Curriculum Vitae

Knar Sagherian, PhD, RN
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EDUCATION

2017 **PhD in Nursing**
University of Maryland Baltimore School of Nursing

2012 **Master of Science in Nursing (emphasis Nursing Administration)**
American University of Beirut Hariri School of Nursing

2003 **Bachelor of Science in Nursing**
American University of Beirut Hariri School of Nursing

RESEARCH INTERESTS

Fatigue, sleep, recovery, naps, work-life balance
Outcomes: Absenteeism, performance, patient safety, and quality of life
Measurement, psychometrics and statistics

STATISTICAL/ANALYTICAL SKILLS

Proficient in SPSS and STATA; intermediate experience in Mplus and R studio.
Regression, Longitudinal Data Analysis (general and generalized linear mixed models), Multilevel Modelling, Exploratory and Confirmatory Factor Analyses, Structural Equation Modelling, and Item Response Theory.

PROFESSIONAL EXPERIENCE

Research

2017- Research Assistant
Dr. Erika Friedmann, Associate Dean of Research
Dr. Shijun Zhu, Assistant Professor and Biostatistician
Office of Research, School of Nursing
University of Maryland Baltimore

2014-16 **Graduate Research Assistant**
Dr. Eun-Shim Nahm (PI) "Patient-centered PHR/Portal implementation toolkit for ambulatory clinics: A feasibility study, and "A theory-based Patient Portal eLearning program for older adults with chronic illnesses" (AHRQ)
Duties: managed online survey data, conducted longitudinal data analyses and co-authored a paper.
In concurrent projects, conducted literature search on medication adherence in older adults and caregivers' use of patient portals, developed online surveys in Qualtrics, analysed national data from NHATS and HINTS in support for Dr. Nahm's grant applications and co-authored papers.
University of Maryland Baltimore School of Nursing

2014-16 **Graduate Research Assistant**
Dr. Jeanne Geiger-Brown (PI) "Pilot of comprehensive intervention to improve alertness in nurses (R21OH009979 CDC/NIOSH).

Duties: managed and analysed survey data on fatigue and sleep disorders, prepared PowerPoint and poster presentations for conferences and co-authored papers.
In concurrent projects, interviewed and enrolled participants via phone for a COPD intervention pilot study, conducted literature search on the effectiveness of naps on drowsy driving, prepared regulatory binders and analysed longitudinal survey data.
University of Maryland Baltimore School of Nursing

2011-13 **Research Assistant**
Dr. Huda Abu-Saad Huijer (PI) "Quality of palliative care in Lebanon, the perspectives of patients with cancer (LNCSR funded).
Duties: field experience in interviewing pediatric patients and their families, data coding and entry, statistical analyses, IRB renewal and closure reports, and co-authoring papers.
American University of Beirut Hariri School of Nursing

2011-12 **Research Assistant**
Dr. Hala Darwish (PI) "Vitamin D and cognitive performance in older adults" (AUB-RBMPP funded).
Duties: participant recruitment from community centers, face-to-face interviews, collecting blood samples and data entry
American University of Beirut Hariri School of Nursing

Teaching

2016-17 **Guest Lecturers**
NURS 316: Research and Evidence-based Practice
Lecture topics: Statistical analysis of quantitative data and Sampling
University of Maryland Baltimore School of Nursing

2016 **Guest Lecturer**
NURS 811: Measurement of Nursing Phenomena
Lecture topic: Measures and measurement issues in an observational study
University of Maryland Baltimore School of Nursing

2016 **Guest Lecturer**
NURS 851: Analysis for Experimental Nursing Research Designs
Lecture topic: Variables, Data and SPSS
University of Maryland Baltimore School of Nursing

2013-14 **Graduate Teaching Assistant**
Debra L. Spunt clinical simulation lab
Activities: role play, setting and running simulation scenarios, skills lab
University of Maryland Baltimore School of Nursing

2012-13 **Clinical Preceptor**
Medical-surgical pediatric and nursery units (BSN III students), and leadership practicum in pediatric hematology-oncology, medical-surgical pediatric and neonatal intensive care units (BSN IV students).
American University of Beirut Hariri School of Nursing

Clinical Practice

2009-11 **Pediatric RN; Part-time**
Areas: Medical-surgical units.

American University of Beirut Medical Center

2003-09 **Pediatric RN; Full-time**
Areas: Medical-surgical and step-down units.
Other responsibilities: nurse scheduling, preceptorship and mentorship.
American University of Beirut Medical Center

Administrative

2011 **Strategic Plan Taskforce-project coordinator**
American University of Beirut Hariri School of Nursing

RESIDENCY TRAINING-MASTER'S PROGRAM

240 hrs. Project management: in Continuing Medical Education (CME) office at American University of Beirut.
Activities: planning, organizing, coordinating & collaborating with different multi-disciplinary teams regarding educational activities, writing needs assessments & proposals, budgeting, & different marketing strategies.

HONORS AND AWARDS

2016 3-minute thesis (1st place) at University of Maryland Baltimore School of Nursing, November 10.

2016 University of Maryland Baltimore School of Nursing travel award - 12th International IACFS/ME Biennial Conference: Emerging Science and Clinical Care. Fort Lauderdale, Florida.

2016 Poster award (2nd place) at Maryland Sleep Society 7th Annual Conference. "Acute fatigue predicts sickness absence in the workplace: A 1-year retrospective cohort study in pediatric nurses."

2016 University of Maryland Baltimore School of Nursing travel award - 30th Annual Conference Southern Nursing Research Society, Williamsburg Virginia.

2015 University of Maryland Baltimore School of Nursing travel award - 112th Maryland Nurses Association Annual Convention, Linthicum Heights Maryland.

2015 Student Research Facilitation Award-Biology and Behavior Across the Lifespan Center of Research, School of Nursing, University of Maryland Baltimore.

2012 Poster Award (1st place) at Hariri School of Nursing Research Day. "Fatigue and Nursing Performance among Lebanese bedside nurses" (One of the evaluators was Dr. Jean Watson).

COMPETITIVE INTERNATIONAL SCHOLARSHIPS RECEIVED

2015-16 National League of Nursing Foundation for Nursing Education Scholarship Award
http://www.nln.org/professional-development-programs/grants-and-scholarships/foundation-for-nursing-education-scholarship-awards

2015-16 Armenian General Benevolent Union Scholarship

2014-15 Armenian General Benevolent Union Scholarship

2013-14 Armenian General Benevolent Union Scholarship

2011-12 Dr. Shake Ketefian Nursing Scholarship

PEER-REVIEWED PUBLICATIONS

Under review **Sagherian K,** Zhu S, Storr C, Hinds P. Geiger-Brown J. Bio-mathematical fatigue models predict sickness absence in hospital nurses: An 18 months retrospective cohort study. *Chronobiology International.* (IF=3.540)

Under review **Sagherian K,** Geiger-Brown J. Fatigue as an increased risk for sickness absence in the working population: A systematic review. *Sleep Medicine Reviews.* (IF=7.341)

2017 **Sagherian K,** Unick GJ, Zhu S, Geiger-Brown J, Derickson D, Hinds P. Acute fatigue predicts sickness absence in the workplace: A 1-year retrospective cohort study in pediatric nurses. *Journal of Advanced Nursing.* Accepted for publication. (IF=1.917)

2017 **Sagherian K**, Steege LM, Geiger-Brown J, Harrington D. The Nursing Performance Instrument: Exploratory and Confirmatory Factor Analyses in Registered Nurses. *Journal of Nursing Research.* Accepted for publication. (IF=0.970)

2017 Nahm E-S, Diblasi C, Gonzales E, Zhu S, **Sagherian K,** Kongs K. Patient-Centered PHR/Portal Implementation Toolkit for Ambulatory Clinics: A Feasibility Study. *CIN: Computers Informatics, Nursing*, 35(4), 176-185. doi: 10.1097/CIN.0000000000000318 (IF=0.758)

2016 **Sagherian K,** Clinton ME, Huijer Abu-Saad H, Geiger Brown J. Fatigue, work schedules and perceived performance in bedside care nurses. *Workplace Health and Safety*. doi: 10.1177/2165079916665398 (IF=0.564)

2016 Nahm E-S, **Sagherian K,** Zhu S. Use of Patient Portals in older adults: A comparison of three samples. *Studies in Health Technology and Informatics*, 225, 354-358.

2016 **Sagherian K,** Geiger-Brown J. In depth review of five fatigue measures in shift workers. *Fatigue: Biomedicine, Health & Behavior*, 4(1), 24-38. doi:10.1080/21641846.2015.1124521.

2016 Geiger-Brown J, **Sagherian K,** Zhu S, Wieroniey MA, Blair L, Warren J, Hinds P, Szeles R. Napping on the night shift: a two-hospital implementation project. *American Journal of Nursing*, 116(5), 26-33. doi: 10.1097/01.NAJ.0000482953.88608.80. (IF=1.389)

2014 Huijer Abu-Saad H, **Sagherian K,** Tamim H. Validation of the Arabic version of the Memorial Symptom Assessment Scale among Lebanese cancer patients. *Journal of Pain and Symptom Management*, 50(4), 559-565. doi: 10.1016/j.jpainsymman.2014.08.014. (IF=2.737)

2013 Huijer Abu-Saad H, **Sagherian K,** Tamim H. Quality of life and symptom prevalence as reported by children with cancer in Lebanon. *European Journal of Oncology Nursing*, 17(6), 704-710. doi: 10.1016/j.ejon.2013.09.004. (IF=1.794)

2013 Abu-Saad Huijer H, **Sagherian K,** Tamim H. Quality of life and symptom prevalence in children with cancer in Lebanon: the perspective of parents. *Annals of Palliative Medicine*, 2(2), 59-70. doi:10.3978/j.issn.2224-5820.2013.03.01.

2013 Huijer Abu-Saad H, **Sagherian K,** Tamim H, Khoury MN, Abboud AR. Quality of palliative care in cancer children at a major hospital in Lebanon. *Lebanese Medical Journal*, 61(4), 228-236. doi: 10.12816/0001478

2013 Huijer HA, **Sagherian K,** Tamim H. Validation of the Arabic version of the EORTC quality of life questionnaire among cancer patients in Lebanon. *Quality of Life Research*, 22(6), 1473-1481. doi: 10.1007/s11136-012-0261-0. (IF=2.864)

RESEARCH PRESENTATION

Oral presentation

2016 **Sagherian K,** Unick GJ, Zhu S, Geiger-Brown J. Nurses' acute fatigue predicts sickness absence in the workplace: A 1-year retrospective cohort study. 12th International IACFS/ME Biennial Conference: Emerging Science and Clinical Care (October 27-30).

