MEASURING NURSES’ RESPONSE TO CONFIGURATIONS
OF WORK SYSTEM PARAMETERS
A DATA MINING APPROACH

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Doctor of Philosophy

by
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MAY 2014
The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled:

**MEASURING NURSES’ RESPONSE TO CONFIGURATIONS OF WORK SYSTEM PARAMETERS**
**A DATAMINING APPROACH**

Presented by Shaghayegh Parhizi,

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it is worthy of acceptance.

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Dedication

This dissertation is dedicated to my husband, Mahmood Pariazar and my parents, Ali Parhizi and Fatemeh Jamshidi-Eini for all of their support, inspiration, and love.
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MEASURING NURSES’ RESPONSE TO CONFIGURATIONS OF WORK SYSTEM PARAMETERS
A DATA MINING APPROACH

Shaghayegh Parhizi

Dr. Linsey M. Barker Steege, Dissertation Supervisor

ABSTRACT

Medical error, patient safety and nurses’ performance are some of the critical concerns within healthcare systems. Several factors contribute to nurses’ performance and patient safety including fatigue, sleepiness and work system parameters.

Furthermore, because of a shortage of nurses, working nurses are often experiencing high workloads. They often work in 12-hour shifts and/or consecutive night shifts without receiving enough sleep or recovery. Thus, they frequently are fatigued and suffer from sleep deprivation, which again is negatively associated with patient safety. Therefore, health care researchers and decision makers are interested in developing policies and tools that help decrease nurses’ errors and increase their performance.

Thus, there is a need for a promising approach to understanding nurse fatigue and its causes and consequences that is able to capture dynamic nature of the problem. This study aimed to address this need. In the first step, data were collected from a private hospital. Next, a data mining technique was applied to uncover the patterns and associations among contributing factors that affect performance and patient safety. Finally, a model was developed to measure nurses’ responses to different work system parameters and stressors.
Chapter 1. Introduction

Nurses play a significant role in health care delivery and patient safety as they are the primary caregivers in hospitals (Page, 2004). They also have the most direct contact with patients (Page, 2004). Quality of care and patient safety are two of the current challenges and focus areas within the healthcare industry. Due to their role in patient care, nurses and their performance should be considered to address patient safety. Nurses’ performance is affected by a variety of factors and variables such as fatigue (Barker and Nussbaum, 2011; Pasupathy and Barker, 2011; Rogers, 2008), sleepiness (Rogers, 2008; Suzuki et al., 2005), work system parameters (Rogers, 2004; Rogers et al., 2004; Scott et al., 2006), mental and physical workload (Carayon and Gurses, 2005) and stress (Mcvicar, 2003).

A review of the literature indicates that a number of studies have been done investigating the relationships between fatigue, sleepiness and work system parameters; as well as their associations with performance and safety among nurses or other groups of workers (Barker and Pasupathy, 2010; Barker and Nussbaum, 2011; Barker Steege and Nussbaum, 2012; Geiger-Brown et al., 2012; Pasupathy and Barker, 2011; Rogers et al., 2004; Rogers et al., 2004; Rogers, 2008; Rogers, 2004; Rogers et al., 2004; Scott et al., 2006). However, most of these studies presented conceptual models and did not try to measure and quantify the level of associations. Therefore, little is known about what specific configuration of work system parameters and/or what specific levels of fatigue and sleepiness are associated with significant changes in performance; for example, how much change in fatigue is needed to see a significant change in perceived performance.
and safety? Also, what specific configuration of work system parameters is associated with significant changes in fatigue and sleepiness? Although some studies (Barker and Pasupathy, 2010; Barker and Nussbaum, 2011; Pasupathy and Barker, 2011) addressed some of these questions, more research is needed to quantify and measure the associations between fatigue, sleepiness, work system parameters, performance and patient safety.

Therefore, a comprehensive study that investigates the interactions and relationships between factors contributing to nurse fatigue and sleepiness and changes in performance and safety is needed. For the proposed work, fatigue, sleepiness and work system parameters (e.g. shift hours, shift schedule and work setting), were chosen for investigation in order to develop a model of how these factors interact to influence hospital nurse performance and patient safety. Thus, this research aimed to address the following research questions:

1) How does nurses’ performance change considering different fatigue levels and sleepiness?

2) How does sleepiness relate to fatigue state?

3) How do work system parameters relate to fatigue state, sleepiness, performance and patient safety among hospital nurses?

4) What are the levels of fatigue states, sleepiness variables, performance and patient safety under different configurations of work system parameters?
In order to address these four questions two different methods were applied, namely data mining and prediction modeling. The research questions and proposed methods are shown in Table 1-1.

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Overall, the study had three specific aims:
1.1 Aims

1.1.1 Aim 1: Identify, quantify and measure the associations among fatigue states, sleepiness, performance and patient safety among registered nurses.

The first aim of this study was to uncover the hidden associations and relationships among sleepiness and fatigue, fatigue and performance, fatigue and patient safety, sleepiness and performance and finally sleepiness and patient safety. We were interested in understanding how different sleepiness related variables relate to fatigue states to better understand differences in variables in one state compared to another. Additionally, little is known about what specific level of fatigue states and sleepiness are associated with significant changes in performance and patient safety. Thus, in this study we were interested in measuring and quantifying the associations among these constructs. Data mining techniques were used to uncover the hidden associations.

1.1.2 Aim 2: Identify, quantify and measure the associations among different configurations of work system parameters and fatigue states, sleepiness, performance and patient safety among registered nurses.

The results of previous studies show that there are relationships and associations among work system parameters and the discussed constructs in Aim 1 (Barker and Pasupathy, 2010; Dorrian et al., 2006; Geiger-Brown et al., 2012; Rogers et al., 2004; Rogers, 2004; Rogers et al., 2004). However, there is less known about how states of fatigue, sleepiness, work system parameters, performance and patient safety can be related to each other simultaneously and while considering their mutual effects. Additionally, little is known about what specific configurations of work system
parameters are associated with significant changes in performance and patient safety or levels of fatigue states and sleepiness. Therefore, this study intended to quantify and measure the effects among fatigue states (acute, chronic), sleepiness, different configurations of work system parameters (e.g. shift length, shift schedule, primary role of the nurses, working on call, working more than scheduled work), performance and patient safety. Data mining techniques were applied to discover and extract the unknown relations, associations and trends among these constructs.

1.1.3 Aim 3: Model nurses’ response (fatigue, sleepiness, performance and patient safety) to different configurations of work system parameters

The third purpose of this study was to model the nurses’ response to different configurations of work system parameters. It was intended to measure the level of fatigue states, sleepiness, and performance and patient safety by setting up different configurations of work parameters. For achieving this purpose, the associations that were identified in the first and second aims were applied to formalize, design, initialize and build a prediction model. This model could be applied to measure the level of fatigue states, sleepiness related variables, levels of performance and patient safety in response to changing the work system parameters.

Overall, the results of this study help to measure and quantify the levels of fatigue, sleepiness, performance and safety associated with different configurations of work system parameters. These results also help to measure and quantify the interactions and associations between sleepiness and fatigue. Finally, the results of this study identify
and quantify the levels of fatigue, sleepiness and different configurations of work system parameters associated with varying levels of performance and patient safety.

The first innovation of this study was the selection of the constructs to be studied, which help us to better understand the performance and patient safety measures in hospital nurses and the association between these two factors and undesirable factors like fatigue and sleepiness. Such an approach gives us an improved understanding of how configurations of work system parameters can play a role in increasing or decreasing the levels of fatigue, sleepiness, performance and safety among nurses. The second innovation of this study is focusing on the nurses as part of a system and not as isolated individuals. Thus, each nurse is affected by variety of input factors such as work system parameters, personal and demographic characteristics, workload and psychosocial stressors. Fatigue, sleepiness, performance, patient safety, burnout, stress and well-being are outputs of the system. However, only fatigue, sleepiness, performance and patient safety were selected for this study to have a manageable scope of study and also due to the fact that increased fatigue levels and sleepiness are highly related to reduced performance and risks to patient safety and they are also direct outcomes of nurse shortages, and nurses’ excessive work load. In addition, patient safety and medical errors are some of the current challenges in healthcare industry. Thus, for this study, performance and patient safety, as well as fatigue and sleepiness because of their association with medical errors and quality of care, were selected to be investigated. Due to the scope of this study, we only investigated the associations among darker highlighted constructs (work system parameters as input, fatigue, sleepiness, performance and patient
safety as output) in this conceptual model (Figure 1-1). Further research is needed to study all associations.

Figure 1-1: Overall contributing input factors and outputs to nurse staff; darker highlighted boxes indicate the variables investigated in this dissertation
Chapter 2. Measuring the associations among nurses’ fatigue states, sleepiness, performance and patient safety

Abstract

Night shift work and long shift hours are common among nursing staff and significantly affect nurses’ level of fatigue and their sleep deprivation. In addition, research suggests that fatigue and sleepiness are negatively associated with nurses’ performance and patient safety. However, little is known about the level of association among these constructs. Thus, the aim of this study was to measure and quantify the level of association among fatigue and sleepiness, fatigue and performance, fatigue and patient safety, sleepiness and performance, and sleepiness and patient safety. Data mining, specifically Chi-squared Automatic Interaction Detection (CHAID), was used to investigate the relationships between the constructs. Significant associations were found among fatigue states and perceived performance and patient safety. Also, the results of this study show that sleep quality is more strongly associated with fatigue compared to sleep quantity. Negative correlations and significant associations have been found among fatigue states and perceived performance and patient safety. Also, when the level of acute fatigue is high, chronic fatigue is significantly associated with decreased performance. Further, sleep quality and sleep disturbances has been linked to significant changes in fatigue levels. Overall, the results of this study help to measure and quantify and better
understand the level of association among fatigue, sleepiness, performance and patient safety.

2.1 Introduction

The healthcare industry is encountering a nursing shortage and the aging population is also growing (Dorrian et al., 2008). Thus, nurses are exposed to excessive workload levels (Dorrian et al., 2008). They usually work extended shift hours and work more hours than scheduled during a week and they don’t receive enough breaks or have sufficient inter shift recovery (Dorrian et al., 2008). Due to these schedule and workload demands, nurses frequently suffer from sleep deprivation and poor sleep quality and are fatigued (Scott et al., 2010). They experience daytime sleepiness and decremented alertness on duties or when driving to work or to home (Scott et al., 2010). For example, during 28 days of data collection in a hospital, more than 66% of the nurse staff experienced at least once “Struggling to stay awake on duty” (Rogers et al., 2003; Scott et al., 2006; Scott et al., 2010). Another study shows that the prevalence of sleepiness among hospital nurses is 26% (Suzuki et al., 2005).

Furthermore, these high levels of fatigue and sleepiness have also been associated with increases in errors and risks to patient safety. Specifically, sleepiness and reduced performance and bad patient safety outcomes are positively related (Suzuki et al., 2005). There is a significant relationship between daytime sleepiness and occupational accidents (Suzuki et al., 2005). In addition, the relation between perceived performance and
perceived levels of fatigue is significantly negative (Barker and Nussbaum, 2011; Pasupathy and Barker, 2011). Thus, for enhancing and improving nurses’ performance and patient safety, there is a need to better understand fatigue and sleepiness and their association with each other as well as performance and patient safety.

Fatigue and sleepiness are two common syndromes among shift workers like nurses (Bosch and De Lange, 1987; Novak and Auvil-Novak, 1996; Ruggiero, 2003; Scott et al., 2006; Scott et al., 2010). One simple and commonly accepted definition of sleepiness is “one’s tendency to fall asleep, also referred to as sleep propensity” (P.64) (Shen et al., 2006, p.64). Further, although fatigue and sleepiness are highly related, the most currently accepted definitions define fatigue and sleepiness as two distinct constructs (Shahid et al., 2010; Shen et al., 2006). Fatigue is a multi-state and complex construct, which makes it difficult to present a unique or accepted definition of it across contexts. However, fatigue has been generally defined as a protective reaction caused by prolonged activity, which is affected by a variety of psychological, socioeconomic, and environmental factors (Soh and Crumpton, 1996; Tiesinga et al., 1996). Furthermore, fatigue has two different states; acute and chronic. Acute fatigue is usually a short-term condition, that will be relieved after a short period of rest (Shen et al., 2006). Chronic fatigue on the other hand, will not be relieved after a short period of rest or exercise and it will affect the quality of life and daily activities of people (Shen et al., 2006). In this study, we aimed to investigate the relation between fatigue states and sleepiness related variables to better understand how different sleepiness related variables relate to fatigue states.
In addition, fatigue and sleepiness have both been linked to nurses’ performance and patient safety, and occurrence of adverse events in hospitals (Barker and Nussbaum, 2011; Rogers, 2008). A review of the literature indicates that a number of studies have been done investigating the relationships between fatigue, sleepiness, performance and patient safety (Barker and Nussbaum, 2011; Landrigan et al., 2004; Lockley et al., 2004; Rogers, 2008). Although, there are some fundamental models and concepts of the relationships between each pair of – fatigue, sleepiness, performance, and patient safety, most of these models presented these constructs in isolation and are not able to capture the dynamics and mutual influences among these constructs. For example, it has been demonstrated that sleepiness and performance have negative relationships but little is known about how specific changes in the level of sleepiness (for example frequency of daytime dysfunction) might contribute to specific changes in the levels of performance. Human factors such as fatigue, sleepiness, and performance are complex constructs due to the diversity of contributing factors. Human behavior and performance are dynamic and are affected by variety of contributing factors such as fatigue and sleepiness. Thus, there is a need for a comprehensive model that simultaneously includes the relationships and associations between all these constructs.

Specifically, by identifying the associations between sleepiness and fatigue, we can better understand how different sleepiness related variables relates to fatigue states and also differences between associated sleepiness variables in one state of fatigue compared to another. This better understanding of fatigue states is important to study and understand the consequences of the differing effects of acute and chronic fatigue. Additionally, little is known about what specific levels of fatigue states and sleepiness are
associated with significant changes in performance and patient safety. This investigation may help healthcare organizations to better understand the level of significant changes in nurses’ performance and their patient safety by making policies/decisions to change the level of fatigue and sleepiness among them.

In addition, in this study, we chose both performance and patient safety to investigate because performance captures the effect on the nurse as an individual and patient safety captures the outcomes. Specifically, patient safety demonstrates nurses’ perception of how well safety culture is established in their hospital (The Agency for Healthcare Research and Quality, 2011), while performance shows nurses’ perception of their own performance (Barker and Nussbaum, 2011).

