can have effects similar to too little sleep
- After sleep loss, sleep is deeper (more NREM stages 3 and 4) rather than longer

16

Sleep and Aging

- Sleep becomes less deep (NREM Stage 3 and 4 disappears), more disrupted (awakenings increase) and total nocturnal sleep decreases
- Changes seen as early as 50 years

17

Factors affecting sleep

Age
Circadian phases
Stress
Drugs and substances (alcohol)
Lifestyle
Environment / work conditions – noise , thermal stress
Exercise
Food intake
Illness

18

Factors

- Medications - Delay sleep onset, disrupt sleep structure, alter total sleep time
- Alcohol - supresses REM, disrupts sleep
- Environmental factors - Noise, temperature, light etc may interfere with good sleep

Sleeping pills (No Go Pills)

- Some help you fall asleep, stay asleep and may improve waking alertness
- Some alter sleep structure, create dependency, have carryover effects that may decrease waking alertness and performance
- May have potentially serious side effects

Sleep Debt

- Loss of as little as one hour sleep begins a person's sleep debt
- Can be due to eight hours of disrupted sleep
- Only cure for sleep debt is sleep
- Acute fatigue- Severe, Loss of a night's sleep
- Chronic fatigue

Consequences

- Decreased physical and mental performance
- Decreased positive and increased negative mood
- Increase vulnerability to performance decrements

Microsleeps

- Uncontrolled spontaneous episodes of sleep that could last for seconds or minutes
- Disengages from reality
- Unresponsive
- Failure to respond to outside information

- There is a 10 times increase of microsleep at night than during the day
- There is a 10 times increase of a microsleep relative to each hour worked
- Microsleep increase with cumulative sleep debt
- A microsleep does not decrease a sleep debt

Circadian Rhythms

- Humans, like all mammals, have a 24 hour biological "clock"
  - If people are placed in an environment without any access to daylight, to clocks, or to other markers of time, they follow an activity/rest cycle of about 24.5 hours

  Shown by Nathaniel Kleitman in a study in Mammoth Cave, Kentucky

25

Circadian Rhythms

- Affected by light, temperature, and external factors
- Influence major biological and behavioral functions
  - Body temperature
  - Heart rate , blood pressure
  - Hormone secretion
  - Mood

26

Circadian Rhythm

- Two circadian lows present 3 AM to 5 AM & 3 PM to 5 PM
- Combination of circadian low period and fatigue reduces performance by up to 35%
- Biological marker: Drop in body's core temperature

27

Circadian Rhythm

- Shift works disrupts circadian rhythms (20% of workforce work in nonstandard schedules)

28

Symptoms of Shift Work & Jet Lag

- Disturbed sleep
- Increased work time sleepiness
- Decreased performance
- Increased fatigue
- More negative mood
- Gastrointestinal problems

29

Studies reveal ...

- 60 % shift workers have sleep complaints Vs 20 % of day workers
- 75% of night workers experience sleepiness on every shift and 20 % report falling asleep

30

Subjective Vs Physiological Sleep and Alertness

- Difficult to reliably estimate your own sleep especially if you are already sleepy
- Tendency to report greater alertness than indicated by physiological measures

31

Epworth Sleepiness Scale

Situation	Chance of dozing
Sitting and reading	
Watching TV	
Sitting, inactive in a public place (e.g. a theatre or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in the traffic	
Total	

Score:

0-10	Normal range
10-12	Borderline
12-24	Abnormal

Use the following scale to choose the most appropriate number for each situation:-

0 = would never doze
1 = Slight chance of dozing
2 = Moderate chance of dozing
3 = High chance of dozing

Measures Global Level of Sleepiness

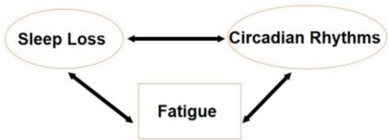
32

What is Fatigue

- A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness and to physical activity that can impair a person's alertness and ability to safely operate or perform safety related duties

33

Causes of Fatigue



Other contributory factors:
Noise, Stress, Strenuous activities, Illness

34

Symptoms of fatigue

Physical Symptoms	Mental Symptoms	Emotional Symptoms
Yawning Heavy eyelids Eye rubbing Poor coordination Head drooping Falling Asleep	Diminished perception Memory lapses - forgetful Difficulty concentrating Channeled concentration – Fixation Poor communication General lack of awareness Slow reaction times "Settling for less" in performance	Quiet and withdrawn Lethargy Lack of motivation Irritable Changes in mood - depressed

35

Recognizing fatigue

- The fatigued person may be unaware of increasing discrepancy and may be the last to know he / she is impaired
  - In single person critical work
    - Be vigilant to monitor own performance on a continual basis and take appropriate action
  - In team work
    - Use CRM to help recognize fatigued teammates

36

Recognizing fatigue

- "There were certain things I was letting slip. Things that would never normally happen if I wasn't so tired"
- "I found myself actually concentrating more, because I was thinking 'I may be missing things here'…"
- "I feel like a basic simple task would take a lot of concentration"
- "Rather than not do something, you'll think 'Did I do that or didn't I?' So you repeat the exercise rather than missing it."