Poster presentation

2016 **Sagherian K,** Unick GJ, Zhu S, Geiger-Brown J. Acute fatigue predicts sickness absence in the workplace: A 1-year retrospective cohort study in pediatric nurses. Maryland Sleep Society 7th Annual Conference (April 29).

2016 Sagherian K, Unick GJ, Steege LM, Geiger-Brown J. An item response theory analysis of the Occupational Fatigue Exhaustion Recovery Scale in nurses.
30th Annual Conference Southern Nursing Research Society (February 24-27).

2015 **Sagherian K,** Clinton M, Huijer H, Geiger-Brown J. Nursing performance associated with nurses' acute and chronic fatigue.
112th Maryland Nurses Association Annual Convention (October 22).

2015 Yang BK, **Sagherian K,** Geiger-Brown J, Trinkoff A. Effect of parity on mental health service use among individuals with mental/substance use disorders: A systematic review.
Academy Health Annual Meeting (June 14-16).

2014 **Sagherian K,** Lee C, Geiger-Brown J. Factors associated with drowsy driving in hospital nurses.
35th Anniversary Celebration of the University of Maryland School of Nursing PhD program (November 8).

2014 **Sagherian K,** Lee C, Geiger-Brown J. Factors associated with drowsy driving in hospital nurses.
Public Health Research Day at University of Maryland College Park (April 8).

2014 Huijer H, **Sagherian K,** Tamim H, Abboud M, Khoury M. Quality of palliative care in Lebanon; the perspective of children with cancer.
Nursing Research Day at American University of Beirut School of Nursing.

2012 **Sagherian K,** Clinton M, Huijer H. Fatigue and nursing performance among Lebanese bedside nurses.
Nursing Research Day at American University of Beirut School of Nursing.

REVIEWER IN PEER-REVIEWED JOURNALS

2016- Journal of Nursing Measurement

TRAINING/CERTIFICATIONS

2015 3rd Annual Maryland Sleep Boot Camp (July 9-10)
Sleep Medicine Core Lecture Series Course, University of Maryland School of Medicine

2014 2rd Annual Maryland Sleep Boot Camp
Sleep Medicine Core Lecture Series Course, University of Maryland School of Medicine

PROFESSIONAL MEMBERSHIPS/ASSOCIATIONS

2015-16 Southern Nursing Research Society (SNRS)
2011-13 Sigma Theta Tau International AUB School of Nursing Honor Society
2004-13 Lebanese Order of Nurses
2003-15 American Heart Association

SOCIAL SERVICE

2015-17 Doctoral Student Organization- treasurer and Executive Nursing Government Board member.
2013-14 Doctoral Student Organization-1st year student representative

LANGUAGES

English, Armenian, Arabic

Abstract

Dissertation Title: Nurse Fatigue Increases the Risk of Sickness Absence

Knar Sagherian, Doctor of Philosophy, 2017

Dissertation Directed by: Jeanne Geiger-Brown, Professor, Stevenson University, School of Nursing and Health Professions

Introduction: Sickness absence (SA) is problematic in occupations requiring 24/7 coverage where one person's SA cascades into more work days, longer shift durations and elevated fatigued states for remaining workers. As part of this dissertation, a systematic literature review found strong evidence that fatigue increased the risk of SA in the workforce. Few studies examined this relationship in nurses, despite reported high fatigue and differences in shiftwork characteristics. Fatigue-risk scores generated from bio-mathematical fatigue models are popular in safety-sensitive industries and may be useful for assessing and monitoring fatigue on nursing units and predicting SA.

Purpose: The purpose of this study was to explore prospective associations between work-related fatigue, bio-mathematically modeled fatigue-risk and SA in 12-hour shift hospital nurses.

Methods: Two studies were conducted that used retrospective cohort design of hospital nurses representing four nursing units from a major pediatric hospital. Baseline data on work-related fatigue were from Fatigue Risk, Alertness Management Effectiveness (FRAME) study (n=40) using the self-reported Occupational Fatigue Exhaustion Recovery Scale. Data on fatigue-risk scores were generated from work-rest schedules of 197 nurses working 41,538 shifts using Fatigue Audit InterDyne (FAID) and Fatigue Risk Index (FRI) software programs. Work-related fatigue and fatigue-risk scores were then linked to SA data that were extracted from the hospital's attendance system. The statistical approach was generalized linear mixed models that account for non-independency of repeated measures.

Results: The SA rate in both studies was ~5%. Among FRAME participants, for every 1SD increase in acute fatigue scores, nurses were 1.29 times more likely to be absent from work (OR=1.29, 95%CI=1.02-1.63). In the bio-mathematical model study, when FAID-scores were moderate (scores=41-79, OR=1.38, 95%CI=1.21-1.58) or high (scores=81-150, OR=1.67, 95%CI=1.42-1.95), nurses were more likely to take SA than nurses with lower (<41) scores. Similarly, when FRI-scores were >60, nurses were 1.58 times (95%CI=1.05-2.37) more likely to take SA compared to nurses with lower scores.

Conclusion: Work-related acute fatigue and fatigue-risk modeled bio-mathematically significantly predicted nurses' SA. While surveys are instrumental in identifying the nature and severity of fatigue, bio-mathematical fatigue models may be more practical to monitor for day-to-day fatigue changes in the workplace.

Nurse Fatigue Increases the Risk of Sickness Absence

by
Knar Sagherian

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, Baltimore in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2017

Dedication

To my precious mom and adorable brother, thank you for being my Rock!
To my dad in heaven, this work is my gift to you!

Acknowledgement

I wish to thank my phenomenal committee members: Drs. Geiger-Brown (Chair), Storr, Rogers, Unick, Zhu and Steege for guiding and supporting me during my dissertation research. Also, I am truly thankful for your words of encouragement and mentoring as I plan my next steps and future endeavors.

This journey would not have been successful without the constant support of my dear family and valuable friends. I am blessed and forever grateful.

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1. Introduction and Purpose

1.1. Introduction

Sickness absence (SA), defined as “failure to report for scheduled work” (Darr & Johns, 2008) costs the US economy $225.8 billion per year, equivalent to $1,685 per worker (CDC Foundation, 2015). According to the Bureau of Labor Statistics, US healthcare practitioners have an absence rate of 3.3% (Bureau of Labor Statistics, 2014), with nurses representing the highest number in this sector. This figure is higher than the 2.9% absence rate among fulltime employees (Bureau of Labor Statistics, 2014). SA is an indicator of nurses’ poor physical and psychosocial health that affects work productivity (Roelen et al., 2014) and unit morale. Frequent and long-term SAs disrupt the workflow on nursing units by creating temporary shortages in staff, and more work days and longer shift durations for unit nurses that can lead to elevated fatigue states, unsafe practices in patient care and increased patient mortality (Arakawa, Kanoya, & Sato, 2011; Duffield et al., 2011; Trinkoff et al., 2011).

Occupational fatigue is commonly reported and a safety hazard in shift working populations including nurses. Most of the fatigue rises from nurses’ non-standard work schedules and increased temporal and job demands in providing excellent patient care (Akerstedt & Kecklund, 2017; Dorrian, Baulk, & Dawson, 2011; Yuan et al., 2011). Research has shown that when fatigued and sleep deprived, nurses experience reductions in job performance that affect the safety and quality of patient care, putting patients at risk for medical errors that may jeopardize their health (Dorrian et al., 2008; Olds & Clarke, 2010; Sagherian, Clinton, Abu-Saad Huijer, & Geiger-Brown, 2016; Scott, Rogers, Hwang, & Zhang, 2006; Wolf, Perhats, Delao, & Martinovich, 2017). This risk is further emphasized when nurses develop chronic health problems and stress-related illnesses (Kane, 2009; Nagai et al., 2011; Whang et al., 2009), which result in frequent absences from work.

1.2. Literature review

Longitudinal studies have reported subjective fatigue experiences to predict SA in the general European workforce. In a national study of 8300 Swedish workers, the authors reported that fatigue significantly predicted intermediate (14-89 days) and long term (≥90 days) sickness absences over 2 years of follow-up when accounting for disturbed sleep, socio-demographic and work characteristics (Akerstedt, Kecklund, Alfredsson, & Selen, 2007). Similarly, a national study of 7495 Dutch workers reported that when chronic fatigue increased, the odds for long-term (>42 days) SA increased by 1.4 times over a period of 6 months (Janssen, Kant, Swaen, Janssen, & Schröer, 2003). Only one Norwegian study (n=1506) of high quality focused on nurses who worked primarily in 8-hour shifts. The results showed that nurses' elevated physical and total fatigue predicted self-reported long-term (>30 days) SA after 1 year of follow up while adjusting for demographic, health, lifestyle and work-related variables (Roelen et al., 2013). One limitation in this study was the risk for recall bias in SA episodes that may under or overestimate the results.

In addition to work-related fatigue, certain work, organizational, personal, and social factors can predict future SAs. Work-related factors can range from specific work-schedule characteristics to increased work demands. A systematic review by Merkus et al. (2012) based on four high quality studies concluded that the risk for SA was increased only in female healthcare workers on permanent evening shifts (Merkus et al., 2012). On the other hand, a study of 464 policemen showed that SAs were significantly higher on night shifts and for those working three or more consecutive nights followed by the afternoon and the day shifts (Fekedulegn et al., 2013). A number of studies have reported that nurses who had high job strains (Trybou et al., 2014) and effort-reward imbalances (Schreuder, Roelen, Koopmans, Moen, & Groothoff, 2010) were more likely to have SA episodes. Nursing workloads that were above the optimal level similarly increased the likelihood of SA in hospital nurses (Rauhala et al., 2007).

Supportive work cultures are considered important organizational factors that influence nurse absenteeism. In a study of 699 nurses from six nursing units, researchers reported that when nurse managers were relationship-oriented, nursing staff were less likely to be absent from work (Schreuder et al., 2011). Conversely, when nurses felt disrespected by peers and supervisors, they were more likely to be absent from work (Schreuder et al., 2010). Regarding personal factors, a number of studies reported that when nurses were depressed or emotionally exhausted, they were more likely to be absent from work (Anagnostopoulos & Niakas, 2010; Peterson et al., 2011). Certain demographic factors such as nurses' age or gender may play a role in SA, however the literature is scare. In a sample of 144 hospital nurses, age was inversely and weakly correlated with absenteeism, however there was no association with gender (Siu, 2002). Social factors such as family obligations also added to nurses' absence too. In a Scottish study of 152 telephone helpline nurses, a conflict in work-family balance contributed to their job dissatisfaction and absenteeism from work (Farquharson et al., 2012).