In order to evaluate the multi-factor relationships between these constructs, data mining methods were used. Data mining techniques can be used to discover complex relationships and associations in databases. Data mining techniques are usually applied to discover the possible relations, useful and accurate trends and patterns among large amounts of data (Berry and Linoff, 2004). Unlike statistics tools, data mining techniques do not require researchers to have a hypothesis a priori, thus they allow for exploration and can uncover unexpected patterns in data (Kovalerchuk and Vityaev, 2002). Because of these advantages, data mining techniques are a valuable tool to discover complex relationships among factors in health care (Cheung et al., 2002), and specifically in our study since we are exploring four different constructs.

Several existing studies have applied data mining techniques to analyze nursing data. Duan et al. (2008) proposed using correlations between nursing diagnoses,
outcomes, and interventions to design a recommender system in order to provide clinical decision support, nursing education, clinical quality control and, in general, a nursing care plan (Duan et al., 2008). Kaur and Wasan (2006) discussed the potential use of classification based data mining techniques, such as rule based, decision tree and artificial neural networks to massive volumes of healthcare data (Kaur and Wasan, 2006). In particular, they considered a case study of using classification techniques on children with diabetes mellitus and diabetes insipidus (Kaur and Wasan, 2006). Goodwin et al. (2003) discussed using data mining methods to build knowledge in nursing (Goodwin et al., 2003). The authors believed that using such a technique will make a significant difference in nurses’ knowledge and this knowledge can be applied to configure a clinical information system (Goodwin et al., 2003). Beckstead (2002) used other data mining techniques like cluster analysis to study what nurses think about working with coworkers whose professional performance is impaired due to drug or alcohol problems (Beckstead, 2002). Sundaramoorthi et al. (2006) Classification and Regression Trees to Estimate Transitions in a Nurse Activity Simulation model. Barker and Pasupathy (2010) also used a decision tree classification method to identify multifactor relationships between specific work system parameters and physical, mental and total dimensions of fatigue. Paupathy and Barker (2011) also used a decision tree classification method to investigate the relationships between multiple dimensions of fatigue and perceived performance in registered nurses. Parhizi et al (2013) also applied a decision tree classification method (CHAID) to investigate the associations between psychosocial factors and fatigue dimensions among registered nurses. Thus, data mining techniques have been effective in identifying relationships amongst data in nursing contexts. However, the majority of
these studies focused on clinical or medical data related to patient care and diagnostic classification. Relatively fewer studies have applied data mining techniques to understanding relationships between multiple human factors such as nurse fatigue, sleepiness, performance and patient safety.

Overall, the aim of this study was to identify and quantify the associations and relationships among sleepiness and fatigue, fatigue and performance, fatigue and patient safety, sleepiness and performance, and finally sleepiness and patient safety.

2.2 Method

2.2.1 Data collection

In order to quantify levels of fatigue, sleepiness, nurse performance, and patient safety, a survey study was conducted. Registered nurses (RNs) currently employed in a large acute care private hospital were eligible to participate. The survey was administered and data collection occurred between November 2011 and February 2012. A total of 1000 RNs were invited to participate and 420 RNs completed some portion of the survey for a response rate of 42%. The survey consisted of 100 items relating to nurse demographics, fatigue, sleepiness, work system parameters, performance, patient safety, stress and well-being. The entire survey set was designed in conjunction with a team of nurse researchers and practicing nurses from the target hospital. For the purposes of this study, items related to demographic data, including gender, age, ethnic identity, marital status, experience and education are considered and
presented here as a description of the sample. A majority of nurses who participated in this study were female (94.2%). The maximum age among participants was 76 years old, while the youngest nurse was 23 years old. The mean age was 46.15 years and standard deviation was 11.4. The distribution of racial identity among participants was as follows: Whites (78.3%), Asian (13.6%), Hispanic (4.9%), Native Hawaiian or other Pacific Islander (2.3%), Black or African-American (0.6%) and American Indian or Alaskan Native (0.3%). A majority of respondents reported being married/partnered (74.2%); 13.6% of nurses were divorced/currently single, 9.6% of nurses were single never married/partnered, and 2.6% of nurses were widowed/currently single. The mean of years of experience among participants was 16.9 years and the standard deviation was 11.4 years. The distribution of degree among participants was as follows: Associate Degree Nursing (ADN) (49.3%), Bachelor Nursing Degree (BSN) (40.1%), Masters in Nursing (9.7%), Doctor of Philosophy (0.6%) and Doctor of Nursing Practice (0.3%).

In addition, to ensure comprehensive measurement of fatigue dimensions and states, items from different instruments including the Chalder Fatigue Scale (Chalder et al., 1993), the Occupational Fatigue Exhaustion Recovery scale (Winwood et al., 2005), and the Professional Quality of Life (ProQOL) were included in the survey. For measuring sleepiness variables, the Pittsburgh Sleep Quality Index (Buysse et al., 1989) and Epworth Sleepiness Scale (Johns, 1991) were used. The AHRQ Hospital Survey of Patient Safety was also included for covering the hospital safety practice, supervisor support, communication, as well as unit safety practices (Sorra and Nieva, 2004). The registered nurses’ perceived performance was quantified using the Nursing Performance Instrument (NPI) (Barker and Nussbaum, 2011). The entire survey set and study design
were approved by the local Institutional Review Board. However, the current study analysis only used items from the Occupational Fatigue Exhaustion Recovery scale (OFER) for measuring fatigue states, the Pittsburgh Sleep Quality Index (PSQI) for measuring sleepiness, the AHRQ Hospital Survey of Patient Safety for measuring patient safety culture (AHRQ) and the Nursing Performance Instrument (NPI) for measuring nurses’ perception of their performance. A detailed overview of OFER, PSQI, AHRQ and NPI is provided below.

- **The Occupational Fatigue Exhaustion Recovery (OFER) scale:**

  The Occupational Fatigue Exhaustion Recovery (OFER) scale has been applied to measure fatigue states including: chronic fatigue, acute fatigue, and inter-shift recovery in shift-workers (Winwood et al., 2005). Fifteen different items are included in this questionnaire as published and the responses range from 0=strongly disagree to 6=strongly agree based on the worker’s experiences of fatigue at work and home (Winwood et al., 2005). However, the version of the questionnaire used in the survey for the current study does not contain the first item of OFER and is coded from 1=strongly disagree to 6= strongly agree. To allow for comparable results to other previously published papers, the coding scale from the current survey was altered during data processing as follows: 1=0, 2=1, 3=2, 4=4, 5=5, 6=6. Thus, we have not recorded any answer for “neither agree nor disagree” because we did not want to include a neutral response. The mean scores of contributing items for each fatigue state subscale (acute fatigue, chronic fatigue, and intershift recovery) multiplied by 100 were used to obtain a
final overall score for each fatigue state subscale. These subscale scores range between 0 = lowest level to 100= highest level.

The OFER and all three subscales have been previously tested among healthcare workers and the results show that the OFER has high internal and test-retest reliability, and is free of gender bias (Winwood et al., 2005). Also, it has been shown that this questionnaire is able to measure and identify the fatigue states among shift workers (Winwood et al., 2005).

- **Pittsburgh Sleep Quality Index**

The Pittsburgh Sleep Quality Index consists of nineteen individual items and measures a global sleep quality score as well as seven components, including: sleep efficiency, sleep disturbance, daytime dysfunction, sleep latency, sleep duration, sleep quality, use of sleeping medications (Buysse et al., 1989). Each item is scored from zero to three and each component also is rated from zero to three. For sleep disturbances, daytime dysfunction and sleep latency, zero is equal to the lowest frequency of occurrence and three is equal to the highest frequency of occurrence. Sleep efficiency score ranges between 0 = >85%, 1= 75-84%, 2 = 65-74%, 3= <65%. Sleep duration scores are defined as follows: 0= >seven hours, 1= six-seven hours, 2= five-six hours and 3= <five hours. Sleep quality scores range from: 0= very good, 1=fairly good, 2=fairly bad, to 3=very bad. Finally, use of sleeping medications is scored as follows: 0= not during the past month, 1= less than once a week, 2= once or twice a week and 3= three or more times a week. The biggest advantage of this instrument is that it provides evaluation
of sleep quality and sleep dysfunction using both qualitative and quantitative data and also generates a unique global score for severity of sleep problems by adding the seven components together (Carpenter and Andrykowski, 1998).

For this study, we only used six components including: sleep efficiency, sleep disturbance, sleep latency, sleep duration, sleep quality, use of sleeping medications. Daytime dysfunction was not included due to the fact that daytime dysfunction is more like an outcome caused by sleepiness, while sleep quality, sleep disturbances and the other components act as contributors to overall sleepiness.

The Pittsburgh Sleep Quality index has been established to be both reliable and valid using Cronbach’s alpha coefficient and Pearson correlation coefficient, respectively (Carpenter and Andrykowski, 1998).

- **Nursing Performance Instrument (NPI):**

  The Nursing Performance Instrument was used to evaluate nurses’ perceptions of their performance using nine items. Items are rated on a six-point response scale ranging from 1=Strongly Disagree to 6=Strongly Agree (Barker and Nussbaum, 2011). This instrument was developed based on a review of other existing tools (Schwirian 1978, Bertram et al. 1990, 1992, Battersby & Hemmings 1991, Garland 1996, Lerner et al. 2001) and was evaluated for content validity by multiple nurses and found to be reliable in a previous survey study of RNs (Barker and Nussbaum, 2011). The advantage of this instrument is that it contains item specifically related to clinical tasks. For the purpose of this study, we used the mean of ratings across the nine items as the overall performance
score. Overall performance score ranges between 1= lowest performance level and 6= highest performance level.

- **The AHRQ Hospital Survey of Patient Safety**

  The Agency for Healthcare Research and Quality (AHRQ) Hospital Survey of Patient Safety was included to assess nurses’ points of view of patient safety in their hospital. This survey was designed by the Agency for Healthcare Research and Quality after reviewing research related to safety, patient safety, error and accidents, and error reporting. Several published and unpublished safety culture assessment questionnaires were also studied to establish the Hospital Survey of Patient Safety (The Agency for Healthcare Research and Quality, 2011). In addition, this instrument has been established as both reliable and valid (Blegen et al., 2009).

  This instrument contains 42 items with response scales ranging from 1=strongly disagree to 5=strongly agree. The scoring system for this instrument includes twelve sub-scales. In each sub-scale the percentage of positive responses is considered as the overall score for that sub-scale. Based on the structure of each item, nurses who responded strongly disagree, disagree, or somewhat disagree were considered as negative respondents and other nurses as positive respondents, or vice versa. In addition, the items in the survey for the current study were coded slightly differently, as 1=strongly disagree to 6=strongly agree. For the purpose of this study, we only used the overall perceptions of patient safety subscale for measuring the levels of patient safety in the hospital to have a better understanding of nurses’ perception of overall patient safety level in the hospital.
2.2.2 Descriptive analysis

Following data collection, data were reviewed in collaboration with nursing researchers and practicing nurses from the target hospital and data cleaning and scoring procedures were completed. Errors in data were identified and eliminated for example mark instead of a digit or unacceptable value for years of experience and then, the coding scales were adjusted to follow the original coding system of previously published instruments. Scoring for each construct included in this study was performed based on previously published criteria for each instrument (as described above). List wise deletion was used to handle missing data across all instruments. Descriptive statistics for the each construct are included below (Tables 2-1 through 2-2).

All fatigue related sub-variables, nurse performance, and patient safety are measured as continuous variables and range between 0-100, 1-6 and 0-100, respectively. Table 2-1 shows a summary of descriptive statistics for fatigue, nurse performance, and patient safety. The number of respondents to each variable, mean, standard deviation and range of each variable are shown in this table. Sleepiness related variables are coded as discrete variables and a summary of descriptive statistics for them is shown in Table 2-2. Each sleepiness related variable is coded as an integer value between [0, 3]. Table 2-2 shows the percentage of participants responding for each choice level for each sleepiness related sub-variable.
Table 2-1: Descriptive statistics of continuous variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Instrument</th>
<th>Sub-Variables</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>Occupational Fatigue Exhaustion Recovery (OFER)</td>
<td>Chronic</td>
<td>310</td>
<td>39.33</td>
<td>25.35</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acute</td>
<td>277</td>
<td>51.25</td>
<td>20.09</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intershift Recovery</td>
<td>291</td>
<td>56.59</td>
<td>22.02</td>
<td>0-100</td>
</tr>
<tr>
<td>Performance</td>
<td>Nursing Performance Instrument (NPI)</td>
<td></td>
<td>280</td>
<td>4.62</td>
<td>0.74</td>
<td>1-6</td>
</tr>
<tr>
<td>Patient safety</td>
<td>AHRQ Hospital Survey of Patient safety</td>
<td></td>
<td>260</td>
<td>69.423</td>
<td>27.04</td>
<td>0-100</td>
</tr>
</tbody>
</table>

Due to the fact that none of the variables from the survey were normally distributed, a Spearman correlation analysis was applied to evaluate the directionality and strength of the relationships between fatigue, sleepiness, performance and patient safety.

Table 2-2 shows the Spearman correlation coefficients among the sub-variables of all variables.
constructs. All the correlations among these constructs are significant at 0.01 and 0.05 except the correlations between intershift recovery and sleep efficiency, performance and sleep efficiency, performance and sleep duration, performance and sleep latency, sleep efficiency and sleep latency, sleep efficiency and sleep medication, sleep duration and sleep latency, sleep duration and sleep medication and sleep duration and patient safety.
Table 2-3: Spearman correlation values among sub-variables included in the study

<table>
<thead>
<tr>
<th></th>
<th>OFER Chronic Fatigue</th>
<th>OFER Acute Fatigue</th>
<th>OFER Intershift Recovery</th>
<th>Performance</th>
<th>Patient Safety</th>
<th>Sleep Efficiency</th>
<th>Sleep Disturbances</th>
<th>Sleep Latency</th>
<th>Sleep Duration</th>
<th>Sleep Quality</th>
<th>Sleeping Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFER Chronic Fatigue</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFER Acute Fatigue</td>
<td>.640**</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFER Intershift Recovery</td>
<td>-.534**</td>
<td>-.630**</td>
<td>1.000</td>
<td>-.415**</td>
<td>-.468**</td>
<td>.405**</td>
<td>-.201**</td>
<td>-.259**</td>
<td>.144*</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.422**</td>
<td>.404**</td>
<td>.541**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient Safety</td>
<td></td>
<td></td>
<td></td>
<td>-.422**</td>
<td>-.419**</td>
<td>.404**</td>
<td>.541**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Efficiency</td>
<td>.195**</td>
<td>.173**</td>
<td>-.058</td>
<td>-.043</td>
<td>-.188**</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Disturbances</td>
<td>.316**</td>
<td>.215**</td>
<td>-.316**</td>
<td>-.201**</td>
<td>-.259**</td>
<td>.144*</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Latency</td>
<td>.216**</td>
<td>.198**</td>
<td>-.333**</td>
<td>-.101</td>
<td>-.180**</td>
<td>.076</td>
<td>.281**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep Duration</td>
<td>.113</td>
<td>.161**</td>
<td>-.158**</td>
<td>.043</td>
<td>-.042</td>
<td>.366**</td>
<td>.145*</td>
<td></td>
<td>.104</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>.285**</td>
<td>.361**</td>
<td>-.461**</td>
<td>-.142*</td>
<td>-.204**</td>
<td>.219**</td>
<td>.246**</td>
<td>.387**</td>
<td>.387**</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Sleeping Medication</td>
<td>.084</td>
<td>.140*</td>
<td>-.251**</td>
<td>-.164**</td>
<td>-.171**</td>
<td>.105</td>
<td>.258**</td>
<td>.346**</td>
<td>.086</td>
<td>.244**</td>
<td>1.000</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).
2.2.3 Analysis

Data mining, specifically Chi-squared Automatic Interaction Detection (CHAID), was applied to investigate the relationships between the constructs in this study. Chi-squared Automatic Interaction Detection (CHAID) is one of the oldest classification methods. Kass (1980) developed this tree method. At each step, the independent (predictor) variable that has the most significant relationship with the dependent variable will be selected by the CHAID algorithm. If two different groups of independent variables are not significantly different with regard to the dependent variable, then these groups will be merged (Berry and Linoff, 2004).