37

Measuring fatigue

There is no single direct measure of fatigue

- No fatigue meter

There are many indirect measures, which include:

- Performance measures e.g. response times, error rates
- Subjective assessments e.g. fatigue, sleepiness
- Electroencephalogram (EEG – electrical activity of the brain)
- Eye movements and pupil size

Fatigue calculators
Sleep Diaries
Fatigue risk analysis


Actiwatch


Reaction time tests


EEG


Optalert

38

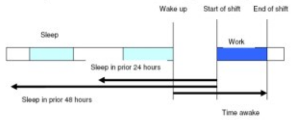
Predicting fatigue from duty rosters

- Bio mathematical models such as FAID

39

Fatigue Risk Calculator

http://www.fatiguecalculator.com.au/fatigue_calculator_online_demo



40

Please take note that you <u>cannot</u> overcome the effects of fatigue by

- Skills
- Increased efforts
- Stamina
- Physical conditioning
- Experience
- Willpower
- Professionalism
- Motivation

41

Alertness management recommendations

- Preventive Strategies - before duty to reduce adverse effects of fatigue, sleep loss and circadian disruption
- Operational Strategies - during duty to maintain alertness and performance

42

Fatigue prevention strategies

- Keep a regular sleep/wake cycle (as far as practicable)
- Develop and practice a regular pre-sleep routine
- Avoid alcohol, caffeine and smoking prior to sleep
- Do not exercise or eat a large meal directly before sleep
- Sleep environment (dark and quite room, comfortable temperature and comfortable sleep surface)

43

Fatigue prevention strategies

- Use caffeine sparingly during work / breaks
- Drink water to prevent dehydration
- If you cannot sleep in 15-20 minutes get up and try to sleep later
- If you feel sleepy and the circumstances permit, sleep!
  - Prior to night shift
- Strategic Napping (40-minute nap dubbed the NASA-nap)
  - During night shift

44

Operational strategies

During work- maintain alertness

- Regular stretch breaks
- Engage in conversations if possible
- Strategic caffeine consumption
- Planned brief nap (up to 40 min duration) – use the nap zone and nap time
- Anchor sleep
- Exercise
- Bright light

45

Operational strategies

Pharmacological agents

- Caffeine
- Melatonin - Studies to demonstrate operational effectiveness currently underway
  - facilitates rapid circadian adaptations and promotes sleep

46

If you remember nothing else

- Physiological mechanisms underlie fatigue
- Sleepiness can have serious consequences - take it seriously
- All people are different - tailor recommendations as per the individuals' needs
- There is no one simple answer - these are recommendations; find out what works for you

47

Thank you

48

Appendix XI Results and Analysis Tables

Coding used in results analysis

Descriptor	*Codes*
Phase	Pre FRMS or "Before" – B Post FRMS or "After" - A
Shift type	Morning –M / Afternoon- A / Night –N
Data point	Start – 0/ End – 1
Variable	SP/SA/ KSS/ RT

1. Comparison of fatigue scores at start of shift (B0SP) and end of all shifts (B1SP)

F-Test Two-Sample for Variances

	B0SP	*B1SP*
Mean	3.454545455	4.831168831
Variance	1.791013584	1.510594668
Observations	88	77
df	87	76
F	1.185634784	
P(F<=f) one-tail	0.224348112	
F Critical one-tail	1.447772911	

2. Comparison of fatigue scores at start of shift

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM0SP	31	117	3.774194	1.713978
BA0SP	29	92	3.172414	1.933498
BN0SP	26	84	3.230769	1.384615

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.583143	2	3.291572	1.949028	0.148876	3.106507
Within Groups	140.1727	83	1.688827			
Total	146.7558	85				

3. Comparison of SP scores at the end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM1SP	29	130	4.482759	1.615764
BA1SP	27	130	4.814815	1.618234
BN1SP	23	123	5.347826	0.873518

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.644370501	2	4.822185	3.440123	0.037134	3.116982
Within Groups	106.5328447	76	1.401748			
Total	116.1772152	78				

4. Comparison of SP scores at end of morning and afternoon shift
T-Test: Two-Sample Assuming Unequal Variances

	BM1SP	*BA1SP*
Mean	4.482759	4.814815
Variance	1.615764	1.618234
Observations	29	27
Hypothesized Mean Difference	0	
df	54	
t Stat	-0.97642	
P(T<=t) one-tail	0.166605	
t Critical one-tail	1.673565	
P(T<=t) two-tail	0.333209	
t Critical two-tail	2.004879	

5. Comparison of SP scores at afternoon and night shift
T-Test: Two-Sample Assuming Unequal Variances

	BA1SP	*BN1SP*
Mean	4.814814815	5.347826087
Variance	1.618233618	0.873517787
Observations	27	23
Hypothesized Mean Difference	0	
df	47	
t Stat	-1.703392992	
P(T<=t) one-tail	0.047549642	
t Critical one-tail	1.677926722	
P(T<=t) two-tail	0.095099284	
t Critical two-tail	2.011740514	

6. Comparison of SP scores at morning and end of night shift
t-Test: Two-Sample Assuming Unequal Variances

	BM1SP	*BN1SP*
Mean	4.482758621	5.347826087
Variance	1.615763547	0.873517787
Observations	29	23
Hypothesized Mean Difference	0	
df	50	
t Stat	-2.826127353	
P(T<=t) one-tail	0.003377513	
t Critical one-tail	1.675905025	
P(T<=t) two-tail	0.006755026	
t Critical two-tail	2.008559112	

7. Comparison of SP scores at start and end of morning shift

T-Test: Two-Sample Assuming Unequal Variances

	BM0SP	*BM1SP*
Mean	3.774193548	4.482758621
Variance	1.713978495	1.615763547
Observations	31	29
Hypothesized Mean Difference	0	
df	58	
t Stat	-2.12670509	
P(T<=t) one-tail	0.018855137	
t Critical one-tail	1.671552762	
P(T<=t) two-tail	0.037710274	
t Critical two-tail	2.001717484	