1.3. Problem and significance

To date, the occupational research on work-related fatigue and SA has been conducted in the general workforce (i.e., blue and white collar workers), and in European countries that have social insurance systems and institutional policies on employee SA distinct from the United States. For US nurses where 12-hour shifts are the norm, and the average age of this workforce is 47 years (AACN, 2014), there is little evidence on the relationship between nurse fatigue and SA despite documented high fatigue levels. Moreover, the nursing research on SA has primarily focused on examining work, organizational and some personal factors that can be fatiguing too. Future research on factors influencing this relationship can provide a better understanding of SA that has complex multifactorial etiology, and contribute to the development of preventive measures where nurses' fatigue can be the modifiable agent.

In SA research, work-related fatigue assessed through the administration of subjective fatigue measures can be a major limitation in hospital environments. To monitor for elevated nurse fatigue levels as part of the day-to-day operational system, surveying nurses would be unrealistic and burdensome. A practical solution for nursing management is to implement bio-mathematical fatigue models on nursing units. These models generate employee fatigue-risk scores that are based on the science of homeostasis and circadian rhythms, and the input of work schedules with some variations in different software. To our knowledge, they are rarely implemented in healthcare nor used to predict SA despite their frequent use in aviation, transportation and other safety-sensitive industries. The knowledge we gain from future research will advance the science by implementing bio-mathematical fatigue models in the healthcare sector, in estimating nurse fatigue-risk scores and predicting SA over time. Nursing management can monitor for fatigue-risk using these models, use the data to support their decisions, intervene strategically prior to the event of SA and maintain safe practice environments.

1.4. Purpose and aims

The purpose of this dissertation research was to explore prospective associations between work-related fatigue and bio-mathematical fatigue-risk, and SA in 12-hour shift hospital nurses.

The specific aims were:

1 To systematically review and synthesize the existing literature on the relationship between fatigue and SA in the working population.

2 To explore the association between work-related fatigue and SA in hospital nurses over 12 months of follow-up.

   - Hypothesis: Nurses with elevated chronic fatigue scores at baseline will have increased odds of SA.
   - Hypothesis: Nurses with elevated acute fatigue scores at baseline will have increased odds of SA. However, the strength of the relationship between acute fatigue and SA will be lower than that of chronic fatigue and SA.

3 To explore the associations between bio-mathematical fatigue-risk scores and SA in hospital nurses over 18 months of follow-up.

   - Hypothesis: Nurses' elevated fatigue-risk scores will increase the odds of SA.

1.5. Fatigue-sickness absence conceptual framework

"Problems associated with abnormal work schedules" original model

In 2011, Drs. Tucker and Folkard presented their theoretical model in the International Labor Office meeting held in Geneva (Appendix A). It was more of a comprehensive model than a unified theory that provided an overview of the etiology of various problems that resulted from abnormal work schedules. Fatigue was defined as "an acute response that can be pinpointed in time and hence related to specific features of a work schedule". Consequently, fatigue is generated from non-standard work schedules and duration of work hours in a shift, and is cumulative in nature. Non-standard work schedules fall outside the typical standard work day that starts from 7 or 8 AM and ends at 5 or 6 PM, from Monday through Friday, with weekends off. They may include shiftwork, part-time, work during weekends and at nights, on-call, split shifts, and extended working hours (more than 8 to 9 hours per day and/or 40 hours per week).

Abnormal work schedules influence or disturb the internal body clock, sleep and family-social life. For example, night shift changes the normal sleep-wake cycle and seldom do night shift workers develop complete circadian adaptation to nocturnal activity (Folkard, 2008). These rhythmic disturbances create fatigue, sleepiness, insomnia, reduced mental capacity, reduced performance and digestive problems (Tucker & Folkard, 2012). The features of a work schedule determine how much fatigue is accumulated during a shift and over successive shifts, and how much of an opportunity there is to dissipate the fatigue during rest periods. Other features include frequency and duration of breaks in a shift, start time and duration of shifts, number of days off following the shifts, number of consecutive shifts of one type, sequencing of consecutive shifts, number of work days, unscheduled overtime, self-scheduling, number of consecutive rest days, and frequency and duration of annual leave.

Individuals, organizational and situational differences affect the relationship between work schedule features, biological clock (circadian rhythm), sleep and family-social life. Individual factors include gender, age, personality type, chronotype, habitual long or short sleepers, and easiness to sleep during unusual times. Organizational factors are the physical availability of rest areas, psychosocial work conditions such as support from colleagues and supervisors, and the physical environment (e.g. light, heat, noise). Situational differences include work commutes, family responsibilities, second jobs, and demanding leisure activities.

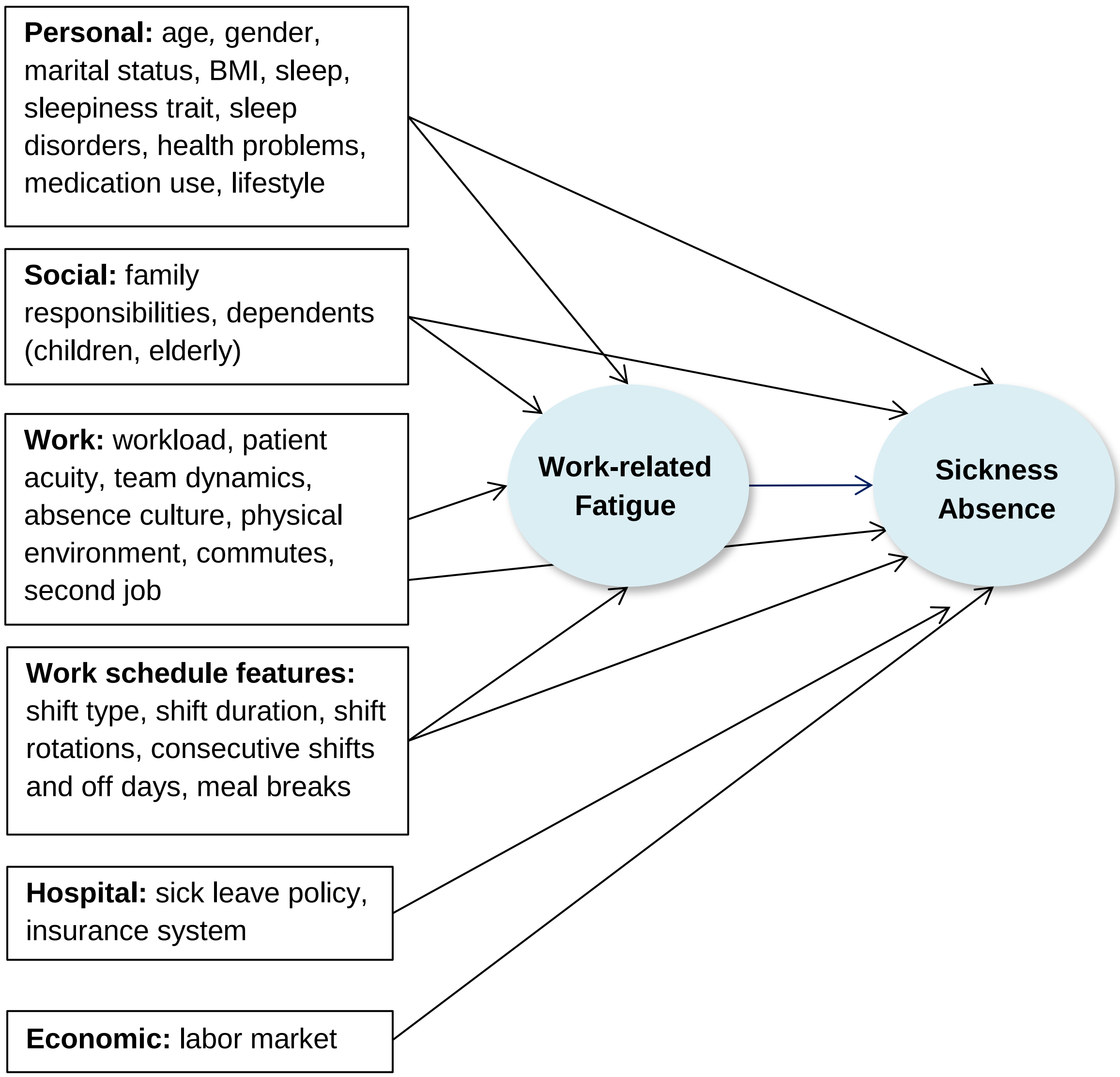
The degree of disturbances in the body clock, sleep and family-social life will create acute manifestations on mood, performance and fatigue. These effects are as well directly influenced by increased job demands and workload. Individual coping strategies can interrupt or decrease the impact of developing chronic effects on mental health and performance and on physical health and safety at a later stage. However, it is not clear the type of coping strategies or recovery measures the researchers refer to in the model.

“Occupational fatigue and sickness absence” model

Figure 1 presents the conceptual framework that guided the dissertation study. This framework was built upon the theoretical framework of Drs. Tucker and Folkard (Tucker & Folkard, 2012). In our framework, fatigue is a “biological drive to rest and sleep because of a days’ work” (Williamson et al., 2011). It can be presented in terms of acute states (i.e., short lived) or chronic traits. In the absence of strong recovery measures after work, occupational fatigue accumulates with over time, and can lead to SA from scheduled work.

In workers, most of fatigue rises from two main sources: work schedule features that create circadian misalignment and disturbed sleep, and work-related factors such as increased workload and physical and psychological demands of the job (Fang, Qiu, Xu, & You, 2013; Lerman et al., 2012; Shen et al., 2006; Yuan et al., 2011). Personal factors can contribute to increased fatigue levels such as depression, sleep disturbance or total hours of sleep. Socio-demographic factors such as age, marital status and family obligations may worsen or ameliorate fatigue levels however the literature is still inconclusive. Certain factors like hospital policy on sick leave and the overall economy may influence an individual's decision to take sick leave or go to work despite being highly fatigued. We acknowledge that some factors may be interrelated with fatigue and SA, however testing the structure of the model is not within the scope of this dissertation study.