In the case of having missing values, CHAID first uses all non-missing values and builds the categories (IBM support portal). Then, missing values will be merged to the most similar category if possible (IBM support portal). Otherwise, the missing values will be added as a separate category (IBM support portal).

SPSS software (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp) was used to analyze the data. Table 2-4, shows the independent and dependent variables that were evaluated using CHAID. All possible relations between each independent and dependent variable shown in Table 2-4 were separately evaluated using CHAID classification trees. All CHAID classifications or splits were significant at p = 0.05. The minimum number of cases in parent nodes is set to be equal to 100 and for child nodes is 50 as default. Using the default values for databases with low number of cases may lead in trees with no nodes. Thus, because of the
low number of participants and to be able to explore the data, the minimum number of cases in parent nodes was set at 50 and 30 for child nodes.

Table 2-4: The independent and dependent variables for CHAID analysis

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>OFER Chronic Fatigue, OFER Acute Fatigue, OFER Intershift Recovery</td>
</tr>
<tr>
<td>Patient safety</td>
<td>OFER Chronic Fatigue, OFER Acute Fatigue, OFER Intershift Recovery</td>
</tr>
<tr>
<td>OFER Chronic Fatigue</td>
<td>Sleep Efficiency</td>
</tr>
<tr>
<td></td>
<td>Sleep Disturbances</td>
</tr>
<tr>
<td></td>
<td>Sleep Latency</td>
</tr>
<tr>
<td></td>
<td>Sleep Duration</td>
</tr>
<tr>
<td></td>
<td>Sleep Quality</td>
</tr>
<tr>
<td></td>
<td>Sleeping Medication</td>
</tr>
<tr>
<td>OFER Acute Fatigue</td>
<td>Sleep Efficiency</td>
</tr>
<tr>
<td></td>
<td>Sleep Disturbances</td>
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<td></td>
<td>Sleep Latency</td>
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<td></td>
<td>Sleep Duration</td>
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<tr>
<td></td>
<td>Sleep Quality</td>
</tr>
<tr>
<td></td>
<td>Sleeping Medication</td>
</tr>
<tr>
<td>OFER Intershift Recovery</td>
<td>Sleep Efficiency</td>
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<tr>
<td></td>
<td>Sleep Disturbances</td>
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<td></td>
<td>Sleep Latency</td>
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<td></td>
<td>Sleep Duration</td>
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<tr>
<td></td>
<td>Sleep Quality</td>
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<tr>
<td></td>
<td>Sleeping Medication</td>
</tr>
<tr>
<td>Performance</td>
<td>Sleep Efficiency</td>
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<td></td>
<td>Sleep Disturbances</td>
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<td></td>
<td>Sleep Latency</td>
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<td>Sleep Duration</td>
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<td></td>
<td>Sleep Quality</td>
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<tr>
<td></td>
<td>Sleeping Medication</td>
</tr>
<tr>
<td>Patient safety</td>
<td>Sleep Efficiency</td>
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<tr>
<td></td>
<td>Sleep Disturbances</td>
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<td></td>
<td>Sleep Latency</td>
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<td></td>
<td>Sleep Duration</td>
</tr>
<tr>
<td></td>
<td>Sleep Quality</td>
</tr>
<tr>
<td></td>
<td>Sleeping Medication</td>
</tr>
</tbody>
</table>
2.2.4 Results

All possible relations between each independent and dependent variable (Table 2-4) were separately evaluated using CHAID. Thus, seven trees were run (Figure 2-1 and Appendices I through VI). For clarity and conciseness in presenting the results of these analyses, all of the significant differences in each dependent variable relating to changes in independent variable levels identified using CHAID were depicted visually in Figures 2-2 through 2-8. For example, the associations found by the classification tree shown in Figure 2-1 relating fatigue to performance are depicted in Figure 2-2.

2.2.4.1 CHAID result for the relationships between fatigue states and performance

The result from the CHAID analysis for the relationships between performance measured by NPI and fatigue measured by OFER is shown in Figure 2-1. The overall mean rating of performance among 278 RNs who responded this scale is equal to 4.624. Overall, acute fatigue has the most significant association with NPI performance scores. As the level of acute fatigue increases, the level of performance decreases. For the group with the highest level of acute fatigue, chronic fatigue also has a significant association with performance. Chronic fatigue equal to 62.5 is the break point. The mean performance score among nurses with chronic fatigue levels less than 62.5 is significantly higher than nurses with levels of chronic fatigue more than 62.5.
Figure 2-1: CHAID result for the relationships between fatigue states and performance
The relationships between fatigue states and performance. Note: Red highlighted color shows lower level of performance. Green highlighted shows the higher level of performance. The corresponding tree is shown in Figure 2-1.

The relationships between fatigue and performance shown in Figure 2-2 demonstrate that there is a general trend of decreasing levels of performance when the level of acute fatigue increases and the level of chronic fatigue is constant. When the level of acute fatigue is in the maximum range (63.3 – 100), by increasing the level of chronic fatigue, the level of performance further decreases.
2.2.4.2 The relationships between fatigue states and patient safety

Figure 2-3: The relationships between fatigue states as independent variables and patient safety as the dependent variable. 
Note: Red highlighted color shows lower level of patient safety. Green highlighted shows the higher level of patient safety. The corresponding tree is shown in Appendix 1. Note: the most significant variable is shown on the X-axis.

The relationships between patient safety and fatigue are shown in Figure 2-3. This figure shows that acute fatigue also has the most significant association with patient safety. Increased levels of acute fatigue are associated with lower levels of patient safety. In addition, when the level of acute fatigue is less than or equal to 63.33, intershift recovery also has significant associations with patient safety. For a constant level of acute fatigue, by increasing the level of intershift recovery, the level of patient safety increases.
2.2.4.3 The relationships between sleepiness related variables and chronic fatigue

Figure 2-4: The relationships between sleepiness related variables as independent variables and chronic fatigue as the dependent variable.

Note: For sleep quality 0= very good, 1=fairly good, 2=fairly bad, to 3=very bad.
Note: Red highlighted color shows higher level of chronic fatigue. Green highlighted shows the lower level of chronic fatigue. The corresponding tree is shown in Appendix 2.
Note: the most significant variable is shown on the X-axis.

The relationships between sleepiness and chronic fatigue are shown in Figure 2-4. Sleep quality has the most significant association with chronic fatigue. When sleep quality is equal to zero or one (sleep quality is very good or fairly good), then sleep disturbances also has a significant association with chronic fatigue. For a constant level of sleep quality, by increasing the level of sleep disturbances, the level of chronic fatigue increases.
2.2.4.4 The relationships between sleepiness related variables and acute fatigue

Figure 2-5: The relationships between sleepiness related variables as independent variables and acute fatigue as dependent variable.
Note: For sleep quality 0= very good, 1=fairly good, 2=fairly bad, to 3=very bad.
Note: Red highlighted color shows higher level of acute fatigue. Green highlighted shows the lower level of acute fatigue. The corresponding tree is shown in Appendix 3.

The relationships between sleepiness and acute fatigue are shown in Figure 2-5. Sleep quality has the only significant association with acute fatigue. When the level of sleep quality is very good or fairly good (a rating of 0 or 1), the level of acute fatigue is lower compared to when the level of sleep quality is very bad or fairly bad.
2.2.4.5 The relationships between sleepiness related variables and intershift recovery

![Graph showing the relationships between sleepiness and intershift recovery]

Figure 2-6: The relationships between sleepiness related variables as independent variables and intershift recovery as the dependent variable.
Note: For sleep quality 0= very good, 1=fairly good, 2=fairly bad, to 3=very bad.
Note: Red highlighted color shows lower levels of intershift recovery. Green highlighted shows the higher levels of intershift recovery. The corresponding tree is shown in Appendix 4. Note: the most significant variable is shown on the X-axis.

The relationships between sleepiness and intershift recovery are shown in Figure 2-6. Sleep quality has the most significant association with intershift recovery and when sleep quality is equal to one (fairly good), sleep disturbances is also significantly associated with intershift recovery. When sleep quality is “very good” (a rating of 0), the level of intershift recovery is at its highest. By changing the level of sleep quality from
“very good” to “fairly good”, the level of intershift recovery decreases. When sleep quality is “fairly good”, sleep disturbances also has a significant association with intershift recovery. The level of intershift recovery is higher when the level of sleep quality is equal to “fairly good” and the level of sleep disturbances is “zero or one” compared to sleep quality is equal to “fairly good” and the level of sleep disturbances is “two or three”. By changing the level of sleep quality from “fairly good” to “very bad or fairly bad”, the level of intershift recovery decreases.

2.2.4.6 The relationships between sleepiness related variables and performance

Figure 2-7: The relationships between sleepiness related variables as independent variables and performance as the dependent variable. Note: The red highlighted color shows the lower level of performance. Green highlight shows the higher level of performance. The corresponding tree is shown in Appendix 5.

The relationships between sleepiness related variables and performance are shown in Figure 2-7. Sleep disturbances has the only significant association with performance. By increasing the level of sleep disturbances, the level of performance decreases.
2.2.4.7 The relationships between sleepiness related variables and patient safety

Figure 2-8: The relationships between sleepiness related variables as independent variables and patient safety as the dependent variable.
Note: Red highlighted color shows the lower level of patient safety. Green highlighting shows the higher level of patient safety. The corresponding tree is shown in Appendix 6.

The relationships between sleepiness and patient safety are shown in Figure 2-8. This figure shows that sleep disturbances has the only significant association with patient safety. By increasing the level of sleep disturbances, the level of patient safety decreases.

2.3 Discussion

In this study, the relationships between fatigue states, sleepiness related variables; performance and patient safety have been investigated using classification trees (CHAID).
The relationship between fatigue states and performance shows that acute fatigue has the most significant associations with nurses’ performance with increased levels of acute fatigue associated with performance decrements. Furthermore, the results of our study show that for nurses who experience the highest level of acute fatigue, chronic fatigue also has significant associations with performance decrements. Considering the current theoretical literature that shows prolonged and high level of acute fatigue generally leads to chronic fatigue in case of continues failure to recover adequately (McEwen B.S. and E., 1993; McEwen B.S., 1998; McEwen B.S. and T., 1999; Winwood et al., 2005; Winwood et al., 2006) and also the high correlation (0.640) among fatigue states confirms that there is a very high chance that nurses with high level of acute fatigue suffer from chronic fatigue and nurses with lower level of acute fatigue don’t suffer from chronic fatigue. Thus, in our findings, chronic fatigue relates to performance decrements when the level of acute fatigue is high.

In addition, the relationships between fatigue states and perceived patient safety have been investigated. The results also show that acute fatigue has the most significant association with nurses’ perception of patient safety and also increased levels of acute fatigue are associated with patient safety decrements. For lower levels of acute fatigue, intershift recovery also has significant associations with patient safety. Specifically, for nurses with lower levels of acute fatigue, higher recovery between shifts is associated with increased patient safety. The reason that the results of this study do not support any associations between chronic fatigue and patient safety might be because of the lower levels of chronic fatigue compared to acute fatigue among participants in this study or the small sample size of the current study. Thus, we were not able to capture the associations
between chronic fatigue and patient safety. However, the result of this study shows that the correlation between chronic fatigue and patient safety is significant (-0.422).

Further, the relationships between fatigue states and sleepiness also have been investigated. We were interested in understanding how different sleepiness related variables relate to fatigue states to better understand differences in variables in one state compared to another. The results of this study show that there is no difference among sleepiness related factors that relate to fatigue states. Rather, the results show that sleep quality and sleep disturbances have the most significant associations with both acute and chronic fatigue states and also intershift recovery. Interestingly, sleep duration was not among the significant predictors of fatigue states. However, sleep duration is significantly correlated with acute fatigue (0.161) and intershift recovery (0.158). Nurses who receive more than six hours of sleep have significantly lower levels of chronic and acute fatigue and higher levels of intershift recovery compared to nurses who receive less than six hours of sleep. Previous studies show that, acute fatigue transits to chronic fatigue when adequate after shift recovery is not persistently achieved (Mcewen B.S. and E., 1993; Mcewen B.S., 1998; Mcewen B.S. and T., 1999; Winwood et al., 2005; Winwood et al., 2006). The results of this study show that sleep quality is more strongly associated with recovery and also fatigue states compared to sleep quantity. The results of previous studies also confirm stronger associations between health, well-being, fatigue and sleepiness defined by sleep quality compared to sleep quantity (Pilcher et al., 1997). Thus, adequate recovery will help to decrease the level of acute and chronic fatigue.

In addition, the relationships between performance and sleepiness and patient safety and sleepiness have been investigated. The results of the study demonstrated that
sleep disturbances is the most significant predictor of nurses’ performance and nurses’ perception of patient safety. However, the difference of mean performance scores among two groups of nurses (nurses who don’t experience sleep disturbances or experience rarely compared to nurses who experience sleep disturbances regularly) is not large (0.289). Sleep disturbances could be the cause of receiving few hours of sleep and/or less quality of sleep during the night. Previous research shows that sleep disturbances lead to lack of sleep and result in increased levels of fatigue (Akerstedt, 1988). However, since in the current literature, the relationships between sleep disturbances, patient safety, nurses’ performance and medical errors have not largely been investigated; future study is needed to explore the possible association between sleep disturbances and discussed constructs.