8. Comparison of SP scores start and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	BA0SP	*BA1SP*
Mean	3.172413793	4.814814815
Variance	1.933497537	1.618233618
Observations	29	27
Hypothesized Mean Difference	0	
df	54	
t Stat	-4.61583745	
P(T<=t) one-tail	1.22811E-05	
t Critical one-tail	1.673564906	
P(T<=t) two-tail	2.45622E-05	
t Critical two-tail	2.004879288	

9. Comparison of SP scores start and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	BN0SP	*BN1SP*
Mean	3.230769231	5.347826087
Variance	1.384615385	0.873517787
Observations	26	23
Hypothesized Mean Difference	0	
df	46	
t Stat	-7.008989674	
P(T<=t) one-tail	4.41682E-09	
t Critical one-tail	1.678660414	
P(T<=t) two-tail	8.83364E-09	
t Critical two-tail	2.012895599	

10. Comparison of SA scores at start and end of all shifts

T-Test: Two-Sample Assuming Unequal Variances

	B0SA	B1SA
Mean	22.68254	22.03175
Variance	43.86534	44.48285
Observations	63	63
Hypothesized Mean Difference	0	
df	124	
t Stat	0.54956	
P(T<=t) one-tail	0.291805	
t Critical one-tail	1.657235	
P(T<=t) two-tail	0.58361	
t Critical two-tail	1.97928	

11. Comparison of SA scores at start of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM0SA	21	491	23.38095	36.04762
BA0SA	21	449	21.38095	45.34762
BN0SA	21	489	23.28571	51.91429

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	53.46032	2	26.73016	0.601536	0.55124	3.150411
Within Groups	2666.19	60	44.43651			
Total	2719.651	62				

12. Comparison of SA scores at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM1SA	21	475	22.61905	40.54762
BA1SA	21	448	21.33333	45.23333
BN1SA	21	465	22.14286	51.22857

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17.74603	2	8.873016	0.194286	0.823938	3.150411
Within Groups	2740.19	60	45.66984			
Total	2757.937	62				

13. Comparison of SA scores at start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	BM0SA	*BM1SA*
Mean	23.38095	22.61905
Variance	36.04762	40.54762
Observations	21	21
Hypothesized Mean Difference	0	
df	40	
t Stat	0.398942	
P(T<=t) one-tail	0.346029	
t Critical one-tail	1.683851	
P(T<=t) two-tail	0.692058	
t Critical two-tail	2.021075	

14. Comparison of SA scores at start and end of afternoon shift

T-Test: Two-Sample Assuming Unequal Variances

	BA0SA	*BA1SA*
Mean	21.38095	21.33333
Variance	45.34762	45.23333
Observations	21	21
Hypothesized Mean Difference	0	
df	40	
t Stat	0.022928	
P(T<=t) one-tail	0.490911	
t Critical one-tail	1.683851	
P(T<=t) two-tail	0.981821	
t Critical two-tail	2.021075	

15. Comparison of SA scores at start and end of night shift

t -Test: Two-Sample Assuming Unequal Variances

	BN0SA	*BN1SA*
Mean	23.28571	22.14286
Variance	51.91429	51.22857
Observations	21	21
Hypothesized Mean Difference	0	
df	40	
t Stat	0.515682	
P(T<=t) one-tail	0.304458	
t Critical one-tail	1.683851	
P(T<=t) two-tail	0.608915	
t Critical two-tail	2.021075	

16. Comparison of KSS scores at start of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM0KSS	30	133	4.433333	2.874713
BA0KSS	30	104	3.466667	2.533333
BN0KSS	26	89	3.423077	1.773846

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19.05307	2	9.526535	3.930333	0.023396	3.106507
Within Groups	201.1795	83	2.423849			
Total	220.2326	85				

17. Comparison of KSS score at start of morning and afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	BM0KSS	*BA0KSS*
Mean	4.433333	3.466667
Variance	2.874713	2.533333
Observations	30	30
Hypothesized Mean Difference	0	
df	58	
t Stat	2.27676	
P(T<=t) one-tail	0.013254	
t Critical one-tail	1.671553	
P(T<=t) two-tail	0.026507	
t Critical two-tail	2.001717	

18. Comparison of KSS score at the start of morning and night shift

t-Test: Two-Sample Assuming Unequal Variances

	BM0KSS	*BN0KSS*
Mean	4.433333	3.423076923
Variance	2.874713	1.773846154
Observations	30	26
Hypothesized Mean Difference	0	
df	54	
t Stat	2.494281	
P(T<=t) one-tail	0.007857	
t Critical one-tail	1.673565	
P(T<=t) two-tail	0.015714	
t Critical two-tail	2.004879	

19. Comparison of the KSS score at start of afternoon and night shift

t-Test: Two-Sample Assuming Unequal Variances

	BA0KSS	BN0KSS
Mean	3.466667	3.423076923
Variance	2.533333	1.773846154
Observations	30	26
Hypothesized Mean Difference	0	
df	54	
t Stat	0.11156	
P(T<=t) one-tail	0.455793	
t Critical one-tail	1.673565	
P(T<=t) two-tail	0.911586	
t Critical two-tail	2.004879	

20. Comparison of KSS scores at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM1KSS	28	147	5.25	3.75
BA1KSS	26	132	5.076923	3.193846
BN1KSS	23	144	6.26087	2.201581

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19.71582	2	9.857908	3.178156	0.047406	3.120349
Within Groups	229.5309	74	3.101769			
Total	249.2468	76				