Figure 1. A conceptual model for occupational fatigue and sickness absence



1.6. Methods

Aim 1 involved a systematic review of longitudinal studies that examined the relationship between fatigue and SA in the working population. The inclusion criteria were: 1) fatigue defined as a symptom or construct, 2) self-reported or company registered SAs, and 3) workers from all occupations. There were no restrictions on publication date and all articles were in the English language. The search engines included: PubMed, CINAHL, Cochrane CENTRAL, and PsycINFO. Some of the keywords were: fatigue, tiredness, worker, sickness absence, or absenteeism. A standardized checklist was devised from previous observational systematic reviews for methodological quality assessment (Dekkers-Sánchez, Hoving, Sluiter, & Frings-Dresen, 2008; Merkus et al., 2012). The strength of the evidence was classified into either strong (≥3 studies with significant relationships in the same direction), weak (2 studies reported significant relationships in the same direction), insufficient (one study) or inconsistent.

Aim 2 was a 1-year retrospective cohort design using data from the FRAME (Fatigue Risk, Alertness Management Effectiveness) study, a pilot study that assessed the effectiveness of fatigue reduction interventions in 12 hour shift hospital nurses in two mid-Atlantic hospital settings (Geiger Brown et al., 2014; Geiger-Brown et al., 2012, 2016). For this study, the sample was focused on 40 female nurses who worked on four nursing units in one of the settings (large pediatric hospital). The participants completed a work diary over four weeks and self-reported other factors such as workload, sleep disturbances, sleepiness and personal characteristics. Acute fatigue and chronic fatigue were measured by the 15-item Occupational Fatigue Exhaustion Recovery scale. Acute fatigue is a byproduct of daily work activities that resolves with rest and sleep. In chronic fatigue, the condition is more of long term where individuals besides reductions in physical performance, experience decreased motivation and difficulty in concentration. The data on nurses' sickness absence were extracted from the hospital's time and attendance system (i.e. clock-in and clock out data) (Kronos, Inc.) by a system analyst. The system stored the dates, times and pay codes that indicated nurses' absences from work. These pay codes were tagged as SICK, Accrued Sick and Safe Leave Act (ASSLA)-sick, Family Medical Leave Act (FMLA)-sick or UNPAID LEAVE. Absences that indicated scheduled vacation days, holidays or family bereavement were not part of the SA analyses. In STATA 14.1, generalized linear mixed models were used to test the associations between fatigue, work, personal factors and SA, while accounting for the non-independency of repeated measures.

Aim 3 was also a retrospective cohort design study using data from 197 nurses from the same hospital setting as aim 2. Daily work schedules were extracted from the hospital's time and attendance system (Kronos, Inc.) by a system analyst. Work schedules (dates and clock-in and clock-out data) were uploaded to the Fatigue Audit InterDyne (FAID) and Fatigue Risk Index (FRI) software. These bio-mathematical fatigue models estimate fatigue-risk based on the science of homeostatic sleep drive, circadian rhythms, sleep inertia and research in the area. Fatigue-risk scores were generated for each work day and linked to SA data. In STATA 14.1, generalized linear mixed models were used to test the associations between the fatigue-risk scores and SA, while accounting for the non-independency of repeated measures. The follow-up period was for 18 months.

1.7. Summary

This introductory chapter presented an overview of SA and work-related fatigue in nurses, the literature on this relationship, and other work-related, organizational, social, and personal factors that may influence the outcome of SA. In subsequent sections, the chapter described the potential significance of monitoring and managing fatigue on nursing units, the conceptual framework that was developed for this dissertation research, the three study aims, hypotheses and a summary of the methods.

As for the following three chapters, they encompass a systematic review on the prospective association between fatigue and SA in the working population, and two studies that test the prospective associations between fatigue, fatigue-risk scores and SA in hospital nurses. In the final chapter, we provided a synthesis of the main research findings, strengths and limitations of the dissertation, implications for nursing practice and for future research.

2. Fatigue as an increased risk for sickness absence in the working population: A systematic review[1]

2.1. Abstract

High sickness absence rates are indicative of poor health in working populations. Absenteeism is influenced by personal, social, workplace, organizational and economic factors. Fatigue, a common complaint in workers, has been associated with sickness absence. To date, there is no systematic review that examined the prospective association between fatigue and sickness absence in the workforce. Thus, the purpose of this paper was to conduct a systematic review and synthesize the existing literature. A literature search was conducted in PubMed, Embase, CINAHL, PsycINFO and Cochrane databases. Longitudinal studies were selected that focused on fatigue and sickness absence in workers. There were no restrictions on publication date, and studies were English language publications. Seventeen studies met inclusion criteria, of which 15 were of high methodological quality. There was strong evidence for chronic fatigue and fatigue as a symptom to predict long-term sickness absence. Evidence for this association was strong among men only, irrespective of the different measures of fatigue utilized in these studies. We conclude that there is strong evidence for a prospective association between occupational fatigue and long-term sickness absence. We recommend consensus among researchers on the type of fatigue measures that can increase the quality of future sickness absence research.

Keywords: fatigue, sickness absence, workers, workplace

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2.2. Introduction

Sickness absence (SA) is an indicator of poor health in working populations. Research has shown that employees on long-term SA for more than 4 weeks require longer periods to return to work because of psychosomatic symptoms, low self-efficacy and high physical job demands (Nielsen et al., 2012; Vlasveld et al., 2012; Volker, Zijlstra-Vlasveld, Brouwers, van Lomwel, & van der Feltz-Cornelis, 2015). Moreover, employees with frequent long-term SA are at high risk for disease-related and all-cause mortality (Kivimäki et al., 2003; Lund, Kivimaki, Christensen, & Labriola, 2009; Mittendorfer-Rutz et al., 2012; Vahtera, Pentti, & Kivimäki, 2004). In some cases, SA is related to an employee's disaffection from the workplace and the need to fulfill family responsibilities.

From an organization point of view, low SA rates are preferred because it decreases the enormous cost burden related to medical care, paid sick leaves, staff replacements and overtime. However, SA management is a major challenge because a myriad of personal, social, workplace, organizational and economic factors are at play (Alexanderson K, 1998). Fatigue as a risk factor for SA has been of research interest in the occupational literature. In the European workforce, overall fatigue reported by 22.5% of workers, was one of the most commonly reported symptoms after backache (24.7%) and muscular pains (22.8%) (European Agency for Safety and Health at Work, 2010). Fatigue is also prevalent in the US workforce, estimated at 37.9% over a period of two weeks (Ricci, Chee, Lorandeau, & Berger, 2007). In the workplace, fatigue creates a safety hazard not only for the employee but also to others and the environment (e.g., oil spills, fires).

A simple perspective of fatigue views it as a symptom of tiredness but it can also be viewed as a condition with multiple components. With the latter being more accepted, fatigue is conceptualized as a subjective experience where feelings of tiredness impair an individual's physical, mental and/or psychosocial functioning (Beurskens et al., 2000; Dorrian, Hussey, & Dawson, 2007; Shen et al., 2006). Most of the fatigue resulting from work activities is transient, and resolves with rest and sleep. However when recovery is incomplete during non-work hours, fatigue accumulates and becomes chronic in nature. In a study of Finnish industrial workers who were followed over a period of 28 years, incomplete recovery from work was found to increase the hazard for cardiovascular mortality by 1.54 times (Kivimäki et al., 2006). Fatigued employees are also susceptible to developing psychological problems and stress-related illnesses (Sluiter, De Croon, Meijman, & Frings-Dresen, 2003).

Often fatigue and sleepiness are used interchangeably among workers. Despite commonalities, each phenomenon is different from the other. Sleepiness is a normal physiologic condition defined as the propensity to fall asleep and is relieved only by sleep (Lerman et al., 2012; Shen, Barbera, & Shapiro, 2006). Fatigue is a response to extended periods of wakefulness, sleep loss and prolonged physical and mental exertion that is relieved by rest and sleep (Lerman et al., 2012). From an occupational standpoint, fatigue can be considered a biological signal to recuperate and sleep because of work. Most of the fatigue arises from circadian misalignment and sleep deprivation, workload, and the work environment (Lerman et al., 2012). Additional fatigue risk factors include health problems and certain personal characteristics such as age and marital status.

Although a number of longitudinal studies have examined the relationship between fatigue and SA in different occupations, a review of the literature identified that no systematic review of this relationship has been done to date. This gap may be related to differences in SA operational definitions that are heavily influenced by a country's SA insurance practices, compensation benefits, employer-employee contracts and the researcher's study objectives. In a systematic review on SA measures, Hensing reported that there are five different approaches to quantifying this outcome: frequency, length, incidence rate, cumulative incidence and the duration of SA (Hensing, 2009). Another reason may be related to the symptom of fatigue itself that is non-specific in nature, and can be a precursor or byproduct of illnesses and/or working conditions.

With this paper, we aim to examine the existing literature on fatigue and SA in workers, and determine 1) if there is conclusive evidence of this relationship, 2) what is the nature of fatigue that predicts SA, and 3) if SA is of short or long term. We also present our synthesis by country in which studies were conducted because of differences in social systems and government laws regarding SA.

2.3. Methods

This systematic review included longitudinal studies that examined the relationship between fatigue and SA in the working population. Inclusion criteria were: 1) fatigue defined as a symptom (tiredness, being tired, lack of energy, or weariness) or construct (unidimensional or multidimensional), 2) SA or absenteeism operationalized as short or long term, or by frequency or duration of an episode of absence from work, and 3) the population of interest included workers or employees from all occupations or disciplines. There were no restrictions on publication date. The study design included prospective and retrospective cohort studies that were published in the English language. Exclusion criteria included cross-sectional studies, papers that focused on "chronic fatigue syndrome" cases, SA in patient groups and employees who were already on sick leave.

2.3.1. Search strategy

A literature search was conducted by the first author and a librarian independently. Five databases were searched, included: PubMed, Embase, CINAHL, PsycINFO, and Cochrane CENTRAL. Keywords were: fatigue, tired, exhaustion, weariness, worker, employee, occupation, workforce, SA, absenteeism, sick leave and absent. The last day of retrieval was March 17, 2016. A reference hand search of systematic reviews on SA yielded no additional papers.

An example of one electronic search strategy, in PubMed is presented below.