While our findings did not identify sleep duration, sleep quality or the global PSQI score as a significant predictor of performance, previous research has found significant associations between above constructs. For example, a study shows that residents who received 5 hours or less of sleep per night are more likely to report experiencing use of sleeping medication, and also encountered increased accident reports and medication errors and performance decrements (Baldwin and Daugherty, 2004). Another study also investigated the relationships between sleep quality and cognitive performance and found that they are negatively associated (Nebes et al., 2009). The sleep quality for Nebes’s study was evaluated using Pittsburg Sleep Quality Index (PSQI) and they considered PSQI ≤5 as the good sleepers and PSQI>5 as the bad sleepers (Nebes et al., 2009). To better understand our findings in the context of previous work, we ran an additional CHAID analysis between global PSQI and performance. The investigation of
the relationships between global PSQI and performance support the results of the Nebes’s study. PSQI=5 is where the changes of performance occurs between good and poor sleepers in our study. The level of performance for PSQI <=5 is 4.904 and the level of performance for PSQI>5 is 4.516. Thus, using this threshold might be useful for future researches aimed at monitoring nurses’ sleepiness and fatigue. This threshold could be applied as a risk point for job assignments to manage risks and increase performance. However, performance in this study was measured based on nurses’ perception of their own performance. Thus, future work is needed to relate this threshold to rates of errors or other objective measurements of performance.

It is important to note that this study has some limitations. First, due to the challenges of successfully implementing longitudinal surveys, the data for the current study was collected using a cross sectional survey. Collecting data for future studies using a longitudinal survey will have considerable analytical advantages. It will help researchers to observe individual trends of change. It also provides more accuracy for predicting desired outcomes. Second, the variables of this study were measured subjectively. For example, the level of performance and patient safety were measured by nurses’ perception of their own performance or overall patient safety in the organization. However, future work is needed to apply the actual number of errors or nurses’ performance to investigate the associations among constructs in this study. In addition, the sample size of this study was a limitation. Among 1000 nurses who were asked to participate only 420 nurses were answered to some part of survey. Also, there were several missing values due to the length of survey and/or participants’ unwillingness to answer. Therefore, a larger sample size will help to capture the associations among the
constructs of this study more accurately. Also, future work is needed for practical use of this study’s finding to help nurse managers in designing of hospital nurse work systems and work assignment.

2.4 Conclusion

In this study, the relationships between fatigue states, sleepiness, performance and patient safety have been investigated using classification trees (CHAID). Overall, the results of this study help to measure and quantify the associations among fatigue states, sleepiness, performance and patient safety and help to better understand these constructs as well as their relationships. Overall negative correlations and significant associations were found among fatigue states and perceived performance and patient safety. Findings of this study shows that chronic fatigue relates to performance decrements when the level of acute fatigue is high. Sleep quality and sleep disturbances were also associated with significant changes in fatigue levels. Sleep disturbances was the only sleepiness related variable that was linked to significant changes in performance and patient safety levels. Future study is needed to better understand the possible association between sleep disturbances and discussed constructs in the current study. Also, by investigating the association between global PSQI and performance using CHID, a threshold was found that could be useful for future researches aimed at monitoring nurses’ sleepiness and fatigue. However, future work is needed to relate this threshold to rates of errors or other objective measurements of performance.
Chapter 3. Quantifying the associations between work system parameters, fatigue, sleepiness, performance and patient safety

Abstract

Literature has linked parameters of a work system such as shift length, shift type and shift schedule to changes in fatigue levels, sleepiness, performance and patient safety. This study attempts to clarify and measure the levels of associations among work system parameters and these constructs. Data mining, specifically the Chi-squared Automatic Interaction Detection (CHAID) algorithm was used to uncover the hidden patterns and associations among these variables.

When evaluating how changes in work system parameters were significantly associated with changes in fatigue states, sleepiness related variables, performance and patient safety, there were differences across work system parameters linked to the discussed constructs. For example, there were not any significant associations among performance and work system parameters while shift schedule was related to patient safety. In addition, sleep latency was not significantly related to work system parameters while several parameters of work system such type of shift work (day or night), overtime hours, intensity of nursing care needed in the unit, in different levels of significance were related to sleep efficiency. Nurses’ satisfaction with job schedule also was significantly associated with decreased fatigue levels and increased patient safety. Overall, the results of this study measured and quantified the level of associations between these constructs.
and helped to clarify and better understand uncover relations and association among them.

3.1 Introduction

Work system parameters are characteristics of the work system such as shift length, shift schedule, the amount of time a nurse spends on direct patient care, and work settings. Previous research has demonstrated that various work system parameters are associated with changes in nurse well-being and stress (Hoffman and Scott, 2003; Roberson, 1986; Rogers et al., 2004; Scott et al., 2006).

For example, an investigation of the relationships between shift length and schedule and healthcare provider well-being found that well-being among nurses who work 12 hours per day for seven days and then rest for seven days is much higher than nurses who work other shift schedules (Roberson, 1986). In addition to general well-being, the association between shift length and stress levels also has been studied. Hoffman and Scott (2003) identified that the level of stress among nurses who work 12 hours per shift is significantly higher than nurses who work eight hours per shift (Hoffman and Scott, 2003). However, nurses who have the same level of experience, regardless of the shift length, had the same level of stress. In contrast to the Hoffman and Scott results, other studies demonstrated that applying 12-hour shifts helped and improved the symptoms and frequency of stress compared to eight-hour shifts (Roberson, 1986; Stone et al., 2006).

In addition, various work-related stressors and work system parameters (i.e., the shift worked) might cause nurses to be at high risk for illness, fatigue, and decreasing
work performance (Dorrian et al., 2008; Rogers et al., 2004). For example, previous research demonstrates that extended work hours and unscheduled work hours without receiving enough inter-shift recovery leads to sleep deprivation, increased fatigue levels, performance decrements, and decreased patient safety outcomes (Rogers et al., 2004; Rogers et al., 2004; Rogers et al., 2004; Scott et al., 2006).

Of the previously mentioned work-related stressors, fatigue has been most linked to increased stress, job dissatisfaction, psychosocial stressors, performance decrements, and negative patient safety outcomes (Barker and Nussbaum, 2011, 2011; Carayon and Gurses, 2005; Josten E.J. et al., 2003; Parhizi et al., 2013; West et al., 2009). There are a wide range of definitions regarding fatigue (Shen et al., 2006). Some of these definitions consider fatigue dimensions, while others tried to define fatigue states (Shen et al., 2006). For the purpose of this study, two fatigue states have been considered—acute and chronic. Jensen and Given (1991) (p. 182) defined fatigue states as follows: “Acute fatigue is most often caused by excessive physical or mental exertion and can be relieved by rest. Normative fatigue may be influenced by circadian rhythm and results from the activities of daily living, while chronic fatigue is most often prolonged by stress or tension on the body and is less likely to be relieved by rest alone.”

The relationships between levels of fatigue among nurses and shift length, shift type, and shift schedule also have been studied. For example, several studies show that nurses who work long shift hours and extended unscheduled work hours are likely to experience higher levels of sleepiness and fatigue and increased numbers of reported errors (Dorrian et al., 2008; Scott et al., 2006). Further, investigation shows that nurses
who work a regular day shift experience less fatigue, depression, stress, and sleep problems than those who work in night shifts (Gold et al., 1992).

The term *sleepiness* is also highly related to fatigue, but they are distinct constructs regarding their causes and measurements (Rupp, 2013; Shen et al., 2006). Several studies investigated the relationships between sleepiness and work system parameters (Akerstedt, 1988; Åkerstedt, 2003; Scott et al., 2006; Waage et al., 2012). The results of a study show the association between extended work hours and decremented alertness (Scott et al., 2006). Working the night shift is also linked to sleepiness and performance decrements (Akerstedt, 1988; Åkerstedt, 2003; Waage et al., 2012). Research shows the negative relationships between shift type, especially night shift, long work hours, and patient safety (Estryn-Béhar and Heijden, 2012).

Overall, the results of previous studies show that there are relationships and associations among work system parameters and fatigue, sleepiness, performance, and patient safety (Barker and Pasupathy, 2010; Dorrian et al., 2006; Geiger-Brown et al., 2012; Rogers et al., 2004; Rogers, 2004; Rogers et al., 2004). Further, increased levels of fatigue and sleepiness are linked to performance decrements and bad patient safety outcomes. Thus, all of these constructs are related and changes in levels of one construct may lead to significant changes in levels of others. However, most of the past researchers did not try to find the levels of associations among the configurations of work system parameters and the discussed constructs. For example, previous studies show that shift length and shift type are associated with fatigue states. However, little is known about the strength and levels of the association between work system parameters (i.e. shift length and shift type) and increased fatigue levels. Moreover, little is known about if both
fatigue states are significantly associated with the same configurations of work system parameters and how levels of association between configurations of work system parameters and fatigue states changes. Further, most of the studies are limited to investigating the association between a small number of work system parameters such as shift length, shift type, and shift schedule and discussed constructs. Studying the association between a wider number of work system parameters and discussed constructs may be helpful to gain a more precise knowledge in the context of work system parameters and its association with fatigue, sleepiness, performance, and patient safety. Therefore, this study is designed to quantify and measure the association among fatigue states (acute, chronic), sleepiness, and different configurations of work system parameters (e.g. shift length, shift schedule, primary role of the nurses, working more than scheduled work), performance and patient safety. Because of the importance of nurses’ performance and patient safety in the healthcare industry, these two constructs were selected to be studied. Work system parameters, fatigue, and sleepiness also were selected due to their association with performance and patient safety.

Data mining techniques, which are used to uncover associations in large amounts of data, were applied to discover and extract the unknown relations and trends among these constructs (Berry and Linoff, 2004). Although these kinds of techniques have not been largely used in the context of nursing, there are a few other studies that used data mining techniques in this specific context. For example, CHAID has been used by Pasupathy and Barker (2010, 2011) to measure the multifactor relationships between work system parameters and fatigue dimensions and between perceived performance and fatigue dimensions among registered nurses. Parhizi et al. (2013) also used the CHAID
technique to identify the relations among psychosocial factors and fatigue dimensions. This research aimed to address the following research question: How do work system parameters relate to fatigue states, sleepiness, performance, and patient safety among hospital nurses?

### 3.2 Methods

#### 3.2.1 Data Collection

For data collection, an online survey called “Nurse Force and Fatigue Survey” was conducted. 1000 RNs currently employed in a private hospital were asked to participate and 420 RNs responded to some part of the survey. The details of data collection, data cleaning and validity and reliability of the instruments used in this survey were explained in the second chapter of this dissertation. Overall, the Occupational Fatigue Exhaustion Recovery (OFER) has been applied to measure fatigue states including acute fatigue, chronic fatigue and intershift recovery (Winwood et al., 2005). The Pittsburgh Sleep Quality Index was used to measure sleep quality and sleep quantity. This instrument quantifies seven components including: sleep efficiency, sleep disturbance, daytime dysfunction, sleep latency, sleep duration, sleep quality, use of sleeping medications (Buysse et al., 1989). However for this study, we were more interested in the components that contribute to overall sleepiness, thus daytime dysfunction was not included. Nurses’ performance was measured using the Nursing Performance Instrument. This instrument includes nine items and the mean of ratings
across the nine items as the overall performance score was used to evaluate performance (Barker and Nussbaum, 2011). The Agency for Healthcare Research and Quality (AHRQ) Hospital Survey of Patient safety was applied to measure patient safety. This instrument contains forty two items and twelve sub-scales including: teamwork within units, supervisor/manager expectations and actions promoting patient safety, management support for patient safety, overall perception of patient safety, feedback and communication about error, frequency of events reported, communication openness, teamwork across units, staffing, handoffs and transitions and no punitive response to error (The Agency for Healthcare Research and Quality, 2011). However, only the overall perception of patient safety subscale was used to measure perception of patient safety in the hospital to have a better understanding of how nurses grade their own performance as well as overall grade of patient safety across the hospital. All the discussed instruments are valid and reliable (Barker and Nussbaum, 2011; Blegen et al., 2009; Carpenter and Andrykowski, 1998; Winwood et al., 2005). Also, work system parameters were measured using a number of open-ended and scaled questions. The details of open-ended and scaled questions for work system parameters as well as a summary of descriptive statistics of all the instruments used in this study are included in the descriptive analysis section (3.2.2).

3.2.2 Descriptive Analysis

Table 3-1 shows a summary of descriptive statistics for fatigue states, performance and patient safety.
### Table 3-1: Descriptive statistics of fatigue, performance and patient safety

<table>
<thead>
<tr>
<th>Variable</th>
<th>Instrument</th>
<th>Sub-Variables</th>
<th>N</th>
<th>Mean</th>
<th>Std</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>Occupational Fatigue</td>
<td>Chronic</td>
<td>310</td>
<td>39.33</td>
<td>25.35</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acute</td>
<td>277</td>
<td>51.25</td>
<td>20.09</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intershift Recovery</td>
<td>291</td>
<td>56.59</td>
<td>22.02</td>
<td>0-100</td>
</tr>
<tr>
<td>Performance</td>
<td>Nursing Performance Instrument</td>
<td></td>
<td>280</td>
<td>4.62</td>
<td>0.74</td>
<td>1-6</td>
</tr>
<tr>
<td>Patient safety</td>
<td>AHRQ Hospital Survey of Patient</td>
<td></td>
<td>260</td>
<td>69.423</td>
<td>27.04</td>
<td>0-100</td>
</tr>
</tbody>
</table>

Table 3-2 shows a summary of descriptive statistics of sleepiness related variables.