21. Comparison of KSS scores at end of morning and afternoon shift

T-Test: Two-Sample Assuming Unequal Variances

	BM1KSS	*BA1KSS*
Mean	5.25	5.076923
Variance	3.75	3.193846
Observations	28	26
Hypothesized Mean Difference	0	
df	52	
t Stat	0.341561	
P(T<=t) one-tail	0.367029	
t Critical one-tail	1.674689	
P(T<=t) two-tail	0.734058	
t Critical two-tail	2.006647	

22. Comparison of KSS scores at end of morning and night shift

t-Test: Two-Sample Assuming Unequal Variances

	BM1KSS	*BN1KSS*
Mean	5.25	6.26087
Variance	3.75	2.201581
Observations	28	23
Hypothesized Mean Difference	0	
df	49	
t Stat	-2.109416713	
P(T<=t) one-tail	0.020020595	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	0.040041189	
t Critical two-tail	2.009575237	

23. Comparison of KSS scores between end of afternoon and night shift

t-Test: Two-Sample Assuming Unequal Variances

	BA1KSS	*BN1KSS*
Mean	5.076923077	6.26087
Variance	3.193846154	2.201581
Observations	26	23
Hypothesized Mean Difference	0	
df	47	
t Stat	-2.532477463	
P(T<=t) one-tail	0.007362547	
t Critical one-tail	1.677926722	
P(T<=t) two-tail	0.014725093	
t Critical two-tail	2.011740514	

24. Comparison of KSS scores at start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	BM0KSS	*BM1KSS*
Mean	4.433333333	5.25
Variance	2.874712644	3.75
Observations	30	28
Hypothesized Mean Difference	0	
df	54	
t Stat	-1.703785316	
P(T<=t) one-tail	0.047085064	
t Critical one-tail	1.673564906	
P(T<=t) two-tail	0.094170128	
t Critical two-tail	2.004879288	

25. Comparison of KSS scores at start and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	BA0KSS	*BA1KSS*
Mean	3.466666667	5.076923077
Variance	2.533333333	3.193846154
Observations	30	26
Hypothesized Mean Difference	0	
df	51	
t Stat	-3.536807581	
P(T<=t) one-tail	0.000436312	
t Critical one-tail	1.67528495	
P(T<=t) two-tail	0.000872624	
t Critical two-tail	2.00758377	

26. Comparison of KSS scores at start and end of night shift

t-Test: Paired Two Sample for Means

	BNOKSS	*BN1KSS*
Mean	3.454545	6.272727
Variance	1.402597	2.30303
Observations	22	22
Pearson Correlation	-0.20473	
Hypothesized Mean Difference	0	
df	21	
t Stat	-6.2721	
P(T<=t) one-tail	1.6E-06	
t Critical one-tail	1.720743	
P(T<=t) two-tail	3.21E-06	
t Critical two-tail	2.079614	

27. Comparison of RT at start of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM0RT	24	8654	360.5833	4219.21
BA0RT	28	9466	338.0714	2551.995
BN0RT	23	7745	336.7391	3071.747

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8740.541	2	4370.271	1.347439	0.266379	3.123907
Within Groups	233524.1	72	3243.391			
Total	242264.7	74				

28. Comparison of RT at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BM1RT	29	11245	387.7586	8405.475
BA1RT	27	10075	373.1481	3734.823
BN1RT	23	9183	399.2609	6692.383

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8592.822	2	4296.411	0.680703	0.50932	3.116982
Within Groups	479691.2	76	6311.726			
Total	488284	78				

29. Comparison of RT between start and end of all shifts

t-Test: Two-Sample Assuming Unequal Variances

	B0RT	*B1RT*
Mean	344.8667	386.1139
Variance	3273.847	6260.051
Observations	75	79
Hypothesized Mean Difference	0	
df	142	
t Stat	-3.72077	
P(T<=t) one-tail	0.000143	
t Critical one-tail	1.655655	
P(T<=t) two-tail	0.000285	
t Critical two-tail	1.976811	

30. Comparison of RT between start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	BM0RT	*BM1RT*
Mean	360.5833	387.7586
Variance	4219.21	8405.475
Observations	24	29
Hypothesized Mean Difference	0	
df	50	
t Stat	-1.25935	
P(T<=t) one-tail	0.106875	
t Critical one-tail	1.675905	
P(T<=t) two-tail	0.213751	
t Critical two-tail	2.008559	

31. Comparison of RT at start and end of afternoon shift
T-Test: Two-Sample Assuming Unequal Variances

	BA0RT	*BA1RT*
Mean	338.0714	373.1481
Variance	2551.995	3734.823
Observations	28	27
Hypothesized Mean Difference	0	
df	50	
t Stat	-2.31556	
P(T<=t) one-tail	0.012362	
t Critical one-tail	1.675905	
P(T<=t) two-tail	0.024724	
t Critical two-tail	2.008559	

32. Comparison of RT scores at start and end of night shift
t-Test: Two-Sample Assuming Unequal Variances

	BN0RT	*BN1RT*
Mean	336.7391	399.2609
Variance	3071.747	6692.383
Observations	23	23
Hypothesized Mean Difference	0	
df	39	
t Stat	-3.03444	
P(T<=t) one-tail	0.002138	
t Critical one-tail	1.684875	
P(T<=t) two-tail	0.004275	
t Critical two-tail	2.022691	

33. Comparison of SP score at start and end of all shifts
F-Test Two-Sample for Variances

	A1SP	*A1SP*
Mean	2.93055556	4.2
Variance	1.55848983	2.307246377
Observations	72	70
df	71	69
F	0.67547612	
P(F<=f) one-tail	0.05126428	
F Critical one-tail	0.67349686	

34. Comparison of SP score at start of all shifts

Groups	*Count*	*Sum*	*Average*	*Variance*
AM0SP	26	86	3.307692	1.661538
AA0SP	25	65	2.6	1.666667
AN0SP	21	60	2.857143	1.128571