(fatigue[tiab] OR "fatigue"[mesh] OR exhaust*[tiab] OR tired*[tiab] OR weariness[tiab] OR burnout[tiab] OR "burnout, professional"[mesh] OR "work schedule tolerance"[mesh])

AND

(absent*[tiab] OR absence[tiab] OR absenteeism[mesh] OR sick[tiab] OR sickness[tiab] OR "sick leave"[mesh])

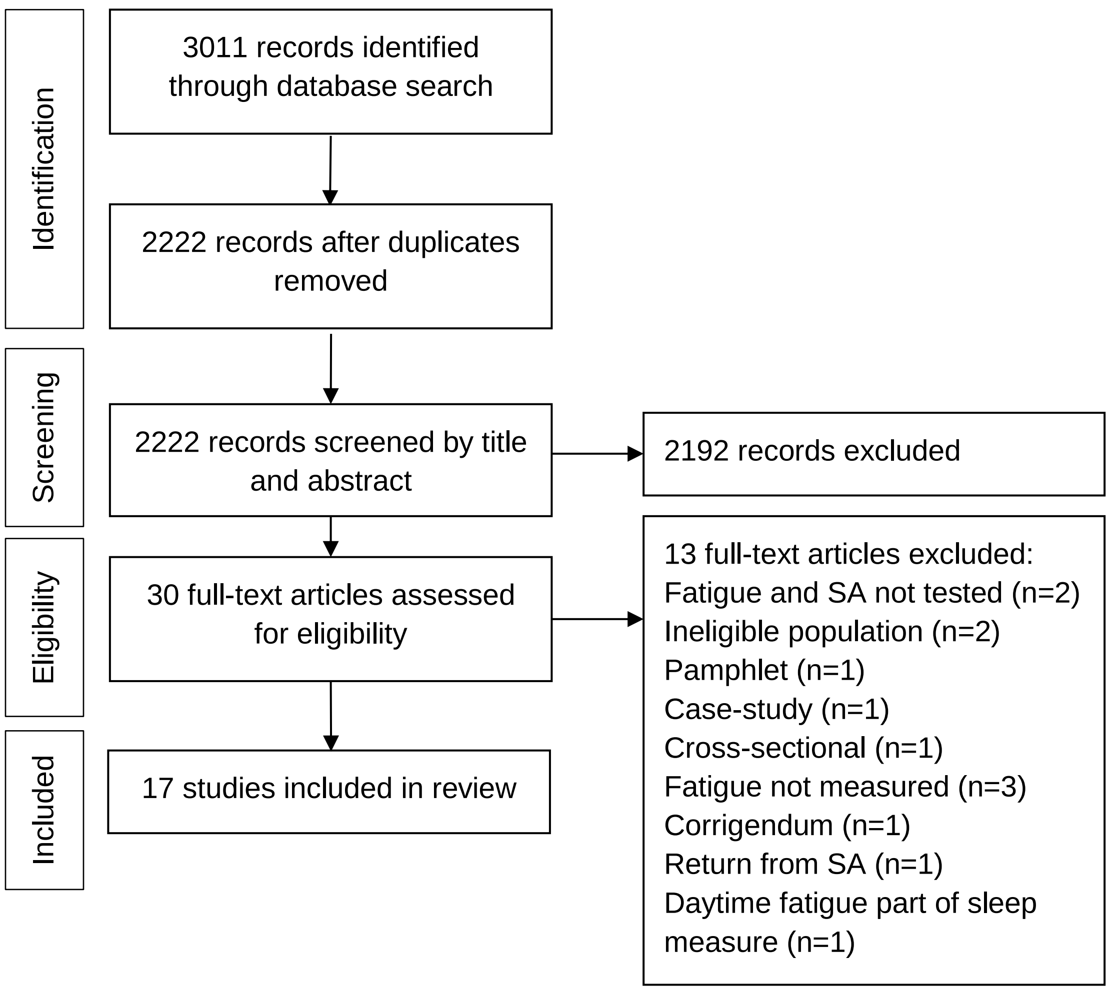
AND

(work*[tiab] OR workplace[mesh] OR employ*[tiab] OR job[tiab])

2.3.2. Selection process

The primary search identified 3011 references. After removing duplicates, the reference list included 2222 studies. Two authors (KS and JGB) independently screened the titles and abstracts of the studies. Thirty potentially relevant articles were retrieved and reviewed by the two authors based on inclusion and exclusion criteria. Each article was evaluated independently and disagreements were resolved by consensus. The final sample included 17 articles. The PRISMA flow diagram illustrates the detailed steps from the initial search of the literature to the final selection of the studies for the systematic review (see Figure 2).

Figure 2. PRISMA flow diagram for relevant studies



2.3.3. Methodological quality assessment

The quality of the 17 studies was appraised based on an 18-item standardized checklist developed for this review (see Table 1). The criteria, except for item 1, were adopted from two previous standardized checklists that were used in systematic reviews of observational studies (Andersen, Fallentin, Thorsen, & Holtermann, 2016; Dekkers-Sánchez, Hoving, Sluiter, & Frings-Dresen, 2008; Merkus et al., 2012). Our checklist included seven headings: background, study objectives, study population, exposure (fatigue) assessment, outcome (SA) assessment, assessment of confounders/covariates, and statistical rigor/data presentation. Each item was scored as positive, negative or not applicable (depending on study design). Quality scores were constructed as the sum of positive items divided by the total number of applicable items and then multiplied by 100. The quality scores were classified into high (>75%), medium (50-75%) and low (≤50%). Low and medium quality studies were not considered as part of rating the evidence.

Categories for rating the evidence were strong, weak, insufficient (if only one study was available) or inconsistent evidence (Dekkers-Sánchez et al., 2008). When three or more studies reported significant relationship in the same direction, the evidence was considered as strong. When two studies reported significant relationship in the same direction, or three studies of which two only reported significant associations, the evidence was considered as weak.

Table 1. Standardized checklist for methodological quality assessment of the prospective and retrospective cohort studies.

Item	Criterion
Background	1. Positive if there is a clear and focused description of the problem
Study objectives	
	2. Positive if the objective of the main study is clearly stated.
Study population	
	3. Positive if the population of interest and the occupational settings are clearly described (e.g., insurance, hospital, population).
	4. Positive if participation/response rate is ≥ 80%, or if participation rate is 60-80% and non-respondent analysis is done to assess for selection bias.
	5. Positive if at follow-up participation rate is ≥80% or company registered absence data is available for ≥80% of employees, or if non-respondent analysis is not selective (data provided).
Exposure assessment	Fatigue
	6. Positive if the instruments for measuring fatigue are clearly described.
	7. Positive if fatigue as a symptom is assessed and the rating scale provided.
	8. Positive if personal recall for fatigue data is in the past 3 months.
Outcome assessment	Sickness absence
	9. Positive if the outcome data are from company records or personal recall is within the past 3 months.
	10. Positive if follow-up data were for 1 year or longer
Assessment of confounders/covariates	
	11. Positive if data on personal characteristics and health problems are measured.
	12. Positive if data on work-related characteristics (e.g., psychosocial work environment, work hours) are measured.
	13. Positive if history of sickness absence is measured or cases excluded with positive history at baseline.
	14. Positive if confounder data are measured for all participants using the same standardized method.
Statistical rigor/ data presentation	
	15. Positive if appropriate statistical approach is used.
	16. Positive if measures of association (e.g. OR, RR, HR or betas) with 95% CI are presented.
	17. Positive if statistical models are adjusted for confounders or covariates (depending on statistical approach)
	18. Positive if the number of sickness absence cases is reported and is 7-10 per independent variable or 7-10 participants/ variable in multivariate analyses.

This checklist was modified from Dekkers-Sánchez et al. 2008 and Merkus et al. 2012

2.4. Results

Between 1989 and 2016, 17 longitudinal studies were published in the literature. The majority were from the Netherlands (12) followed by Scandinavian countries (4), and Canada (1). It is worth noting that only one study, a cross-sectional study addressing fatigue and SA, was reported in US workers. The working populations studied were diverse and consisted of white collar employees, blue-collar workers, truck drivers, eldercare employees, and nurses. The primary objective in most studies was to determine the predictive capacity of fatigue on SA. However, in two studies fatigue was not the main objective and was measured as part of a subjective health questionnaire (Roelen, Koopmans, & Groothoff, 2010) and an item in a depression scale (Rugulies et al., 2013). One study focused on establishing the criterion validity of the Trucker Strain Monitor that consisted of work-related fatigue and sleeping problems subscales in relation to future SA (De Croon, Blonk, Sluiter, & Frings-Dresen, 2005). Another study examined whether fatigue contributed to a SA prognostic model in risk reclassification analyses (Roelen, Bültmann, Groothoff, Twisk, & Heymans, 2015).

The methodological quality assessment of these studies (16 prospective and 1 retrospective cohort in design) is presented in Table 2. Fifteen studies were of high quality, thus indicating good methodological rigor. When examining each criterion in detail, most studies had low response rates (<60%) at baseline that raised concerns for selection bias. However the majority from the Maastricht cohort (Bültmann et al., 2005; Huibers et al., 2004; Mohren, Swaen, Kant, van Schayck, & Galama, 2005) and other studies (de Croon, Sluiter, & Frings-Dresen, 2003; Roelen, van Rhenen, Groothoff, van der Klink, & Bültmann, 2014) reported non-response analyses in detail. Important confounders such as presence of health problem were missed in a few studies which may be related to secondary data analysis (Akerstedt, Kecklund, Alfredsson, & Selen, 2007; de Croon et al., 2003; Roelen et al., 2014; Roelen et al., 2014; Rugulies et al., 2013). Regarding measuring the history of SA, most studies censored or excluded participants who had a recent SA or who were on sick leave at the time of the study. For statistical rigor, a few studies using logistic regression analyses included more than the appropriate number of covariates in their statistical models (i.e., ~10 cases in the outcome per one variable) that may raise concerns about overfitting the regression models

Table 2. Methodological quality assessment of the included studies.