### Table 3-2: Descriptive statistics of sleepiness related variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Instrument</th>
<th>Sub-Variables</th>
<th>N</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleepiness</td>
<td>Pittsburgh Sleep Quality Index</td>
<td>Sleep Efficiency</td>
<td>278</td>
<td>72.7%</td>
<td>13.7%</td>
<td>6.8%</td>
<td>6.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleep Disturbances</td>
<td>297</td>
<td>1%</td>
<td>45.1%</td>
<td>52.9%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleep Latency</td>
<td>282</td>
<td>9.9%</td>
<td>48.2%</td>
<td>29.1%</td>
<td>12.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleep Duration</td>
<td>282</td>
<td>26.6%</td>
<td>60.3%</td>
<td>11%</td>
<td>2.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleep Quality</td>
<td>297</td>
<td>18.2%</td>
<td>51.5%</td>
<td>25.3%</td>
<td>5.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleeping Medication</td>
<td>297</td>
<td>58.6%</td>
<td>15.5%</td>
<td>12.5%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

Sleep Efficiency: >85%, 75-84%, 65-74%, <65%
Sleep Disturbances and Sleep Latency: 0= never, 1=rarely, 2=sometimes, 3=often/very often
Sleep Duration: >7 hours, 6-7 hours, 5-6 hours, <5 hours
Sleep Quality: 0=very good, 1=fairly good, 2=fairly bad, 3=very bad,
Sleeping medication: 0=not during the past month, 1=less than once a week, 2=once or twice a week, 3=three or more times a week

Table 3-3 shows a summary of descriptive statistics of work system parameters.
Table 3-3: Descriptive statistics of work system parameters

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurses years of experience</td>
<td>379</td>
<td>17.59</td>
<td>11.82</td>
<td>1-54</td>
</tr>
<tr>
<td>Average hours worked per shift</td>
<td>343</td>
<td>11.47</td>
<td>1.5</td>
<td>6-14</td>
</tr>
<tr>
<td>Day shift years</td>
<td>270</td>
<td>15.05</td>
<td>10.87</td>
<td>0-50</td>
</tr>
<tr>
<td>Night shift years</td>
<td>258</td>
<td>7.87</td>
<td>7.77</td>
<td>0-40</td>
</tr>
<tr>
<td>Average number of hours per week worked more than schedule</td>
<td>325</td>
<td>4.42</td>
<td>5.26</td>
<td>0-24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>N</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the typical severity of illness or injury of unit patients?</td>
<td>283</td>
<td>9.2%</td>
<td>47.7%</td>
<td>43.1%</td>
</tr>
<tr>
<td>What is the intensity of nursing care needs required by typical unit patients?</td>
<td>283</td>
<td>2.1%</td>
<td>38.9%</td>
<td>59.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>N</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNs have control over their work schedules</td>
<td>330</td>
<td>2.7</td>
<td>3.0</td>
<td>3.0</td>
<td>20.6</td>
<td>45.2</td>
<td>45.5</td>
</tr>
<tr>
<td>RNs are satisfied with their work schedules</td>
<td>335</td>
<td>1.8</td>
<td>3.0</td>
<td>3.3</td>
<td>22.1</td>
<td>49.9</td>
<td>20.0</td>
</tr>
<tr>
<td>1: Strongly disagree, 2: Disagree, 3: Somewhat disagree, 4: Somewhat agree, 5: Agree, 6: Strongly agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>N</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>My primary work shift is : Night or Day</td>
<td>360</td>
<td>63.1</td>
<td>36.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>N</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your current work position?</td>
<td>360</td>
<td>9.4</td>
<td>68.3</td>
<td>10.6</td>
<td>5.0</td>
<td>1.7</td>
<td>5.0</td>
</tr>
<tr>
<td>1: Other, 2: Staff (bedside) RN, 3: Charge RN, 4: Manager RN, 5: Director RN, 6: More than one position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work system parameters</td>
<td>Response choices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the primary role of your work?</td>
<td>342 75.1 14.3 10.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1: Patient care, 2: Managing patient care, 3: Directing patient care providers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>Response choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>What is the usual type of shift you work on the unit?</td>
<td>342 13.2 43.6 0.0 3.8 0.0 33.0 0.3 1.8 1.8 2.6</td>
</tr>
<tr>
<td>1: 8 hour days, 2: 12 hour days, 3: 8 hour evenings, 4: 12 hour evenings, 5: 8 hour nights, 6: 12 hour nights, 7: combinations of 8 and 12 hour shifts, 8: Irregular shift arranged by employer, 9: Irregular shifts arranged by employee, 10: A combination of different shifts</td>
<td></td>
</tr>
</tbody>
</table>

### 3.3 Analysis

In order to evaluate the multifactor relationships between work system parameters and fatigue states, performance and patient safety, data mining methods specifically Chi-squared Automatic Interaction Detection (CHAID), was used. CHAID is one of the most well-known tree based methods (Kass, 1980). SPSS software (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp) was used to analyze the data. The significance level of all splits was considered to be equal to 0.05. The minimum number of cases in parent nodes was changed from 100 (default number) to 50 and for child nodes from 50 (default number) to 30. Due to the fact that the number of participants in our study is low, setting the default number may give us trees with no nodes. Figure 3-1, shows the independent and dependent variables that were evaluated using CHAID. All possible relations between the set of independent and each dependent variable shown in Figure 3-1 were separately evaluated using CHAID classification trees.
Figure 3-1: The relationships between dependent and independent variables evaluated using CHAID

3.3.1 Results

All possible relations between the set of independent variables and each dependent variable (Figure 3-1) were separately evaluated using CHAID. Thus, eleven trees were run (Appendices VII through XVI and Figure 3-2). For clarity and conciseness in presenting the results of these analyses, all of the significant differences in each dependent variable relating to changes in independent variables level identified using CHAID were depicted visually in Figures 3-3 through 3-10.
3.3.1.1 The relationships between intershift recovery and work system parameters

The result from the CHAID analysis for the relationships between intershift recovery measured by OFER and work system parameters is shown in Figure 3-2. The relationships between work system parameters and intershift recovery show that “average hours worked per shift” has the most significant association with intershift recovery. Nurses who work less than or equal to 12 hours per shift have significantly higher levels of intershift recovery compared to nurses who work more than twelve hours per shift. When average hours worked per shift is less than or equal to twelve, then nurse rating of the statement “RNs have control over their schedule” has the most significant associations with intershift recovery. Nurses who strongly agreed with the statement had significantly higher levels of intershift recovery compared to nurses who agreed, somewhat agreed, somewhat disagreed, disagreed or strongly disagreed. For nurses who did not strongly agree with the statement “RNs have control over their schedule”, the average number of hours worked more than scheduled also has a significant association with intershift recovery. Nurses who did not work any overtime hours have a significantly higher level of intershift recovery compared to other nurses who worked over schedule.
Figure 3-2: The relationships between intershift recovery and work system parameters
3.3.1.2 The relationships between acute fatigue and work system parameters

The relationships between acute fatigue measured by OFER and work system parameters are shown in Figure 3-3. A Nurse’s years of experience has the most significant association with acute fatigue. For nurses who have less than twenty five years of experience, their satisfaction with job schedule has the most significant associations with acute fatigue.

![Figure 3-3: The relationships between OFER acute fatigue and work system parameters.](image)

Note: Red highlighted color shows higher level of acute fatigue. Green highlighted shows the lower level of acute fatigue.

Note: The corresponding tree is shown in Appendix 7.

Note: the most significant variable is shown on the X-axis.
Generally, acute fatigue has a negative relationship with work experience. As the level of experience increases, acute fatigue decreases significantly. Nurses who strongly agreed and agreed with their satisfaction with job schedule have a significantly lower level of acute fatigue compared to nurses who strongly disagreed, disagreed, somewhat disagreed or somewhat agreed.

3.3.1.3 The relationships between chronic fatigue and work system parameters

The relationships between chronic fatigue measured by OFER and work system parameters are shown in Figure 3-4. Nurses’ response to the statement “nurses are satisfied with their work schedules” has the most significant associations with chronic fatigue. Nurses who strongly disagreed, disagreed, somewhat disagreed and somewhat agreed with their satisfaction with the job schedule have the highest level of chronic fatigue. Nurses who strongly agreed with their satisfaction with the job schedule have the lowest level of chronic fatigue.
The relationships between chronic fatigue and work system parameters.

Note: Red highlighted color shows higher level of chronic fatigue. Green highlighted color shows the lower level of chronic fatigue.

Note: The corresponding tree is shown in Appendix 8.

3.3.1.4 The relationships between sleep efficiency and work system parameters

The relationship between sleep efficiency and work system parameters is shown in Figure 3-5. The average number of hours worked more than scheduled (overtime hours) has the most significant association with sleep efficiency. The percentage of nurses with sleep efficiency more than 74% is significantly higher among nurses who spend less than two hours on unscheduled work. For nurses who spend more than two hours on unscheduled work, the typical severity of illness or injury of patients, is also a significant predictor. The percentage of nurses with sleep efficiency more than 74% is significantly higher among nurses who work in a unit with low or medium patient severity of illness and injury.
Figure 3-5: The relationships between sleep efficiency and work system parameters.

Note: Red highlighted color shows the lower percentage of nurses with sleep efficiency more than 75%. Green highlighted color shows the higher percentage of nurses with sleep efficiency more than 75%.

Note: the most significant variable is shown on the X-axis.

Note: The corresponding tree is shown in Appendix 9.

3.3.1.5 The relationships between sleep disturbances and work system parameters

The relationships between sleep disturbances and work system parameters are shown in Figure 3-6. A nurse’s years of experience has the most significant associations with sleep disturbances. Nurses who have more than twelve years of experience are more likely to frequently suffer from sleep disturbances. Since years of experience are logically associated with age, age might be a confounding variable affecting the relationships between sleep disturbances and experience.
Figure 3-6: The relationships between sleep disturbances and work system parameters. Note: Red highlighted color shows the higher percentage of nurses who more frequently experience sleep disturbances. Green highlighted color shows the lower percentage of nurses who more frequently experience sleep disturbances. Note: The corresponding tree is shown in Appendix 10.

3.3.1.6 The relationships between sleep latency and work system parameters

The relationships between sleep latency and work system parameters are not significant. The corresponding tree is shown in Appendix 11.

3.3.1.7 The relationships between sleep duration and work system parameters

The relationships between sleep duration and work system parameters are shown in Figure 3-7. Average hours worked per shift is the only parameter that has a significant association with sleep duration. The percentage of nurses who get at least six hours of sleep is significantly lower among nurses who work more than twelve hours per shift.
Figure 3-7: The relationships between sleep duration and work system parameters. Note: Red highlighted color shows the higher percentage of nurses who have sleep duration more than 6 hours. Green highlighted color shows the lower percentage of nurses who have sleep duration more than 6 hours. Note: The corresponding tree is shown in Appendix 12.

3.3.1.8 The relationships between sleep quality and work system parameters

The relationships between sleep quality and work system parameters are shown in Figure 3-8. The usual type of shift work has the most significant association with sleep quality. The percentage of nurses who experience very good and fairly good sleep quality is higher among nurses who work in 8 hour days, 12 hour days and 12 hour evenings shifts compared to nurses who work in 12 hour nights, combinations of 8 and 12 hour shifts, Irregular shift arranged by employer, Irregular shifts arranged by employee and a combination of different shifts. Average number of hours worked more than scheduled, has the next most significant association with sleep quality. For nurses who spend less
than one hour on unscheduled work, the intensity of nursing care needs required by typical unit patients also is a significant predictor of sleep quality. When the intensity of nursing care needs required by typical unit patients is low and medium, the percentage of very good and fairly good sleep quality is higher compared to when high level of intensity of nursing care needs is required.

Figure 3-8: The relationships between sleep quality and work system parameters.

Note: Red highlighted colors show the higher percentage of nurses who experience poor sleep quality. Darker red shows the most poor sleep quality. Green highlighted color shows the lower percentage of nurses who experience poor sleep quality. Darker green shows the lowest poor sleep quality. Note: the most significant variable is shown on the X-axis and the next most significant variable is shown in Y-axis. Note: The corresponding tree is shown in Appendix 13. Note: The usual type of shift work correspond to numbers as follows 1: 8 hour days, 2: 12 hour days, 3: 8 hour evenings, 4: 12 hour evenings, 5: 8 hour nights, 6: 12 hour nights, 7: combinations of 8 and 12 hour shifts, 8: Irregular shift arranged by employer, 9: Irregular shifts arranged by employee, 10: A combination of different shifts.
3.3.1.9 The relationships between sleep medication and work system parameters

Figure 3-9 shows the associations between sleeping medication consumption and work system parameters. The usual type of shift work has the most significant association with sleep medication.

![Diagram showing relationships between sleep medication and work system parameters]

Figure 3-9: The relationships between sleep medication and work system parameters. Note: Red highlighted colors show the higher percentage of nurses who consume sleep medication more frequently. Green highlighted color shows the lower percentage of nurses who consume sleep medication more frequently.

Note: The corresponding tree is shown in Appendix 14. Note: The usual type of shift work correspond to numbers as follows 1: 8 hour days, 2: 12 hour days, 3: 8 hour evenings, 4: 12 hour evenings, 5: 8 hour nights, 6: 12 hour nights, 7: combinations of 8 and 12 hour shifts, 8: Irregular shift arranged by employer, 9: Irregular shifts arranged by employee, 10: A combination of different shifts

The percentage of nurses who consume sleeping medication less frequently is higher among nurses who work in 8 hour days, 12 hour days and 12 hour evenings shifts compared to nurses who work in 12 hour nights, combinations of 8 and 12 hour shifts,
Irregular shift arranged by employer, Irregular shifts arranged by employee and a combination of different shifts.

3.3.1.10 The relationships between performance and work system parameters

The relationships between performance and work system parameters are not significant. The corresponding tree is shown in Appendix 15.

3.3.1.11 The relationships between patient safety and work system parameters

The relationships between patient safety and work system parameters are shown in Figure 3-10. Nurses’ satisfaction with their work schedule has the most significant association with patient safety. For nurses who agreed or strongly agreed with the satisfaction with their work schedule then, the level of patient safety is significantly higher compared to other nurses.
Figure 3-10: The relationships between patient safety outcomes and work system parameters.

Note: Red highlighted color shows lower level of patient safety. Green highlighted shows the higher level of patient safety. Note: The corresponding tree is shown in Appendix 16.

3.4 Discussion

Previous studies show the associations among work system parameters and fatigue states, sleepiness related variables, performance, and patient safety. However, most of the past studies did not quantify and measure the levels of associations among work system parameters and the discussed constructs. Therefore, little is known about what specific configuration of work system parameters are associated with significant changes in performance. Also, what specific configuration of work system parameters is associated with significant changes in fatigue and sleepiness?

Further, most of the studies are limited to investigating the association between a small number of work system parameters such as shift length, shift type, shift schedule,
and discussed constructs. In consideration of this void, this study investigated and measured the levels of association between a wide number of work system parameters and fatigue states, sleepiness related variables, performance, and patient safety. The aim of this study was to gain a more comprehensive understanding of work system parameters and their associations with undesired work related stressors (i.e., fatigue, sleepiness) and desired work related constructs (i.e., performance, patient safety).

In this study, the associations between work system parameters and fatigue states have been measured. The results of this study show that a nurse’s years of experience has the most significant association with acute fatigue. Nurses with fewer than 25 years of experience reported higher levels of acute fatigue compared to those with more than 25 years of experience. Barker and Pasupathy (2010) also found an inverse relationship between fatigue dimensions (physical, mental, total) and years of experience. Authors linked this inverse relationship to changing job expectations and also changing in responsibilities among more experienced nurses. However, in the current study, 80% of nurses with less than 25 years of experience identified the primary role of their work as “patient care”, while this percentage decreases to 60% for nurses with more than 25 years of experience. 13% of nurses with less than 25 years of experience identified the primary role of their work as “managing patient care” and 7% identified as “directing patient care”. For nurses with more than 25 years of experience, these percentages increase to 20% for “managing patient care” as well as “directing patient care”. Varying shift schedule, long shift hours and also psychosocial stressors are some of the characteristics of “patient care” being the primary role of the work and is also associated with excessive
physical exertion and increased fatigue level compared to other primary role such as “management”

Further, satisfaction with work schedule—which has the most significant association with chronic fatigue—was also significantly linked to lower levels of acute fatigue for nurses with less than 25 years of experience. The level of satisfaction with job schedule among nurses in the current study is shown in Table 3-4. As it is shown, the highest percentage of satisfaction (strongly agree + agree) is for nurses who work in a 12-hour day shift and 12-hour night shift. Therefore, nurses who work in long 12-hour shift are more satisfied with their schedule.