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.542888	2	3.271444	2.168186	0.122116	3.129644
Within Groups	104.1099	69	1.508839			
Total	110.6528	71				

35. Comparison of SP score at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM1SP	26	103	3.961538	1.958462
AA1SP	23	82	3.565217	2.529644
AN1SP	21	109	5.190476	1.161905

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31.34819	2	15.6741	8.213919	0.000645	3.133762
Within Groups	127.8518	67	1.908236			
Total	159.2	69				

36. Comparison of SP score at end of morning and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AM1SP	*AA1SP*
Mean	3.961538462	3.565217391
Variance	1.958461538	2.529644269
Observations	26	23
Hypothesized Mean Difference	0	
df	44	
t Stat	0.92065679	
P(T<=t) one-tail	0.181125011	
t Critical one-tail	1.680229977	
P(T<=t) two-tail	0.362250022	
t Critical two-tail	2.015367574	

37. Comparison of SP score at end of afternoon and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	AA1SP	*AN1SP*
Mean	3.565217391	5.19047619
Variance	2.529644269	1.161904762
Observations	23	21
Hypothesized Mean Difference	0	
df	39	
t Stat	-3.997316965	
P(T<=t) one-tail	0.000138031	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.000276063	
t Critical two-tail	2.02269092	

38. Comparison of SP score at end of morning and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	AM1SP	*AN1SP*
Mean	3.961538462	5.19047619
Variance	1.958461538	1.161904762
Observations	26	21
Hypothesized Mean Difference	0	
df	45	
t Stat	-3.399915475	
P(T<=t) one-tail	0.000711084	
t Critical one-tail	1.679427393	
P(T<=t) two-tail	0.001422169	
t Critical two-tail	2.014103389	

39. Comparison of SP score at start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	AM0SP	*AM1SP*
Mean	3.307692308	3.961538462
Variance	1.661538462	1.958461538
Observations	26	26
Hypothesized Mean Difference	0	
df	50	
t Stat	-1.752297987	
P(T<=t) one-tail	0.042926693	
t Critical one-tail	1.675905025	
P(T<=t) two-tail	0.085853386	
t Critical two-tail	2.008559112	

40. Comparison of SP score at start and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AA0SP	*AA1SP*
Mean	2.6	3.565217391
Variance	1.666666667	2.529644269
Observations	25	23
Hypothesized Mean Difference	0	
df	42	
t Stat	-2.296502076	
P(T<=t) one-tail	0.013351283	
t Critical one-tail	1.681952357	
P(T<=t) two-tail	0.026702565	
t Critical two-tail	2.018081703	

41. Comparison of SP score at start and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	AN0SP	*AN1SP*
Mean	2.857142857	5.19047619
Variance	1.128571429	1.161904762
Observations	21	21
Hypothesized Mean Difference	0	
df	40	
t Stat	-7.065185059	
P(T<=t) one-tail	7.61029E-09	
t Critical one-tail	1.683851013	
P(T<=t) two-tail	1.52206E-08	
t Critical two-tail	2.02107539	

42. Comparison of SA score at start and end of all shifts

t-Test: Two-Sample Assuming Unequal Variances

	A0SA	*A1SA*
Mean	23.74603175	23.52380952
Variance	45.031234	46.0921659
Observations	63	63
Hypothesized Mean Difference	0	
df	124	
t Stat	0.184774827	
P(T<=t) one-tail	0.42685376	
t Critical one-tail	1.65723497	
P(T<=t) two-tail	0.853707519	
t Critical two-tail	1.979280117	

43. Comparison of SA score at start of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM0SA	22	525	23.86364	52.50433
AA0SA	21	491	23.38095	48.04762
AN0SA	20	480	24	38.10526

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.393218	2	2.196609	0.047281	0.953855	3.150411
Within Groups	2787.543	60	46.45905			
Total	2791.937	62				

44. Comparison of SA scores at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM1SA	22	499	22.68182	51.17965
AA1SA	21	491	23.38095	52.74762
AN1SA	20	492	24.6	36.25263

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	39.18918	2	19.59459	0.417124	0.660835	3.150411
Within Groups	2818.525	60	46.97542			
Total	2857.714	62				

45. Comparison of SA scores at start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	AM0SA	*AM1SA*
Mean	23.86363636	22.6818182
Variance	52.504329	51.1796537
Observations	22	22
Hypothesized Mean Difference	0	
df	42	
t Stat	0.544385028	
P(T<=t) one-tail	0.29452766	
t Critical one-tail	1.681952357	
P(T<=t) two-tail	0.58905532	
t Critical two-tail	2.018081703	

46. Comparison of SA scores at start and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AA0SA	*AA1SA*
Mean	23.38095238	23.38095238
Variance	48.04761905	52.74761905
Observations	21	21
Hypothesized Mean Difference	0	
df	40	
t Stat	0	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.683851013	
P(T<=t) two-tail	1	
t Critical two-tail	2.02107539	

47. Comparison of SA scores at start and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	AN0SA	*AN1SA*
Mean	24	24.6
Variance	38.10526	36.25263
Observations	20	20
Hypothesized Mean Difference	0	
df	38	
t Stat	-0.31117	
P(T<=t) one-tail	0.378685	
t Critical one-tail	1.685954	
P(T<=t) two-tail	0.757369	
t Critical two-tail	2.024394	