Study references	Methodological items																		%
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Roelen et al. (2015)	+	+	+	-	+	+	*	+	+	+	+	n	+	+	+	+	*	*	93
Roelen et al. (2014)	+	+	+	-	+	+	*	+	+	+	-	-	+	+	+	+	+	+	82
Roelen et al. (2014)	+	+	+	-	+	+	*	+	+	+	-	+	-	+	+	+	+	+	82
Roelen et al. (2013)	+	+	+	-	+	+	*	+	-	+	+	+	+	+	+	+	+	-	82
Bültmann et al. (2013)	+	+	+	+	+	+	*	+	+	+	+	-	+	+	+	+	+	+	94
Rugulies et al. (2013)	+	+	+	+	+	*	+	+	+	+	-	-	+	+	+	+	+	+	88
Roelen et al. (2010)	+	+	+	+	+	*	+	+	+	+	+	+	-	+	+	+	+	+	94
Akerstedt et al. (2007)	+	+	+	+	+	*	+	+	+	+	-	+	-	+	+	+	+	+	88
de Croon et al. (2005)	+	+	+	-	+	+	*	+	-	+	-	+	+	+	+	+	*	*	80
Bültmann et al. (2005)	+	+	+	-	+	+	*	+	+	+	+	-	+	+	+	+	+	+	88
Mohren et al. (2005)	+	+	+	-	+	+	*	+	-	-	+	+	+	+	+	+	+	+	82
Huibers et al. (2004)	+	+	+	-	+	+	+	+/-	+	+	+	+	+	+	+	+	+	+	92
Janssen et al. (2003)	+	+	+	-	+	+	*	+	+	-	+	+	+	+	+	+	+	+	88
Andrea et al. (2003)	+	+	+	-	+	+	*	+	+	+	+	+	+	+	+	+	+	-	88
Sluiter et al. (2003)	+	+	+	-/-	-/-	+	*	+	?/-	+	+	+	-	-	+	+	+	+	71
de Croon et al. (2003)	+	+	+	-	+	+	*	+	-	+	-	+	+	+	+	+	+	?	76
Hackett et al. (1989)	-	+	+	-	-	*	+	+	+	-	+	+	?	+	+	*	*	*	64

? =not mentioned/unable to determine from the study; *=not applicable; Quality score= high (>75%), medium (50%-75%) and low (≤50%).

2.4.1. Fatigue

Almost three quarter of the studies conceptualized fatigue as a construct of unidimensional or multidimensional in nature (see Table 3), however few provided clear conceptual definitions. In two studies by Roelen and colleagues, fatigue was defined as "an overwhelming sense of tiredness, lack of energy, and a feeling of exhaustion associated with impaired physical and/or cognitive functioning" (Roelen et al., 2014; Roelen, Heymans et al., 2014). In another study, Roelen and colleagues defined prolonged fatigue as fatigue lasting for 2 weeks or longer (Roelen et al., 2013). There were five studies published from the epidemiological Maastricht Cohort Study of "Fatigue at Work" where the authors did not provide conceptual definitions (Andrea et al., 2003; Bültmann et al., 2005; Huibers et al., 2004; Janssen, Kant, Swaen, Janssen, & Schröer, 2003; Mohren et al., 2005). However in a separate paper, the "Fatigue at Work" research program defined the construct as "the change in the psychophysiological control mechanism that regulates task behavior, resulting from preceding mental and/or physical efforts which have become burdensome to such an extent that the individual is no longer able to adequately meet the demands that the job requires of his or her mental functioning; or that the individual is able to meet these demands only at the cost of increasing mental effort and the surmounting of mental resistance" (van Dijk & Swaen, 2003). Moreover, the team conceptualized fatigue as subjective sensation that consists of behavioral, emotional and cognitive domains (Kant et al., 2003).

Fatigue as a symptom of tiredness or lack of energy was assessed in four studies, while the rest operationalized the construct using five different measures. Briefly, the Checklist Individual Strength-CIS is a measure of chronic fatigue with fatigue severity, reduced motivation and concentration, and decreased physical activity domains. The Need for Recovery scale-NFR measures end-of-shift acute fatigue and the Chalder's Fatigue Questionnaire with its physical and mental components measures the extent and severity of fatigue. As part of the Short Form (SF)-36, the vitality subscale assesses an individual's own perception of fatigue and energy level. Specific to truck drivers, the Trucker Strain Monitor has two subscales of work-related fatigue and sleeping problems. In most studies, evidence of reliability and adequate information about the validity of the scales in the general workforce were reported.

2.4.2. Sickness absence

A conceptual definition of SA was not present in most studies, a weakness also commonly reported in the literature (Hensing, 2009). In Roelen et al.'s four studies, the definition included absence or paid leave from work because of work or non-work related illness or injury (Roelen, Heymans et al., 2014; Roelen et al., 2013; Roelen et al., 2015, 2014).

As shown in Table 3, the SA event was measured by the duration and frequency of absence episodes. Moreover, the duration of a SA varied across the studies. Heterogeneity in measuring the outcome depended partly on study objectives, prior research in the area, whether absence was self or medically certified, and the country's social insurance system policy toward paid leaves. In two studies, SA was measured as an event (present vs. absent) without being duration-specific (Hackett, Bycio, & Guion, 1989; Mohren et al., 2005). Long-term SA was defined as the number of consecutive or cumulative days lasting >14 days related to psychological complaints, ≥21 days, ≥30days, ≥42 days or ≥90 days. In two studies, long-term SA was defined as episodes of

>7 consecutive days (over 1-year) or >42 days (over 2-years) (Roelen et al., 2015; van Dijk & Swaen, 2003).

Short-term SA in two studies was considered an episode lasting 1 to 7 days. Medium or intermediate SA was considered duration of 14 to 89 days or 8 to 42 days. In one study, the number of SA days was categorized into 5 groups: no/short 1-7 days, 8-29 days, 30-89 days, 90-179 days and ≥180 days. Most data on SA were objective in nature accessed from company records, occupational health registries, social insurance administrations and national register of social transfer payments. Three studies used self-reporting of sick days with a recall period of two weeks (Ricci et al., 2007) and 12 months (de Croon et al., 2003; Roelen et al., 2013), the latter two raising concerns for recall bias.

Table 3. Studies on fatigue and sickness absence in the working population (n=17)

Author, Year	Country	Design	Sample	Measures of Fatigue	Measures of Sickness Absence
Roelen et al. (2015)	Netherlands	Prospective 1-year follow-up	633 white collar employees	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	High SA: ≥ 30 days (yes) High SA episode: ≥ 3
Roelen et al. (2014)	Netherlands	Prospective 1-year follow-up	633 white collar employees	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	Short-term SA episode: 1-7 days Long-term SA episode: > 7 days Total number of SA episodes
Roelen et al. (2014)	Netherlands	Prospective 1-year follow-up	633 white collar employees	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	Long-term SA: ≥ 30 days (medically-certified) Long-term mental SA: ≥ 30 days (medically-certified)
Roelen et al. (2013)	Norway	Prospective 1-year follow-up	2059 nurses	Chalder's Fatigue Questionnaire: physical fatigue (7 items) and mental fatigue (4 items) subscales	High SA: > 30 days (yes)
Bültmann et al. (2013)	Denmark	Prospective 1-year follow-up	6538 employees	SF-36 vitality subscale (4 items)	Long-term SA: ≥ 3 weeks
Rugulies et al. (2013)	Denmark	Prospective 1-year follow-up	6670 female eldercare employees	Item: "Have you felt lacking in energy and strength?" from Major Depression Inventory	Long-term SA: ≥ 3 weeks
Roelen et al. (2010)	Netherlands	Retrospective 2-years follow-up	470 employees	Health complaints (22 items) Item: fatigue (present or absent	Short SA episode: 1-7 days Medium SA episode: 8-42 days Long SA episode: > 42 days
Akerstedt et al. (2007)	Sweden	Prospective 2-years follow-up	8300 workers	Item: tired and listless 1 day/ week or more often vs. less often.	Intermediate-SA: 14-89 days Long-term SA: ≥ 90 days
de Croon et al. (2005)	Netherlands	Prospective 2-years follow-up	755 truck drivers	Trucker strain monitor: work-related fatigue (6 items) and sleeping problems (4 items).	SA: > 14 days related to psychological health complaints

Table 3. (continued)

Author, Year	Country	Design	Sample	Measures of Fatigue	Measures of Sickness Absence
Bültmann et al. (2005)	Netherlands	Prospective 1.5-years follow-up	6403 employees	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	Long-term SA: ≥ 42 days
Mohren et al. (2005)	Netherlands	Prospective 8-months follow-up	5531 employees with common infections (3685 common cold, 1101 flu-like illness and 745 gastro-enteritis)	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	Item: SA as a result of common cold, flu-like illness or gastroenteritis (yes or no).
Huibers et al. (2004)	Netherlands	Prospective 2-years follow-up	2108 fatigued employees	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items). Item: Did you suffer from fatigue complaints in the previous 4 months? If yes, fatigue complaint causes: physical (yes/no), psychological (yes/no) or unknown attribution (yes/no).	Long-term SA: ≥ 42 days (Note. SA data were available for 548 days of follow-up).
Janssen et al. (2003)	Netherlands	Prospective 6-months follow-up	7495 employees	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	Short-term SA: 1-7 days Long-term SA: > 42 days
Andrea et al. (2003)	Netherlands	Prospective 1.5-years follow-up	1271 employees who visited the OP and/or GP	CIS: fatigue severity (8 items), reduced concentration (5 items), reduced motivation (4 items) and reduced physical activity (3 items).	SA: no/short SA 1-7 days (ref), 8-29 days, 30-89 days, 90-179 days, ≥ 180 days.

Table 3. (continued)

Author, Year	Country	Design	Sample	Measures of Fatigue	Measures of Sickness Absence
Sluiter et al. (2003)	Netherlands	Prospective 1-year follow-up; nurses Prospective 1-year follow-up; truck drivers	1239 workers (614 nurses and 625 truck drivers)	NFR (after work): 11 items	Duration of SA
de Croon et al. (2003)	Netherlands	Prospective (2-years follow-up)	526 truck drivers	NFR (after work): 11 items	SA: > 14 days
Hackett et al. (1989)	Canada	Prospective (4-5 months)	2950 work shifts of 54 nurses	Item: How tired were you just before your shift today? (1) very tired (very sluggish), (2) quite tired (quite sluggish), (3) neither tired nor particularly awake, (4) quite awake (quite energetic), and (5) very awake (very energetic).	Attendance vs. absence

SA-Sickness Absence; CIS-Checklist Individual Strength; SA-Sickness Absence; NFR-Need for Recovery

2.4.3. Summary findings

In Table 4, we present a detailed summary of the 17 studies in chronological order. From the 15 studies that were of high quality, 13 reported fatigue to be a significant predictor of SA in the working population. The follow-up period in these studies ranged from 6 months to 2 years. Specifically, there was strong evidence that chronic fatigue and fatigue as a symptom predicted long-term SA. The cut point for the duration of long-term SA differed both by study and country. Gender influenced the relationship between fatigue and SA. In most studies, this effect was controlled statistically and in four studies by using stratification. There was strong evidence regarding the association between fatigue and long-term SA in men, but only weak evidence in women. There was insufficient evidence to determine the prospective association between end-of-shift fatigue (i.e., acute fatigue) and SA.