Although, other studies showed that longer work hours were related to nurses’ satisfaction with work schedule and, therefore, it is linked to lower levels of stress and improved wellbeing, both physically and psychologically; the authors were concerned about increased fatigue levels and decreased patient safety (Josten E.J. et al., 2003; Smith et al., 1998). Other study also developed a fatigue-based nurse scheduling which help to incorporate both nurse preferences and fatigue in scheduling (Lin et al., 2013). However, the result of the current study show that satisfaction with work schedule is higher among nurses who work in 12 hour day/night shifts and in cases of acute fatigue in nurses who have less than 25 years of experience, satisfaction with work schedule will help to reduce their fatigue level. In the case of chronic fatigue, nurses who strongly agreed with their work schedule had the lowest levels of chronic fatigue.
Table 3-4: the percentage of satisfaction among nurses in each shift type

<table>
<thead>
<tr>
<th>Shift Type</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Somewhat disagree</th>
<th>Somewhat agree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 hour days</td>
<td>0.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>1.9%</td>
<td>7.2%</td>
<td>4.1%</td>
</tr>
<tr>
<td>12 hour days</td>
<td>0.6%</td>
<td>1.3%</td>
<td>0.9%</td>
<td>10.7%</td>
<td>21.0%</td>
<td>8.8%</td>
</tr>
<tr>
<td>8 hour evenings</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>12 hour evenings</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.3%</td>
<td>1.3%</td>
<td>1.9%</td>
<td>0.3%</td>
</tr>
<tr>
<td>8 hour nights</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>12 hour nights</td>
<td>0.9%</td>
<td>1.9%</td>
<td>1.9%</td>
<td>6.6%</td>
<td>16.0%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Combination of 8 and 12 hour shifts</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.3%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Irregular shift arranged by employer</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.3%</td>
<td>0.6%</td>
<td>0.6%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Irregular shift arranged by employee</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.9%</td>
<td>0.3%</td>
<td>0.6%</td>
</tr>
<tr>
<td>A combination of different shifts</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>2.5%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

Note: The number of nurses in each cell was divided by total number of nurses in all shift types

In the case of intershift recovery, the results of this study show working more than 12 hours per shift is significantly associated with poor intershift recovery. Control over work schedule is also significantly associated with higher levels of intershift recovery. Thus, the results of this study support the associations between satisfaction with work schedule and control over job schedule and reduced fatigue levels. These two factors can be considered as psychosocial risk factors or stressors. The Karasek demand-control model and the job control-demand-support model are two well-known models of
psychosocial factors (Karasek, 1979, 1997). Other studies also showed the negative association between control over the job and fatigue (Parhizi et al., 2013; Van Yperen and Hagedoorn, 2003). Thus, the best strategy might be to reduce the work hours or unscheduled work hours and then, try to satisfy nurses as much as possible within those limited hours by improving psychosocial work stressors and factors (i.e. control and support) in the workplace.

Although other studies showed that shift pattern is the most significant predictor of maladaptive fatigue outcomes and poor recovery (Winwood et al., 2006), in our study, shift schedule was not significantly associated with fatigue states. It should be mentioned that shift schedule was not so varied among our participants. Among participating nurses, 43.6% worked in 12-hour day shifts, 33% worked in 12-hour night shifts, and 13.2% worked in 8-hour day shifts. Due to the above limitation, there is a possibility that we did not capture this association. Thus, further research may need to be conducted using a more diverse database in terms of shift types.

In addition, the relationships between work system parameters and nurses’ perception of their performance and overall patient safety in the hospital were studied. The results show that the associations between work system parameters and performance were not significant. The reason might be that the variance of performance scores among our participants was very low (0.547); this variation matters because in decision trees, nodes are split in a way that variation in each node is minimized and variation between nodes is maximized. Further studies are needed to measure nurses’ performance and investigate their associations with work system parameters. The associations between
patient safety and work system parameters show that nurses’ satisfaction with their job schedule also has the most significant associations with patient safety.

Furthermore, the associations between work system parameters and sleepiness related variables were investigated. The association between sleep disturbances and work system parameters demonstrated that years of experience has the most significant association with sleep disturbances. Since years of experience are logically associated with age, age might be a confounding variable affecting the relationships between sleep disturbances and experience. Other study also showed that age is a risk indicator for disturbed sleep (Åkerstedt et al., 2002).

The investigation of the relationships between sleep duration and work system parameters shows that average hours worked per shift has the most significant association with sleep duration. A previous study also found an association between work hours and sleepiness; specifically, working more than 12.5 hours or longer significantly decreased the level of alertness among nurses and also decreased sleep duration by about half an hour (Scott et al., 2006). Another study also linked 12-hour shifts and working more than scheduled to increased risk of making errors, having trouble staying awake, and reduced sleep duration (Rogers et al., 2004). Also, an analysis of the 2010 National Health Interview Survey (NHIS) by Centers for Disease Control and Prevention demonstrated that sleep duration was significantly lower among workers who worked more than 40 hours per week (2012). Therefore our results support a growing body of literature that demonstrates a negative relationship between shift length and sleep quantity.
The relationships between sleep quality and work system parameters demonstrated that usual types of shift work have the most significant association with sleep quality. Table 3-5 shows the percentage of nurses’ sleep quality for each shift type.

<table>
<thead>
<tr>
<th>What is the usual type of shift you work on the unit?</th>
<th>Sleep Quality</th>
<th>Very good</th>
<th>Fairly good</th>
<th>Fairly bad</th>
<th>Very bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 hour days</td>
<td></td>
<td>12.5%</td>
<td>57.5%</td>
<td>25.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>12 hour days</td>
<td></td>
<td>25.9%</td>
<td>54.3%</td>
<td>17.2%</td>
<td>2.6%</td>
</tr>
<tr>
<td>8 hour evenings</td>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>12 hour evenings</td>
<td></td>
<td>22.2%</td>
<td>44.4%</td>
<td>33.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8 hour nights</td>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>12 hour nights</td>
<td></td>
<td>13.3%</td>
<td>46.9%</td>
<td>31.6%</td>
<td>8.2%</td>
</tr>
<tr>
<td>Combination of 8 and 12 hour shifts</td>
<td></td>
<td>0.0%</td>
<td>100.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Irregular shift arranged by employer</td>
<td></td>
<td>0.0%</td>
<td>50.0%</td>
<td>50.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Irregular shift arranged by employee</td>
<td></td>
<td>0.0%</td>
<td>50.0%</td>
<td>33.3%</td>
<td>16.7%</td>
</tr>
<tr>
<td>A combination of different shifts</td>
<td></td>
<td>14.3%</td>
<td>57.1%</td>
<td>28.6%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Note: The number of nurses in each cell was divided by the number of nurses in each shift type (row).

The results show that a higher percentage of nurses who work 12-hour day and 12-hour night shifts experience very good sleep quality. A full 80% of nurses who worked in 12-hour day shifts experienced “very good” or “fairly good” sleep quality. This percentage decreased to 70% for nurses who worked in 8-hour day shifts and to 66.6% for nurses who worked in 12-hour night shifts.

The number of hours worked more than scheduled is also significantly associated with both sleep quality and sleep efficiency. Several other studies linked long work hours
and overtime hours to sleep duration (Czeisler et al., 1980; Rogers, 2008). However, the results of our study did not find any association between overtime hours and sleep quantity; rather, it linked overtime hours to sleep quality. For nurses who work in specific types of shift work and/or a specific number of overtime hours, the intensity of care needed by patients and the severity of injury have been linked to sleep quality of nurses.

Finally, this study has some limitations. The data was collected using a cross-sectional survey. However, a future investigation using a longitudinal study may be helpful in clarifying more hidden associations and relationships among constructs contributing to patient safety and nurses’ performance. Despite the fact that the survey was very comprehensive and measured different constructs, there were several missing values due to the length of survey and/or participants’ unwillingness to answer. Furthermore, the result of data mining will be more accurate when large amounts of data are used. Thus, even though several interesting associations have been found by this study, there is a possibility that we were not able to capture some of the significant associations because of insufficient data and sample size.

3.5 Conclusion

In this chapter, the associations between different work system parameters and fatigue states, sleepiness related variables, performance, and patient safety were studied. The results of this study identified the significant associations among these constructs and showed that nurses’ satisfaction with job schedule is significantly associated with
decreased fatigue levels and increased patient safety, even in long 12-hour shifts. The results also demonstrated that overtime hours are significantly linked to sleep quality and sleep efficiency rather than sleep duration. Age also might be a confounding variable to years of experience affecting disturbed sleep. Typical severity of illness or injury and intensity of nursing care needs were significantly, in order, linked to sleep efficiency and sleep quality. The associations between performance and work system parameters and sleep latency and work system parameters were not significant.
Chapter 4. Modeling nurses’ response to the assigned work system parameters

Abstract

Work system parameters such as shift length, shift type, overtime, shift schedule, and work setting have been associated with nurses’ fatigue, sleepiness, performance, and patient safety. Previous studies have investigated the associations between one or two of these work system parameters and one or two of the above constructs. However, a more comprehensive model is needed for a better understanding of nurses’ perception of the assigned work system parameters. This model should consider all possible associations between work system parameters and fatigue states, sleepiness, performance, and patient safety. The associations between the constructs should be considered as well. As such, this study investigated the associations between different configurations of work system parameters and fatigue states, sleepiness related variables, performance, and patient safety. The associations among the discussed constructs were also considered. All of the associations among variables were measured by a classification method, namely Chi-squared Automatic Interaction Detection (CHAID). All the discovered associations were modeled using Python programming language. The results of this study will help managers and policy makers measure and quantify the levels of fatigue states, sleepiness related variables, performance, and patient safety based on the assigned work system
parameters and enable them to design work systems in such a way so as to keep fatigue and sleepiness at manageable levels and performance and safety as high as possible.

4.1 Introduction

Nurses have a critical role in patient caregiving and they have the most direct contact with patients (Page, 2004); the performance of nurses has real life or death implications. Further, nurses work in complex environments with many factors that might contribute to their fatigue, sleepiness, and may influence their performance and patient safety. Work system parameters such as shift length, shift schedule, usual type of shift (day or night), unscheduled work hours, job satisfaction, and job control are some of the most prominent factors linked to fatigue, sleepiness, performance, and patient safety (Åkerstedt et al., 2002; Åkerstedt et al., 2002; Åkerstedt, 2003; Barker and Nussbaum, 2011; Olds and Clarke, 2010; Rogers, 2008; Rogers et al., 2004).

Thus, nurses’ level of alertness, fatigue states, and performance should be considered when assigning a nurse to specific work parameters. However, due to the nurse shortage and the resulting extreme workload, decreasing the number of work hours or unscheduled work hours or consecutive night shifts are sometimes inevitable. Nurse managers are faced with making staffing and patient assignment decisions multiple times a day. They are faced with the task of using their nursing team most effectively to carry out safe patient care in the context of a challenging work system. However, as industry literature shows, researchers have been focused on only a few parameters such as budget and human resources limitations and workload or nurse-to-patient ratios when assigning
nurses to patients (Mullinax and Lawley, 2002; Punnakitikashem et al., 2008; V Ericourt and Jennings, 2006). Therefore, there is limited work that accounts for the complexities and multiple important variables in the work system related to nurse fatigue and resulting performance and patient safety decrements.

Of the previously mentioned work system parameters related to nurse performance, for example, night shift is linked to increased levels of sleepiness and performance decrements (Waage et al., 2012). Furthermore, shifts longer than twelve hours, working more than scheduled, or greater than forty work hours per week is associated with greater likelihood of making errors and sleep deprivation (Åkerstedt et al., 2002; Åkerstedt et al., 2002; Åkerstedt, 2003; Garde et al., 2011; Rogers et al., 2004). Moreover, because of working in long shift hours and completing both mentally and physically demanding tasks, nurses usually suffer from increased fatigue levels (Barker and Nussbaum, 2011). Fatigue has also been linked and related to sleepiness (Shen et al., 2006). In addition, changes in levels of fatigue and sleepiness also are associated with nurses’ performance and patient safety (Barker and Nussbaum, 2011; Landrigan et al., 2004; Lockley et al., 2004; Pasupathy and Barker, 2011; Rogers, 2008; Suzuki et al., 2005). Overall, all work system parameters and discussed constructs are highly associated, complex, and dynamic; changes in one variable—shift type, for instance—may lead to significant changes in other variables (i.e., sleep duration, fatigue levels, or performance).

Considering these associations, a promising method is needed to help nurse managers to measure and quantify the level of fatigue states, sleepiness related variables, performance, and patient safety in response to the changes in work system parameters as
well as the nurse characteristics. In order to achieve this aim, a better understanding of the complex and dynamic associations among work system parameters and, fatigue states, sleepiness related variables, performance, and patient safety is needed.

This study addressed this need by modeling the nurses’ response to different configurations of work system parameters. For achieving this purpose, the associations between work system parameters, fatigue states, sleepiness related variables, performance, and patient safety were identified using a data mining technique, namely Chi-squared Automatic Interaction Detection (CHAID). The results of CHAID for the associations among the discussed constructs have been explained in detail in Chapters 2 and 3. The established associations were applied to formalize, design, initialize, and build a model using Python programming language. This model consisted of all discovered associations between work system parameters, fatigue states, sleepiness related variables, performance, and patient safety.

Most current work assignments or nurse scheduling models do not consider nurses’ fatigue, sleepiness related variables, or performance and patient safety as quantitative variables affecting day-to-day assignment decisions. Lin et al, (2013) demonstrated that fatigue can be incorporated in a mathematical form in nurse scheduling models. The authors developed a fatigue-based nurse scheduling model considering both nurse preferences and fatigue. Same to Lin et al (2013) approach, the calculated level of the discussed constructs in response to different configurations of work system parameters could be applied in different work assignment methods and models as objective functions (i.e., maximizing performance, patient safety, and minimizing fatigue and sleepiness) or constraints (i.e., limiting the level of fatigue or decremented
performance and patient safety) in a unit. Overall, this model could help in the design of hospital nurse work systems and work assignment by quantifying the levels of constructs that have not previously been used in the decision-making process.