48. Comparison of the KSS score at start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	AM0KSS	*AM1KSS*
Mean	4.222222222	4.777777778
Variance	4.487179487	4.025641026
Observations	27	27
Hypothesized Mean Difference	0	
df	52	
t Stat	-0.989401669	
P(T<=t) one-tail	0.163524159	
t Critical one-tail	1.674689154	
P(T<=t) two-tail	0.327048319	
t Critical two-tail	2.006646805	

49. Comparison of KSS scores at the start and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AA0KSS	*AA1KSS*
Mean	3.130434783	3.857143
Variance	1.754940711	3.428571
Observations	23	21
Hypothesized Mean Difference	0	
df	36	
t Stat	-1.484726361	
P(T<=t) one-tail	0.073160334	
t Critical one-tail	1.688297714	
P(T<=t) two-tail	0.146320669	
t Critical two-tail	2.028094001	

50. Comparison of KSS scores at start and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	AN0KSS	*AN1KSS*
Mean	3	6.238095238
Variance	1.789473684	2.29047619
Observations	20	21
Hypothesized Mean Difference	0	
df	39	
t Stat	-7.267102024	
P(T<=t) one-tail	4.61849E-09	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	9.23697E-09	
t Critical two-tail	2.02269092	

51. Comparison of KSS scores at the start of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM0KSS	27	114	4.222222	4.487179
AA0KSS	23	72	3.130435	1.754941
AN0KSS	20	60	3	1.789474

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.21035	2	11.10518	3.931028	0.024307	3.133762
Within Groups	189.2754	67	2.825005			
Total	211.4857	69				

52. Comparison of KSS scores at start of morning and afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AM0KSS	*AA0KSS*
Mean	4.222222	3.130435
Variance	4.487179	1.754941
Observations	27	23
Hypothesized Mean Difference	0	
df	44	
t Stat	2.217114	
P(T<=t) one-tail	0.015914	
t Critical one-tail	1.68023	
P(T<=t) two-tail	0.031829	
t Critical two-tail	2.015368	

53. Comparison of KSS scores at start of morning and night shift

t-Test: Two-Sample Assuming Unequal Variances

	AM0KSS	*AN0KSS*
Mean	4.222222	3
Variance	4.487179	1.789474
Observations	27	20
Hypothesized Mean Difference	0	
df	44	
t Stat	2.417208	
P(T<=t) one-tail	0.009926	
t Critical one-tail	1.68023	
P(T<=t) two-tail	0.019852	
t Critical two-tail	2.015368	

54. Comparison of KSS scores at the start of afternoon and night shift

t-Test: Two-Sample Assuming Unequal Variances

	AA0KSS	*AN0KSS*
Mean	3.130435	3
Variance	1.754941	1.789474
Observations	23	20
Hypothesized Mean Difference	0	
df	40	
t Stat	0.320356	
P(T<=t) one-tail	0.375183	
t Critical one-tail	1.683851	
P(T<=t) two-tail	0.750366	
t Critical two-tail	2.021075	

55. Comparison of KSS scores at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM1KSS	27	129	4.777778	4.025641
AA1KSS	21	81	3.857143	3.428571
AN1KSS	21	131	6.238095	2.290476

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	60.7205	2	30.36025	9.147675	0.000311	3.135918
Within Groups	219.0476	66	3.318903			
Total	279.7681	68				

56. Comparison of KSS scores at the end of morning and afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AM1KSS	*AA1KSS*
Mean	4.777778	3.857143
Variance	4.025641	3.428571
Observations	27	21
Hypothesized Mean Difference	0	
df	45	
t Stat	1.647243	
P(T<=t) one-tail	0.053237	
t Critical one-tail	1.679427	
P(T<=t) two-tail	0.106475	
t Critical two-tail	2.014103	

57. Comparison of KSS scores at end of morning and night shift

t-Test: Two-Sample Assuming Unequal Variances

	AM1KSS	*AN1KSS*
Mean	4.777778	6.238095
Variance	4.025641	2.290476
Observations	27	21
Hypothesized Mean Difference	0	
df	46	
t Stat	-2.87406	
P(T<=t) one-tail	0.003058	
t Critical one-tail	1.67866	
P(T<=t) two-tail	0.006116	
t Critical two-tail	2.012896	

58. Comparison of KSS scores at end of afternoon and night shift

t-Test: Two-Sample Assuming Unequal Variances

	AA1KSS	*AN1KSS*
Mean	3.857143	6.238095
Variance	3.428571	2.290476
Observations	21	21
Hypothesized Mean Difference	0	
df	38	
t Stat	-4.56245	
P(T<=t) one-tail	2.58E-05	
t Critical one-tail	1.685954	
P(T<=t) two-tail	5.15E-05	
t Critical two-tail	2.024394	

59. Comparison of RT between start and end of morning shift

t-Test: Two-Sample Assuming Unequal Variances

	AM0RT	*AM1RT*
Mean	375.65	382.8696
Variance	3050.661	4801.209
Observations	20	23
Hypothesized Mean Difference	0	
df	41	
t Stat	-0.37983	
P(T<=t) one-tail	0.353016	
t Critical one-tail	1.682878	
P(T<=t) two-tail	0.706033	
t Critical two-tail	2.019541	

60. Comparison of RT at start and end of afternoon shift

t-Test: Two-Sample Assuming Unequal Variances

	AA0RT	*AA1RT*
Mean	356.4762	388.7368
Variance	1493.462	5225.427
Observations	21	19
Hypothesized Mean Difference	0	
df	27	
t Stat	-1.73399	
P(T<=t) one-tail	0.047163	
t Critical one-tail	1.703288	
P(T<=t) two-tail	0.094325	
t Critical two-tail	2.051831	