Netherlands

Three recent prospective cohort studies used Dutch insurance data including 1137 white-collar employees who were invited for an occupational health checkup. After 1 year of follow-up, these studies reported similar findings; however there were some differences in operationalizing the outcome. Men with high chronic fatigue and fatigue severity, and reduced concentration had an increased risk for the number of long-term (>7 days) and total SA episodes. Men with high chronic fatigue and fatigue severity were at higher odds for long-term (≥21 days) medically-certified and mental SA than those with low chronic fatigue. Moreover, those with reduced motivation and concentration were more likely to have mental SA. When evaluating the contribution of fatigue in a SA prognostic model, for every 10 point increase in chronic fatigue scores, insurance employees were 16% and 14% more likely to have high SA (≥30 days) and high SA episodes (≥3). Similarly, fatigue as a symptom of subjective health complaints was associated with intermediate-SA episodes in the blue and white collar workers after 2 years of follow-up.

In 1998, the Maastricht cohort study (MCS) was initiated to explore the etiology and course of prolonged fatigue and to develop preventive measures in the working population. A total of 12161 employees from 45 companies participated in the baseline survey and were followed over a period of three years. Five prospective studies were published from the MCS data that examined fatigue as a predictor of SA. When following participants over 6 months (July-December 1998), Janssen and colleagues found that chronic fatigue was related to shorter onset of the first SA episode and short-term SA, and increased the odds for long-term (>42 days) SA. Similarly, in Mohren et al.'s study, the risk of SA from work increased in employees who experienced elevated fatigue during a common cold over 8 months follow-up (May 2000-January 2001). Interestingly, Huibers et al.'s study of 1681 fatigued employees found that the physical attribution of fatigue at baseline increased the risk of long-term SA where follow-up SA data were available over 18 months. Contrary to these three, two studies did not find significant results after adjusting the models for health problems. In Andrea et al.'s study of 1271 employees who visited the occupational physician and/or general practitioner in relation to work, chronic fatigue significantly predicted SA of ≥6 months duration only. However, this relationship lost significance when adjusting for the psychosocial work environment and health problems. In Bültmann et al.'s study, being a case of fatigue (CIS scores >76) alone did not significantly predict long-term SA after accounting for chronic diseases. Together, being a case of fatigue and psychological distress increased the risk of long-term SA both in men and women after 18 months of follow-up.

In addition to chronic fatigue, increased need for recovery (NFR) after work, an indicator for acute fatigue, was associated with increased number of SA days in nurses and truck drivers. Moreover, truck drivers with high NFR scores had twice the odds of self-reported SA (>14 days). In the same cohort, drivers with SA related to psychological health complaints had significantly higher fatigue both at baseline and after a 2-year period when compared to the rest of the drivers.

Scandinavian countries

Four studies were carried out in Scandinavia. These studies showed that fatigue significantly predicted long-term SA in the general workforce that included white-collar employees, blue-collar workers and healthcare providers. Two Danish prospective cohort studies reported that fatigue increased the hazards of long-term SA (≥3 weeks) after 1-year of follow-up. In Bültmann et al.'s study, which included workers of both genders, this relationship was only significant in men, while the second Danish study focused on female eldercare workers. A Norwegian study of nurses who were working in hospital, psychiatric and nursing home care settings found that elevated physical and total fatigue increased the odds of high SA (>30 days) after 1-year of follow-up. In a national Swedish study, fatigued workers were more likely to have intermediate (14-89 days) and long-term (≥90 days) SA after a period of two years. When stratified by gender, only fatigued women were more likely to have intermediate SA. This finding was significant in both men and women for long-term SA.

Canada

Almost three decades ago, Hackett and colleagues conducted one of the earlier idiographic-longitudinal studies on absenteeism in 54 Canadian hospital nurses. Nurses completed daily absence diaries over 4 to 5 months that resulted in a total of 2950 work shifts. One of the findings of this study was the prospective association between feeling tired (as an absence-inducing event) and the actual absence from work. One major limitation is the poor statistical rigor in this study when compared to modern statistical methods in analyzing SA data. Nevertheless, the strong theoretical background and the available statistical approach at the time that allowed for more individualized observations provided a better understanding of certain behaviors or events leading to absenteeism from work.

Table 4. A summary of the findings from the included studies (n=17).

Authors	Analysis	Adjusted for	Findings
Roelen et al. (2015)	Logistic regression		OR=1.16, 95%CI=1.03-1.31 (high SA) OR=1.14, 95%CI=1.01-1.28 (high SA episodes).
Roelen et al. (2014)	Negative binomial regression	Age, gender, job type, and history of SA	RR=1.25, 95%CI=1.01-1.54 (CIS), RR=1.34, 95%CI=1.01-1.73 (fatigue severity), RR=1.42, 95%CI=1.03-1.84 (reduced concentration) and long-term SA in men only. RR=1.07, 95%CI=1.01-1.14 (CIS), RR=1.24, 95%CI=1.01-1.30 (fatigue severity), RR=1.22, 95%CI=1.02-1.46 (reduced concentration) and total number of SA episodes in men only.
Roelen et al. (2014)	Logistic regression	Age, gender, job type, duration of employment and worked hours/week.	OR=1.28, 95%CI=1.06-1.56 (fatigue severity) and OR=1.34, 95%CI=1.04-1.72 (CIS) and long-term SA in men only. OR=1.57, 95%CI=1.19-2.06 (fatigue severity), OR=1.75, 95%CI=1.30-2.35 (reduced concentration), OR=1.77, 95%CI=1.34-2.33 (reduced motivation), OR=1.97, 95%CI=1.41-2.75 (CIS) and long-term mental SA in men only.
Roelen et al. (2013)	Logistic regression	Model 1: age, gender, marital status, children at home and coping. Model 2: exercise, smoking, alcohol, caffeine use and BMI. Model 3: physical and mental health-related functioning, and history of SA. Model 4: nurse experience, work hours, and shift schedule. Model 5: job demand, job control, job support, role clarity, role conflict, and fair leadership.	Physical fatigue predicted high-SA from hospital (crude OR=1.36, 95%CI=1.24, 1.50), psychiatric care (crude OR=1.35, 95%CI=1.09, 1.67), and nursing home/home care (crude OR=1.75, 95%CI= 1.28, 2.40) services. Adjusting for models 1, 4 and 5 separately did not influence the ORs. In model 2, physical fatigue predicted high-SA from hospital (adj. OR=1.21, 95%CI=1.08, 1.36) and nursing home/home care (adj. OR=1.60, 95%CI=1.12, 2.28) services. In model 3, physical fatigue predicted high-SA in nursing home/home care (adj. OR=1.05, 95%CI=1.01, 1.09) only. Total fatigue predicted high-SA in hospital (crude OR=1.35, 95%CI=1.20, 1.52), psychiatric care (crude OR=1.36, 95%CI=1.08, 1.72), and nursing home/home care (crude OR=1.86, 95% CI=1.30, 2.65) services. Adjusting for models 1, 4 and 5 separately did not influence the ORs. In model 2, total fatigue predicted high-SA in hospital (adj. OR=1.21, 95%CI=1.05, 1.39) and nursing home/home care (adj. OR=1.57, 95%CI=1.06, 2.32) services. In model 3, total fatigue predicted SA in nursing home/home care (adj. OR=1.63, 95%CI=1.04, 2.49) only.

Table 4. (continued).

Authors	Analysis	Adjusted for	Findings
Bültmann et al. (2013)	Cox proportional hazard models	Model 1: gender, age, cohabitation, children < 3 years, occupational grade, survey method, smoking, alcohol use, leisure-time physical activity, BMI, and physician-diagnosed disease. Model 2: Model 1+ depressive symptoms. Model 3: Model 2+ sleep disturbances.	HR=1.25, 95%CI=1.00, 1.56 in men only.
Rugulies et al. (2013)	Cox proportional hazard models	Age, family status, smoking, leisure time physical activity, BMI, occupational group and history of long-term SA.	HR=1.33, 95%CI=1.08-1.64.
Roelen et al. (2010)	Negative binomial regression Poisson regression	Age, gender and educational level.	RR=1.6, 95%CI=1.1-2.2 (medium SA episodes only).
Akerstedt et al. (2007)	Logistic regression	Age, gender, marital status, children at home, socioeconomic group, heavy physical work, twisted work posture, shiftwork, fulltime/part-time, job demands, low job control, overtime and disturbed sleep.	OR=1.38, 95%CI=1.16-1.65 (intermediate-SA) OR=1.69, 95%CI=1.23-2.33 (long-term SA) OR=1.41, 95%CI=1.04-1.90 (long-term SA in men). OR=1.37, 95%CI=1.12-1.65 (intermediate-SA) and OR=1.86, 95%CI=1.27-2.71 (long-term SA) in women.
de Croon et al. (2005)	Spearman rank correlation coefficients (rho) Parametric tests (ANOVA, ANCOVA)	Age	Fatigue was weakly associated with SA related to psychological health complaints at baseline (rho=0.18, $p<.01$) and 2-years follow-up (rho=0.21, $p<.01$) After adjusting for age, truck drivers with SA related to psychological health complaints scored higher at baseline (mean=12.3, SD=3.8) and follow-up (mean=13.5, SD=4.5) when compared to the rest (baseline mean=8.4, SD=4.4, follow-up mean=8.5, SD=4.2); F=40.3, df=1637, $p<.01$.
Bültmann et al. (2005)	Cox proportional hazard models	Model 1: age, education, and living alone. Model 2: model 1 + chronic disease	RR=1.52, 95%CI=1.07-2.81 (model 1) RR=1.40, 95%CI=0.97-2.02 (model 2)
Mohren et al. (2005)	Cox proportional hazard models	Age, gender, education, and smoking.	RR=1.20, 95%CI=1.05, 1.37 (SA when having common cold) only.

Table 4. (continued).