4.2 Method

4.2.1 Data collection

Thousand nurses employed in a large, acute care private hospital were asked to participate in an online survey study about these measures/constructs. A response rate of 42% was attained. This survey consisted of several previously published instruments as well as a number of open-ended and scaled questions measuring fatigue, sleepiness, performance, patient safety, well-being, stress, psychosocial factors, and health and work system parameters. Nurses’ demographic characteristics such as age, gender, ethnic identity, degree, and experience were also included. Fatigue states, both acute and chronic were measured using Occupational Fatigue Exhaustion Recovery (OFER) (Winwood et al., 2005). Sleep quality and sleep quantity were measured by Pittsburgh Sleep Quality Index (Buysse et al., 1989). The Nursing Performance Instrument was used to evaluate nurses’ perception of their performance (Barker and Nussbaum, 2011). The overall perception of patient safety subscale in the Agency for Healthcare Research and Quality (AHRQ) hospital survey of patient safety was used to measure patient safety (The Agency for Healthcare Research and Quality, 2011). Also, work system parameters were measured using a number of open-ended and scaled questions. All of these instruments are previously published and are known to be valid and reliable (Barker and Nussbaum, 2011; Blegen et al., 2009; Carpenter and Andrykowski, 1998; Winwood et
al., 2005). The details of the scoring process for these instruments, data cleaning and data analysis were explained in detail in Chapter 2 of this dissertation.

4.2.2 Analysis

In order to evaluate the multi-factor relationships among fatigue, sleepiness, performance, patient safety, and work system parameters, data mining methods—specifically Chi-squared Automatic Interaction Detection (CHAID)—used. CHAID is a classification technique (Berry and Linoff, 2004). This technique classifies the dependent variables based on their associations regarding the independent variable (Berry and Linoff, 2004). The results of CHAID can be summarized as a number of associations. For example, Figure 4-1 shows a sample of CHAID results.
Figure 4-1: The relationships between performance and fatigue using CHAID

The results of CHAID can be summarized as follows:

1. For the nurses with acute fatigue levels less than 36.667, the level of performance is 5.079.
2. For the nurses with acute fatigue levels between 36.667 and 63.33, the level of performance is 4.658.
3. For the nurses with acute fatigue levels of more than 63.33, the level of performance is 4.139.
For the nurses with acute fatigue levels of more than 63.33, if chronic fatigue is less than 62.5 then performance is equal to 4.382. Otherwise, performance is equal to 3.873.

The associations shown in Figure 4-2 were investigated using CHAID.

**Figure 4-2:** The relationships between dependent and independent variables evaluated using CHAID.

Note: The solid blue lines show work system parameters as dependent variables, the solid orange line show fatigue as dependent variable and the dashed blue lines show sleepiness as dependent variable.

Note: the construct that the arrow points to is the independent variable.

The associations found investigating the above associations were discussed in detail in Chapters 2 and 3. Summaries of all the discovered associations are shown in Figure 2-3 through 2-7. For example, in Figure 2-3, the association shows that if the level of sleep quality is less than or equal to 1, then the level of OFER chronic fatigue is equal to 34.146. Otherwise, the level of OFER chronic fatigue is equal to 51.019. It also shows that if the level of sleep quality is less than or equal to 1 and the level of sleep
disturbances is less than or equal to 1, then the value of OFER chronic fatigue is equal to 27.434.
Figure 4-3: The relationships between sleepiness (independent variable) and fatigue states, performance and patient safety (dependent variables)
Figure 4-4: The relationships between fatigue states (independent variable) and performance and patient safety (dependent variables)
Figure 4-5: The relationships between work system parameters (dependent variable) and fatigue states, performance and patient safety (independent variables)
Figure 4-6: The relationships between work system parameters (dependent variable) and sleepiness (independent variables)
The associations found among the discussed constructs (fatigue, sleepiness, performance, patient safety, and work system parameters) were used to initialize, build, and develop a model using Python programming language which is a powerful and efficient programming language (Python Programming Language).

The model helps us to calculate and measure the level of fatigue states, sleepiness related variables, performance and patient safety for a nurse based on the known levels of work system parameters. These values will be calculated based on the value of work system parameters, the discovered associations and relationships between work system parameters and discussed constructs, and also the associations among the constructs (shown in Figure 4-3 to 4-6). When the associations between work system parameters and constructs and the associations among the constructs lead to two or three values for the constructs, the average of all the values is considered to be the predicted level of the construct.

4.2.3 Results

Investigating the associations between selected work system parameters for this study (shown in Figure 2-2) and fatigue states, sleepiness related variables, performance and patient safety shows the relationships between different constructs (fatigue states, sleepiness related variable, performance, and patient safety) and the following work system parameters were identified as significant at least once.

- Years of experience
- Average hour per shift
• Usual type of work shift
• Average number of hours worked more than scheduled
• Typical severity of illness or injury
• Control over schedule
• Satisfaction with work schedule
• Intensity of nursing care needs

The associations between the following work system parameters and other contributing constructs of the study have not been identified as significant.

• Current work position
• Primary role of the work
• Primary work shift

Thus, only the work system parameters that have significant associations with other discussed constructs in this study were used as inputs for the model. Suppose that we are interested in measuring the level of fatigue states, sleepiness related variables, performance, and patient safety among ten hospital nurses using the work system parameters as inputs shown in Table 4-2. These input values are randomly generated. A uniform distribution was used to generate random data using Microsoft Excel 2010. Ranges were set as shown in Table 4-1 based on the ranges of the data gathered from participated nurses in the survey study.
Table 4-1: Applied ranges for generating input for the model

<table>
<thead>
<tr>
<th>Work system parameters</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurses years of experience</td>
<td>1-54</td>
</tr>
<tr>
<td>Average hours worked per shift</td>
<td>6-14</td>
</tr>
<tr>
<td>Average number of hours per week worked more than schedule</td>
<td>0-24</td>
</tr>
<tr>
<td>What is the typical severity of illness or injury of unit patients?</td>
<td>1-3</td>
</tr>
<tr>
<td>What is the intensity of nursing care needs required by typical unit patients?</td>
<td>1-3</td>
</tr>
<tr>
<td>RNs have control over their work schedules</td>
<td>1-6</td>
</tr>
<tr>
<td>RNs are satisfied with their work schedules</td>
<td>1-6</td>
</tr>
<tr>
<td>What is the usual type of shift you work on the unit?</td>
<td>1-12</td>
</tr>
</tbody>
</table>

**Typical severity of illness or injury/Intensity of nursing care needs**  (1: Low, 2: Medium, 3: High)

**Control/Satisfaction with work schedule**  (1: Strongly disagree, 2: Disagree, 3: Somewhat disagree, 4: Somewhat agree, 5: Agree, 6: Strongly agree)

**Usual type of shift work**  (1: 8 hour days, 2: 12 hour days, 3: 8 hour evenings, 4: 12 hour evenings, 5: 8 hour nights, 6: 12 hour nights, 7: combinations of 8 and 12 hour shifts, 8: Irregular shift arranged by employer, 9: Irregular shifts arranged by employee, 10: A combination of different shifts.)

The generated data using the uniform distribution is shown in Table 4-2.
Table 4-2: The values of work system parameters assigned to each nurse

<table>
<thead>
<tr>
<th>Nurse Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of experience</td>
<td>5</td>
<td>12</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>1</td>
<td>50</td>
<td>42</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>Average hour per shift</td>
<td>12</td>
<td>12.5</td>
<td>8</td>
<td>13</td>
<td>10</td>
<td>12</td>
<td>12.5</td>
<td>8.5</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Average number of hours worked more than scheduled</td>
<td>4</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>12</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Typical severity of illness or injury</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Intensity of nursing care needs</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Control over schedule</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Satisfaction with work schedule</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Usual type of work shift</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Typical severity of illness or injury/Intensity of nursing care needs** (1: Low, 2: Medium, 3: High)

**Control/Satisfaction with work schedule** (1: Strongly disagree, 2: Disagree, 3: Somewhat disagree, 4: Somewhat agree, 5: Agree, 6: Strongly agree)

**Usual type of shift work** (1: 8 hour days, 2: 12 hour days, 3: 8 hour evenings, 4: 12 hour evenings, 5: 8 hour nights, 6: 12 hour nights, 7: combinations of 8 and 12 hour shifts, 8: Irregular shift arranged by employer, 9: Irregular shifts arranged by employee, 10: A combination of different shifts.)

The results of the model contain the expected value for fatigue states, sleepiness variables, performance, and patient safety for each nurse, considering the input values and the associations shown in Figure 4-3 through 4-6. The results are presented in Table 4-3.
**Table 4-3: The value of fatigue states, sleepiness related variables, performance and patient safety corresponding to the work system parameters in Table 4-2**

<table>
<thead>
<tr>
<th>Nurse Number</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Fatigue</td>
<td>48.33</td>
<td>54.14</td>
<td>54.14</td>
<td>45.26</td>
<td>45.26</td>
<td>48.33</td>
<td>53.31</td>
<td>45.26</td>
<td>54.14</td>
<td>45.26</td>
</tr>
<tr>
<td>Chronic Fatigue</td>
<td>31.65</td>
<td>40.94</td>
<td>40.94</td>
<td>40.94</td>
<td>31.65</td>
<td>44.41</td>
<td>40.94</td>
<td>40.94</td>
<td>40.94</td>
<td>40.94</td>
</tr>
<tr>
<td>Intershift Recovery</td>
<td>64.12</td>
<td>51.86</td>
<td>56.22</td>
<td>51.86</td>
<td>68.32</td>
<td>42.29</td>
<td>60.43</td>
<td>56.22</td>
<td>56.22</td>
<td>56.22</td>
</tr>
<tr>
<td>Patient Safety</td>
<td>74.66</td>
<td>66.63</td>
<td>70.75</td>
<td>70.75</td>
<td>70.75</td>
<td>70.75</td>
<td>70.54</td>
<td>70.75</td>
<td>70.75</td>
<td>66.63</td>
</tr>
<tr>
<td>Sleep Efficiency</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sleep Disturbances</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sleep Duration</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sleeping Medication</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

**Sleep Efficiency** 0: >85%, 1: 75-84%, 2: 65-74%, 3: <65%
**Sleep Disturbances /Sleep Latency** 0: never, 1: rarely, 2: sometimes, 3: often/very often
**Sleep Duration** 1: >7 hours, 2: 6-7 hours, 3: 5-6 hours, 4: <5 hours
**Sleep Quality** 0: very good, 1: fairly good, 2: fairly bad, 3: very bad,
**Sleeping medication** 0: not during the past month, 1: less than once a week, 2: once or twice a week, 3: three or more times a week

Note: Acute fatigue, chronic fatigue, intershift recovery and patient safety range between 0 and 100. 0 shows the lower level of constructs and 100 shows the higher level of construct. Performance range between 1 and 6, 1 shows the lower level of constructs and 6 shows the higher level of construct.

These results show that, for example, for nurse A with parameters of work system set as years of experience=5 years, average hour per shift =12 hours, average number of hours worked more than scheduled=4 hours, typical severity of illness or injury=low, intensity of nursing care needs= low, control over schedule= strongly agree, satisfaction with work schedule= strongly agree, usual type of work shift= 12 hour days, the levels of fatigue, sleepiness, performance and patient safety are expected as follows: acute fatigue=48.33, chronic fatigue=31.65, intershift recovery=64.12, performance=4.718,
patient safety=74.66, sleep efficiency=0, sleep disturbances=1, sleep duration=2, sleep quality=1, sleeping medication=0.

4.2.4 Accuracy of prediction model

For measuring the accuracy of the results of this study, the data originally collected from 1000 nurses who participated in the Nurse Force and Fatigue survey were used. The nurses’ responses to the following questions of work system parameters included: years of experience, average hour per shift, and average number of hours worked more than scheduled, typical severity of illness or injury, intensity of nursing care needs, control over schedule, satisfaction with work schedule and usual type of work shift, as well as their perception of the level of fatigue states, sleepiness related variable, performance, and patient safety were considered. Only 163 out of 420 nurses, who responded to some part of survey, completely responded to all questions related to work system parameters (fatigue, sleepiness, performance, and patient safety). Among these 164 records, there are some values equal to zero recorded for the level of fatigue, patient safety, performance or sleepiness related variables. Since in calculating errors using the absolute mean percentage errors (Formula (4-1)), the actual value should not be equal to zero, data transformation was applied. The recorded value equal to zero for fatigue, performance, and patient safety were changed to 0.0001. For sleepiness related variables, data was transformed as follows: 3=4, 2=3, 1=2, 0=1. Next, nurses’ responses to the work system parameters were applied as inputs to the model. Then, the nurses’ actual levels of
fatigue states, sleepiness related variables, performance, and patient safety were compared to the expected value of the discussed constructs. Finally, the absolute mean percentage errors were measured for each construct using the following formula (4-1).

\[
\text{The absolute mean percentage error} = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{\left| \hat{Y}_i - Y_i \right|}{Y_i} \right) \times 100
\]  

(4-1)

Where \( \hat{Y}_i \) is the predicted value of the construct and is measured by model and \( Y_i \) is the value provided by the nurse. For identifying outliers among calculated errors, the standard score (Zscore) was measured for each observation/nurse. The absolute values of standard scores more than 3.29 were considered to be outliers.

Z-scores are defined as:

\[
Z\text{score}(i) = \frac{x_i - \bar{x}}{s} \quad \text{where} \quad s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]  

(4-2)

The total number of observations that were used for calculating error in each construct and the absolute mean percentage error value for each construct are shown in Table 4-4.
Table 4-4: The level of absolute mean percentage error for each predicted construct

<table>
<thead>
<tr>
<th>Nurse Number</th>
<th>Number of Observation</th>
<th>The Absolute Mean Percentage Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Fatigue</td>
<td>160</td>
<td>36.97%</td>
</tr>
<tr>
<td>Chronic Fatigue</td>
<td>157</td>
<td>78.78%</td>
</tr>
<tr>
<td>Intershift Recovery</td>
<td>160</td>
<td>43.40%</td>
</tr>
<tr>
<td>Performance</td>
<td>162</td>
<td>13.06%</td>
</tr>
<tr>
<td>Patient Safety</td>
<td>158</td>
<td>43.30%</td>
</tr>
<tr>
<td>Sleep Efficiency</td>
<td>164</td>
<td>51.22%</td>
</tr>
<tr>
<td>Sleep Disturbances</td>
<td>163</td>
<td>19.68%</td>
</tr>
<tr>
<td>Sleep Duration</td>
<td>163</td>
<td>43.40%</td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>162</td>
<td>41.46%</td>
</tr>
<tr>
<td>Sleep Medication</td>
<td>164</td>
<td>71.65%</td>
</tr>
</tbody>
</table>

The errors of predicting the value for performance (13.06%) and sleep disturbances (19.68%) are lowest, while the errors of predicting the value for chronic fatigue (78.78%) and sleep medication (71.65%) are highest.