61. Comparison of RT at start and end of night shift

t-Test: Two-Sample Assuming Unequal Variances

	AN0RT	*AN1RT*
Mean	374.1	418.2105
Variance	8209.147	7989.842
Observations	20	19
Hypothesized Mean Difference	0	
df	37	
t Stat	-1.5302	
P(T<=t) one-tail	0.067237	
t Critical one-tail	1.687094	
P(T<=t) two-tail	0.134473	
t Critical two-tail	2.026192	

62. Comparison of RT at start of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM0RT	20	7513	375.65	3050.661
AA0RT	21	7486	356.4762	1493.462
AN0RT	20	7482	374.1	8209.147

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4685.559	2	2342.78	0.557334	0.57577	3.155932
Within Groups	243805.6	58	4203.545			
Total	248491.1	60				

63. Comparison of RT at end of all shifts

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
AM1RT	23	8806	382.8696	4801.209
AA1RT	19	7386	388.7368	5225.427
AN1RT	19	7946	418.2105	7989.842

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14335.24	2	7167.619	1.210248	0.30554	3.155932
Within Groups	343501.5	58	5922.439			
Total	357836.7	60				

64. Comparison of RT at start and end of shift

t-Test: Two-Sample Assuming Unequal Variances

	A0	*A1*
Mean	368.541	395.7049
Variance	4141.519	5963.945
Observations	61	61
Hypothesized Mean Difference	0	
df	116	
t Stat	-2.11047	
P(T<=t) one-tail	0.018483	
t Critical one-tail	1.658096	
P(T<=t) two-tail	0.036966	
t Critical two-tail	1.980626	

65. Comparison of SP scores Pre and Post FRMS at start of shift

T-Test: Two-Sample Assuming Unequal Variances

	B0SP	*A0SP*
Mean	3.406976744	2.930555556
Variance	1.726538988	1.558489828
Observations	86	72
Hypothesized Mean Difference	0	
df	153	
t Stat	2.332437047	
P(T<=t) one-tail	0.010490409	
t Critical one-tail	1.654873847	
P(T<=t) two-tail	0.020980817	
t Critical two-tail	1.975590315	

66. Comparison of SP scores Pre and Post FRMS at end of shift

T-Test: Two-Sample Assuming Unequal Variances

	B1SP	*A1SP*
Mean	4.848101266	4.2
Variance	1.489451477	2.307246377
Observations	79	70
Hypothesized Mean Difference	0	
df	132	
t Stat	2.847195596	
P(T<=t) one-tail	0.002558316	
t Critical one-tail	1.65647927	
P(T<=t) two-tail	0.005116632	
t Critical two-tail	1.978098842	

67. Comparison of SA scores Pre and Post FRMS at start of shift

T-Test: Two-Sample Assuming Unequal Variances

	B0SA	*A0SA*
Mean	*22.68254*	*23.74603*
Variance	43.86534	45.03123
Observations	63	63
Hypothesized Mean Difference	0	
df	124	
t Stat	-0.89529	
P(T<=t) one-tail	0.186184	
t Critical one-tail	1.657235	
P(T<=t) two-tail	0.372369	
t Critical two-tail	1.97928	

68. Comparison of SA scores Pre and Post FRMS at end of shift

t-Test: Two-Sample Assuming Unequal Variances

	B1SA	*A1SA*
Mean	22.03175	23.52381
Variance	44.48285	46.09217
Observations	63	63
Hypothesized Mean Difference	0	
df	124	
t Stat	-1.24438	
P(T<=t) one-tail	0.107853	
t Critical one-tail	1.657235	
P(T<=t) two-tail	0.215706	
t Critical two-tail	1.97928	

69. Comparison of KSS score Pre and Post FRMS at start of shift

t-Test: Two-Sample Assuming Unequal Variances

	B0KSS	*A0KSS*
Mean	3.790698	3.514286
Variance	2.590971	3.06501
Observations	86	70
Hypothesized Mean Difference	0	
df	142	
t Stat	1.016705	
P(T<=t) one-tail	0.155511	
t Critical one-tail	1.655655	
P(T<=t) two-tail	0.311023	
t Critical two-tail	1.976811	

70. Comparison of KSS score Pre and Post FRMS at end of shift

t-Test: Two-Sample Assuming Unequal Variances

	B1KSS	*A1KSS*
Mean	5.493506	4.942029
Variance	3.279563	4.114237
Observations	77	69
Hypothesized Mean Difference	0	
df	137	
t Stat	1.724898	
P(T<=t) one-tail	0.043401	
t Critical one-tail	1.656052	
P(T<=t) two-tail	0.086801	
t Critical two-tail	1.977431	

71. Comparison of RT at start of shift in Pre and Post FRMS

t-Test: Two-Sample Assuming Unequal Variances

	B0RT	*A0RT*
Mean	344.8667	368.541
Variance	3273.847	4141.519
Observations	75	61
Hypothesized Mean Difference	0	
df	121	
t Stat	-2.24157	
P(T<=t) one-tail	0.013406	
t Critical one-tail	1.657544	
P(T<=t) two-tail	0.026812	
t Critical two-tail	1.979764	

72. Comparison of RT at end of shift in pre and post FRMS

t-Test: Two-Sample Assuming Unequal Variances

	B1RT	*A1RT*
Mean	386.1139	395.7049
Variance	6260.051	5963.945
Observations	79	61
Hypothesized Mean Difference	0	
df	131	
t Stat	-0.72088	
P(T<=t) one-tail	0.236133	
t Critical one-tail	1.656569	
P(T<=t) two-tail	0.472267	
t Critical two-tail	1.978239	