Although the suggested model of this study is helpful to measure and quantify the discussed construct, the error of prediction is high for all the constructs except performance (13.06%) and sleep disturbances (19.68%). One reason might be that only 420 out of 1000 participating nurses responded to some portion of the survey. Since listwise deletion was used to score all the instruments included in the survey, the number of missing values was high among all the constructs in this study. Generally, the results of data mining techniques will be more accurate when mining a large amount of data.
Thus, increasing the number of participants would help to increase the accuracy of the results. However, obtaining such data for human constructs are difficult, time and cost consuming.

4.3 Discussion

This study aimed to provide a model to help nurse managers measure and quantify the levels of fatigue states, sleepiness related variables, performance, and patient safety considering work system parameters. A model was developed using the associations found by a classification method called CHAID. This model consisted of all the hidden associations between work system parameters and the discussed constructs; this model also analyzed associations among the constructs. Overall, by providing needed information (given values of specific work system parameters), the levels of fatigue states, sleepiness related variables, performance, and patient safety were quantified using the model. The accuracy of this model was measured using the collected data from nurse staff, thus attaining the highest accuracy for predicting performance and sleep disturbances and lowest accuracy for predicting chronic fatigue and sleep medication.

Most studies in the area of nurse assignment and nurse scheduling considered a few parameters mostly related to cost (i.e., budget, resources, workload) to optimize the process of assignment and scheduling. However, since nurses play a critical role in the caregiving process and patient safety, nurses’ cognitive and physical abilities to carry out the safe caregiving and the factors influencing these abilities need to be addressed.
Furthermore, the first step of including these factors in the decision-making process or in other current nurse scheduling-nurse assignment models, is to measure and quantify their values. However, it is time- and cost-consuming to subjectively or objectively quantify these constructs for day-to-day decision making. Thus, a prediction model could help nurse managers to measure and quantify nurses’ levels of fatigue states, sleepiness related variables, performance, and patient safety; these values could be included in nurse assignment and scheduling models.

The next step after measuring the values for the construct is to provide meaning (i.e. low, medium, high) for the predicted values of fatigue, sleepiness related variables, performance, and patient safety. In case of fatigue which was measured by OFER, Winwood et al. (2005) suggested that cut-points into levels of “low, low/moderate, moderate/high and high may be calculated considering quartiles of scale score distribution. In case of sleepiness, Global Pittsburg Sleep Quality Index (PSQI) score is usually used to define good and bad sleepers. Global PSQI score is calculated by summation of values of all seven components of PSQI. Participants with PSQI <=5 is considered as the good sleepers and participants with PSQI>5 are the bad sleepers (Nebes et al., 2009). Also, the results of our study in Chapter 2 show that the changes of performance occurs between good and poor sleepers for PSQI <=5 and PSQI>5. Thus, this threshold could be applied to identify levels of risks for decremented performance. In case of patient safety, user comparative database report is available online and nurses’ perception of their organization’s safety could be compared to min, 10th% quartile, 25th% quartile, 50th% quartile, 75th% quartile, 90th% quartile and max value of statistics provided by the Agency for Healthcare Research and Quality (2011).
Although the suggested model of this study is able to account for between 21.22% to 86.94% of the variance and the error of prediction is high for all the constructs except performance (13.06%) and sleep disturbances (19.68%). However, Social sciences and human-related constructs are associated with higher levels of ambiguity, uncertainty, and errors (Bhattacherjee, 2012). Further, mostly the work system parameters that could be controlled by nurse managers were included in this study. Thus, including some demographics or personal characteristics of nurses, nurses’ health and well-being and also several other variables which affect performance, patient safety and fatigue such as psychosocial factors, stress may be helpful to increase the accuracy of predicted results.

Among all the limitations of this study, only nurses currently employed in one private hospital were asked to participate. Thus, for example, shift schedule did not vary among nurses in the hospital. Thus, we were not able to capture the associations between shift schedule and other contributing constructs (i.e. performance, patient safety and fatigue in this study. Therefore, a more diverse population is needed to help to capture all the associations and hidden relations among discussed constructs in this study. However, the possibility of a significant association between work organizations or work environment and other contributing constructs and work system parameters should be considered.

Considering that the survey used was not generated solely for the purpose of this study and due to the scope of the work, a limited number of work system parameters were included (mostly parameters that could be controlled by nurse manager in work place) in the analysis of the current study. A more comprehensive set of work system parameters (i.e., more detailed information of psychosocial factors, commute time) and
also information related to nurse health and well-being, and their out of work responsibilities may be used to address all the concerns of nurse managers and policy makers.

Finally, future study is needed to include the level of discussed constructs measured by the model in nurse scheduling and nurse assignment models. The level of discussed constructs could be measured by the prediction model of this study and be included as objective functions (i.e. maximizing level of performance, patient safety or minimizing level of fatigue and sleepiness / constraints (i.e. limited level of fatigue or sleepiness) in the nurse scheduling and assignment model.

4.4 Conclusion

In this study, a model was developed to quantify and measure the level of fatigue states, sleepiness related variables, performance, and patient safety with changing the level of work system parameters. Then, the model was applied to identify the levels of discussed constructs in response to ten randomly generated configurations of work system parameters. Next, the absolute mean percentage errors corresponding to each construct was measured. The absolute mean percentage errors showed that the error of prediction was high for all the constructs except performance (13.06%) and sleep disturbances (19.68%). A more diverse and larger population is needed to help the analyzer capture all the associations and hidden relations among discussed constructs and increase the accuracy of the model. This model could be applied for calculating the
levels of fatigue states, sleepiness related variables, performance, and patient safety; these values could be included in nurse assignment and scheduling models.
Chapter 5. Discussion and conclusion

Nurses are the primary caregivers in the hospital and have the most direct contact with patients. Their performance is also associated with patient safety, having life-and-death implications. Thus, it is critical to identify and control the contributing factors to nurses’ performance for improving safety across healthcare organizations.

Further, fatigue, sleepiness, and work system parameters are among the factors affecting performance and patient safety. Each nurse responds to these contributing factors differently considering the levels of contributing factors and personal and demographic variables. Thus, controlling the levels of these contributing factors should be among the critical objectives when assigning a nurse to specific work parameters. However, due to the fact that it is time and cost consuming to measure the levels of these constructs for daily decision making processes, most of the current studies only consider objectives related to nurse availability, budget, and workload when optimizing nurse assignments and scheduling problems. Thus, a promising method is needed to measure and quantify the level of changes in one construct when changing the value of another one. Therefore, this research aimed to address the following research questions:

1) How does nurses’ performance change considering different fatigue levels and sleepiness?

2) How does sleepiness relate to fatigue state?

3) How do work system parameters relate to fatigue state, sleepiness, performance and patient safety among hospital nurses?
4) What are the levels of fatigue states, sleepiness variables, performance and patient safety under different configurations of work system parameters?

To answer these questions, Chi-squared Automatic Interaction Detection (CHAID), a data mining technique, was applied to uncover the hidden patterns and associations between fatigue states, sleepiness related variables, performance, patient safety, and work system parameters. Next, the established associations were applied to formalize, design, initialize, and build a model using Python programming language. This model consists of all discovered associations and interactions between work system parameters, fatigue states, sleepiness related variables, performance, and patient safety.

**Findings**

Overall, the mean of chronic fatigue was lower compared to acute fatigue among the participants of this study. It might be the reason that we did not find any significant association between chronic fatigue and patient safety, although they are significantly correlated. Further, the results show that for participants with low levels of acute fatigue, recovery significantly improves patient safety. Moreover, for participants with the highest levels of acute fatigue, chronic fatigue was significantly associated with decremented performance. Considering the definitions of acute and chronic fatigue, it is reasonable to not find the associations between performance and chronic fatigue among participants with low levels of acute fatigue.
The results of this study show that sleep quality is more associated with significant changes in fatigue level compared to sleep quantity. Pilcher et al. (1997) also confirms this finding.

The association between sleepiness related variables and performance and patient safety shows that, despite the results of other studies that linked decreased sleep duration to medical error and safety (Baldwin and Daugherty, 2004; Rogers et al., 2004 ; Rogers et al., 2003), sleep disturbances was the only significant factor contributing to patient safety and performance in our study. However, sleep disturbances might be the cause of receiving fewer hours of night sleep.

Investigating the association between the Pittsburg sleep quality index overall score (PSQI) and performance shows that PSQI=5 is where the changes of performance occurs between good and poor sleepers in our study. Other studies such as Nebes et al. (2009) also consider PSQI=5 as a threshold to divide good and bad sleepers. Thus, the result of our study confirms that using this threshold might be useful for future studies aimed at monitoring nurses’ sleepiness, performance, and fatigue. This threshold could be applied as a risk point for job assignments to manage risks and decrease errors.

Investigating the relationship between work system parameters and fatigue shows that there is a significant association between years of experience and acute fatigue. Since nurses with less experience are more likely to spend the majority of their time on direct patient care, thus, they are more likely to be physically exhausted and overexerted.

Satisfaction with work schedule also is significantly associated with reduced acute and chronic fatigue levels. Also, the result of this study confirms that nurses who work in

99
12-hour shifts are more satisfied with their schedule. Other studies also showed that 12-hour shifts are related to nurses’ wellbeing and reduced stress (Josten E.J. et al., 2003; Smith et al., 1998). In this study, control over schedule also has been linked to improved intershift recovery. These two factors can be considered psychosocial risk factors or stressors. The Karasek demand-control model and the job control-demand-support model are two well-known models of psychosocial factors (Karasek, 1979, 1997). The association between psychosocial factors and nurses’ performance, fatigue, wellbeing, and job satisfaction has been identified (Begat et al., 2005; De Jonge and Schaufeli, 1998; Harcombe et al., 2010; Lagerstrom et al., 1995; Parhizi et al., 2013; Piko, 2006; Van Yperen and Hagedoorn, 2003; Warming et al., 2009).

The association between work system parameters and patient safety shows that satisfaction with work schedule as a psychosocial variable is significantly linked to improved patient safety outcomes. However, any significant association between work system parameters and performance has not been identified. The reason might be because of low variance of performance among participating nurses. This variation matters because in decision trees, nodes are split in a way that variation in each node is minimized and variation between nodes is maximized.

The association between work system parameters and sleep disturbances shows that “years of experience” has the most significant association with sleep disturbances. Since “years of experience” and age are related, age might be a confounding variable affecting the association between work system parameters and sleep disturbances. Other studies also showed the effect of age on disturbed sleep (Åkerstedt, 2003).
The relationships between work system parameters and sleep duration shows that average hours worked per shift has the most significant association with sleep duration. Other previous studies also found an association between work hours and sleepiness (Centers for Disease Control and Prevention Morbidity and Mortality Weekly Report, 2012; Rogers et al., 2004; Scott et al., 2006).

The number of hours worked more than scheduled is also significantly associated with both sleep quality and sleep efficiency. Several other studies linked long work hours and overtime hours to sleep duration. However, the results of our study did not find any association between overtime hours and sleep quantity; rather, it linked overtime hours to sleep quality.

The model that was developed using the associations found by the classification method called CHAID consisted of all the hidden associations and relationships between work system parameters and the discussed constructs; it also analyzed associations and relationships among the constructs. Overall, by providing needed information (given values of specific work system parameters), the model was able to quantify the levels of fatigue states, sleepiness related variables, performance, and patient safety. Most current work assignments or nurse scheduling models do not consider nurses’ fatigue, sleepiness related variables, or performance and patient safety as quantitative variables affecting day-to-day assignment decisions. The calculated level of the discussed constructs in response to different configurations of work system parameters could be applied in different work assignment methods and models as objective functions (i.e., maximizing performance, patient safety, and minimizing fatigue and sleepiness) or constraints (i.e., limiting the level of fatigue or decremented performance and patient safety) in a unit.
In addition to discussed applications of this dissertation, the findings of this study also could be applied as a tool for measuring nurses’ levels of fatigue, sleepiness, performance and patient safety and assist government policy makers for developing safety regulations and policies. The similar fatigue-fighting rules, safety policies and regulations were announced by The U.S. Department of Transportation’s Federal Motor Carrier Safety Administration (FMCSA) limiting the maximum average work week for truck drivers and requiring truck drivers to take breaks during the first eight hours of a shift (United States Department of Transportation., 2013).

It is important to note that this study has some limitations. First, the validity of model shows that the accuracy of predicted outcomes is low. The reason is that only 420 out of 1000 participating nurses responded to some portion of the survey due to the length of survey and/or participants’ unwillingness to answer. Further, because of applying listwise deletion to score all the instruments included in the survey, the number of participating nurses in each instrument was lower than 420. Second, the data for the current study was collected using a cross sectional survey. Thus, the considerable analytical advantages of longitudinal survey (i.e., observing the individual trends of change and more accuracy for predicting desired outcomes) were missed. Further, objective measurement of the constructs such as performance and patient safety is needed to have a better understanding of the relationships between work system parameters and the discussed constructs, as well as among the constructs in this study. Next, due to the scope of the work, a limited number of work system parameters were included in the analysis of the current study. Thus, future work is needed to include a more comprehensive set of work system parameters to capture all the possible associations and
relationships (i.e., more detailed information of psychosocial factors, number of nurses in the unit, and patient-to-nurse ratio in the unit). Finally, the quantified level of discussed constructs measured by the model should be included as objective functions/constraints in the assignment model and nursing schedule problems to optimize nurses’ physical and mental abilities and performance as well as cost respective to resources and budget limitations.
APPENDIX

Appendix 1. CHAID result for the relationships between patient safety and fatigue states
Appendix 2. CHAID result for the relationships between OFER chronic fatigue and sleepiness
Appendix 3. CHAID result for the relationships between OFER acute fatigue and sleepiness.
Appendix 4. CHAID result for the relationships between OFER intershift recovery and sleepiness
Appendix 5. CHAID result for the relationships between performance and sleepiness
Appendix 6. CHAID result for the relationships between patient safety and sleepiness
Appendix 7. CHAID result for the relationships between OFER acute fatigue and work system parameters
Appendix 8. CHAID result for the relationships between OFER chronic fatigue and work system parameters
Appendix 9. CHAID result for the relationships between sleep efficiency and work system parameters
Appendix 10. CHAID result for the relationships between sleep disturbances and work system parameters
Appendix 11. CHAID result for the relationships between sleep latency and work system parameters
Appendix 12. CHAID result for the relationships between sleep duration and work system parameters
Appendix 13. CHAID result for the relationships between sleep quality and work system parameters
Appendix 14. CHAID result for the relationships between sleep medication and work system parameters
Appendix 15. CHAID result for the relationships between performance and work system parameters
Appendix 16. CHAID result for the relationships between patient safety and work system parameters


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