73. Comparison of Subjective and Objective sleep duration

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Spre M	25	200	8	6.9375
Spost M	24	194	8.083333	5.210145
Spre A	23	178	7.73913	4.201581
Spost A	20	147	7.35	4.002632
Spre N	21	120.225	5.725	3.361875
Spost N	21	120	5.714286	4.239286
Opre M	23	207.5	9.021739	6.738142
Opost M	22	198.5	9.022727	5.630411
Opre A	23	192.5	8.369565	3.504941
Opost A	16	136	8.5	6.033333
Opre N	15	89.5	5.966667	1.695238
Opost N	20	117.5	5.875	3.601974

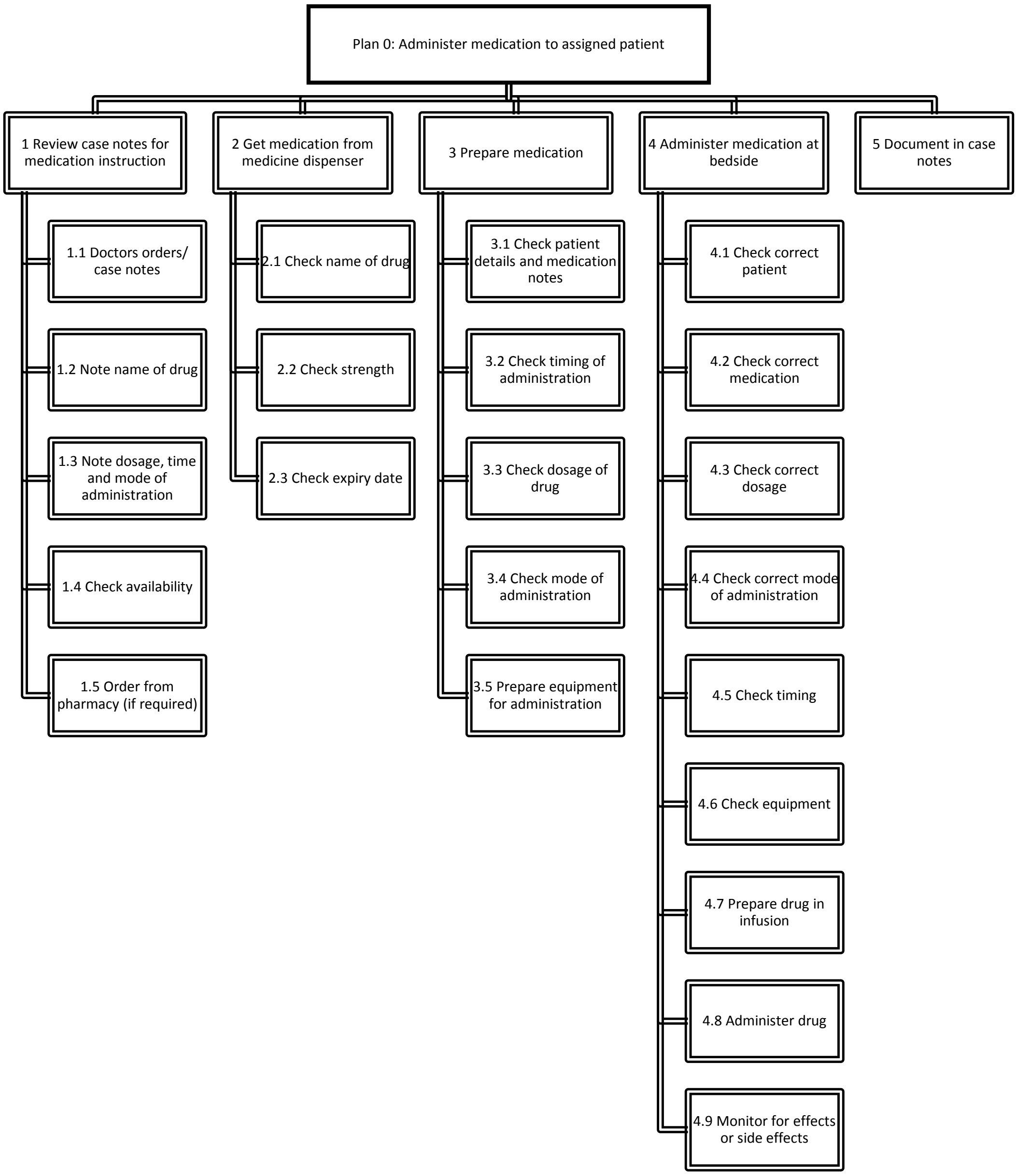
ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	375.0109	11	34.0919	7.251044	1.14E-10	1.828528
Within Groups	1133.099	241	4.701654			
Total	1508.11	252				

74. Age

	Subject Age
Mean	26.77143
Standard Error	0.786531
Median	26
Mode	24
Standard Deviation	4.653182
Sample Variance	21.6521
Kurtosis	12.31719
Skewness	2.953507
Range	27
Minimum	21
Maximum	48
Sum	937
Count	35
Largest(1)	48
Smallest(1)	21

Appendix XII Task Analysis of Medication Administration



Plan 0 (Administer medication to assigned patient): Do 1 then 2 then 3 then 4 then 5

Plan 1 (Review case notes for medication instruction): Do 1.1 then 1.2 then 1.3 then 1.4 then 1.5

Plan 2 (Get medication from medication dispenser): Do 2.1 then 2.2 then 2.3

Plan 3 (Prepare medication): Do 3.1 then 3.2 then 3.3 then 3.4 then 3.5

Plan 4 (Administer medication at bedside): Do 4.1 then 4.2 then 4.3 then 4.4 then 4.5 then 4.6 then 4.7 then 4.8 then 4.9