Authors	Analysis	Adjusted for	Findings
Huibers et al. (2004)	Cox proportional hazard models	Age, decision authority, gender, shift type, and history of SA	RR=1.41, 95%CI=1.05, 1.89 (physical attribute of fatigue and long-term SA only).
Janssen et al. (2003)	Cox proportional hazard models Logistic regression	Age, education, gender, psychological job demands, decision authority, skill discretion, supervisor support and co-worker support	RR=0.85, 95%CI=0.81-0.88 (time-to-onset to first SA) RR=0.85, 95%CI=0.81-0.90 (time-to-onset to first short-term SA). OR=1.40, 95%CI=1.23-1.61 (long-term SA).
Andrea et al. (2003)	Independent t-test Logistic regression	Model 1: age, gender, and education Model 2: model 1 + health problems, job satisfaction, job demands, decision latitude, and social support.	Chronic fatigue was higher in employees with SA > 6 months (mean=82.2, SD=24.0) when compared to no/SA 1-7 days group (mean=68.5, SD=24.2). This relationship was significant *p*< .001. OR=1.75, 95%CI=1.31-2.33 (model 1, SA ≥ 6 months). OR=1.48, 95%CI=0.99-2.21 (model 2, SA ≥ 6 months).
Sluiter et al. (2003)	Multiple linear regression	Model 1: number of hours/week, physical demands, mental/emotional demands, lack of decision latitude, lack of autonomy. Model 2: Model 1 + age.	NFR was associated with duration of SA (β=0.19, *p*<.001) in hospital nurses after 1-year and (β=0.11, *p*=.021) in truck drivers after 2-years of follow-up. The explained variance was 3% and 0.7% respectively.
de Croon et al. (2003) (24)	Logistic regression	Age, history of SA, marital status, education, company size, job control, psychological job demands, physical job demands, and supervisor job demands.	OR=2.15, 95%CI=1.01-4.62.
Hackett et al. (1989)	Spearman rho correlation		Feeling tired was related to actual absence from work (mean *rho*=-0.25, SD=0.14, 17 out of 35 individual correlations were significant *p* < .05.)

OR=Odds Ratio; HR=Hazards Ratio; RR=Relative Risk.

2.5. Discussion

This systematic review found strong evidence for the relationship between fatigue at baseline and future SA in the general workforce. The included 17 studies were assessed for quality using an assessment checklist published in the SA literature (Dekkers-Sánchez et al., 2008; Merkus et al., 2012). A large number of items on this checklist evaluate for selection bias, information bias arising from measurement error and confounding adjustments. A major challenge in this review was the different operational definitions of SA that precluded statistical pooling of the results for a meta-analysis. However, we also acknowledge that differences in SA are also related to employment status, social security and insurance systems and thus we synthesized these studies by their country of origin.

Overall, the included studies had a number of strengths related to design, sample size, use of fatigue instruments with good reliability and validity, application of statistical rigor and decreased risk for recall bias. The longitudinal design established the temporal sequence of events where fatigue at baseline predicted the incidence of SA. Most studies had a large number of participants from multiple sites that were representative of the general working population. The possibility of recall bias was minimal since most researchers used SA data from registries, which gives validity to the data and the findings.

On the other hand, we also acknowledge a number of limitations that should be addressed in future research. One limitation was related to selection bias in most studies because of low response rates at baseline during participant recruitment. However, the large-scale studies addressed this limitation by non-respondent analyses when data were available (Bültmann et al., 2005; de Croon et al., 2003; Huibers et al., 2004; Mohren et al., 2005; Roelen et al., 2014). External validity in a few studies was jeopardized where the data were collected from one institution (Roelen, Heymans et al., 2014; Roelen et al., 2014). While the majority used SA company records and registries, the risk for recall bias was still present in four studies (De Croon et al., 2005; de Croon et al., 2003; Mohren et al., 2005; Roelen et al., 2013). Depending on the duration of personal recall, self-reporting of SA can either under or overestimate the results. In some studies, detection bias was possible where fatigue was measured as a single item. This may cause either under or overestimation of fatigue levels, thus leading to possible misclassification between fatigued and non-fatigued subgroups.

Based on their study objectives, most statistical models adjusted for demographic, work and non-work related variables that gave confidence in the results. Whereas it is not possible to control for all confounders and risk model overfitting, variables such as having second jobs, overtime, shiftwork characteristics, depressive symptoms, and health/medical problems when applicable are important to be factored into the relationship of fatigue and SA. Interestingly only two studies accounted for sleep disturbances when examining the relationship between fatigue and SA (Akerstedt et al., 2007; Bultmann, Nielsen, Madsen, Burr, & Rugulies, 2013). Lack of assessment of sleep health (e.g., sleep duration, sleep quality, insomnia, sleep apnea) in workers that is influenced by the duration of work hours and shift types can confound the relationship between fatigue and SA (Lallukka et al., 2014; Nakata et al., 2004). This limitation may be related to secondary data analysis where researchers are confined to the administered measures, nevertheless requiring consideration in future research.

On a final note, the majority of the studies used either Poisson regression or Cox proportional hazards models in analyzing the SA data. In a simulation study, Christensen and colleagues used in addition to the two methods, frailty models (i.e., random effects model for time-to-event data) that accounted for the dependence between events and person effects when analyzing SA data. The results showed that Cox proportional hazards followed by Poisson regression models underestimated the true effect sizes when compared to frailty models where the heterogeneity between subjects was accounted for (Christensen, Andersen, Smith-Hansen, Nielsen, & Kristensen, 2007). It is conclusive that random effect models can yield better risk estimates (Christensen et al., 2007), however the statistical approach is dependent on the study objectives and the type of available SA data.

2.5.1. Practice points

1. Workers who experience high chronic fatigue are more likely to take long-term sickness absence when compared to their peers. The duration of long-term sickness absence is dependent on a country's social system, absenteeism laws and compensation benefits.
2. Gender influences the relationship between fatigue and sickness absence, where chronically fatigued male workers are more likely to take long-term sickness absence when compared to their non-fatigued peers.
3. When examining the relationship between fatigue and sickness absence in workers, it is important to gather information on sleep quality and quantity, and sleep disturbances that can influence the outcome too.

2.5.2. Research agenda

Work-related fatigue is a subjective experience with physical, cognitive, emotional and behavioral components. Although there is no gold standard in measuring fatigue, it is agreed that multidimensional instruments can better capture this complex phenomenon, in contrast to the single items that were used in four studies (Akerstedt et al., 2007; Hackett et al., 1989; Roelen et al., 2010; Rugulies et al., 2013). We propose the use of fatigue instruments such as the CIS or the Chalder's Fatigue Questionnaire that address the different dimensions of fatigue, examining their validity in measuring the relationship of fatigue with both short- and long-term SA using reliable data retrieved from registries. This should help in tailoring SA management strategies and facilitate employees' quick return to the workplace.

Many researchers consider fatigue to be on a continuum with opposite poles representing acute and chronic conditions. Whereas chronic fatigue is more of a trait, acute fatigue which is the byproduct of day-to-day work stressors and transient in nature significantly predicted more than 14 days of SA in truck drivers after 2 years of follow-up (de Croon et al., 2003). Interestingly, Huibers et al. reported that chronically fatigued Dutch employees had periods of remission and relapse when followed over the same timeframe (Huibers et al., 2004). One potential area of future research is to explore the patterns of acute and chronic fatigue and SA over time, and identify the triggers related to chronic fatigue development or relapses. Based on allostatic load theory, researchers hypothesize that prolonged exposure to acute fatigue leads to the development of chronic fatigue. Since SA suggests a need to recover, examining its mediating or moderating role in terms of frequency and duration can be of great importance. For example, employers or occupational therapists can strategically prescribe off days to high risk employees and prevent a cycle of chronic fatigue relapse and high SA.

2.6. Conclusion

This systematic review conclusively demonstrated that fatigue is a significant predictor of SA in the working population. Specifically, the nature of fatigue is chronic and SA is of long-term. However, more studies are needed to understand the differences in this relationship between men and women. To date, there is no generic approach to reducing SA. Gender-specific approaches to managing work fatigue levels will likely prove to be more effective that one-size fits all approach to fatigue risk management.

3. Acute fatigue predicts sickness absence in the workplace: A 1-year retrospective cohort study in pediatric nurses[1]

3.1. Abstract

Background: Sickness absence (SA), an indication of poor health, creates an economic burden for employers and harms work productivity. This occupational problem is often related to worker fatigue, yet few studies have explored this relationship in nurses despite their documented high fatigue levels.

Objective: The main purpose of this study was to examine the relationship between fatigue at baseline and SA in 12 hour shift nurses from a pediatric hospital over 12 months of follow-up. A secondary purpose was to identify other work and personal factors that predict SA.

Methods: The study used a retrospective cohort design. Baseline data on 40 female nurses from an intervention study were linked to SA data using the hospital's attendance records for the period 2012-13. 6057 work shifts were studied of which 5.2% were SA episodes. Fatigue was measured by the Occupational Fatigue Exhaustion Recovery scale. The questionnaire also included instruments assessing sleep disturbances and sleep disorders, workload and personal characteristics. Generalized linear mixed models were used to test associations between fatigue, work, personal factors and SA, while accounting for the non-independency of repeated measures.

Results: The sample was predominately white (78.9%) and single (72.5%) and had a mean age of 30.90 (± 7.86) years. Symptoms suggesting insomnia (27.5%) and

[1] K. Sagherian, G.J. Unick, S. Zhu, D. Derickson, P.S. Hinds, J. Geiger-Brown (accepted, *Journal of Advanced Nursing)*

obstructive sleep apnea (17.5%) were common. Nurses experienced low-to-moderate levels of chronic fatigue (41.67 ± 24.45) and intershift recovery (43.89 ± 21.15), and moderate-to-high levels of acute fatigue (66.11 ± 18.66). Higher acute fatigue was related to more SA when personal and work factors were controlled. For every 1 standard deviation (SD) increase in acute fatigue scores, nurses were 1.29 times more likely to be absent from work (odds ratio [OR]=1.29, 95%confidence interval [CI]=1.02-1.63, p=.036). Other factors such as intershift recovery, perceived workload, obstructive sleep apnea, and marital status also significantly predicted SA, i.e., with 1SD increase in workload scores, nurses were 1.23 times more likely to be absent from work (OR=1.23, 95%CI=1.03-1.48, p=.024). Nurses with symptoms suggesting obstructive sleep apnea had 2 times higher odds of SA (OR=2.05, 95%CI=1.29-3.25, p=.002).

Conclusion: SA is related to acute fatigue in pediatric nurses in a hospital setting and to workload. Nursing leaders could monitor these factors as predictors of SA and in addition screen nurses for sleep apnea and assist them in receiving appropriate treatment for that condition.

Keywords: fatigue, sleep, sickness absence, nurses, workplace

3.2. Introduction

Sickness absence (SA), defined as “failure to report for scheduled work” (Darr & Johns, 2008) creates a financial burden and harms work productivity. In January of 2015, 3.5 million US employees missed work because of an ailment, physical injury, or medical problems (Bureau of Labor Statistics, 2015). Costs associated with lost days and paid sick leaves are substantial. The Centers for Disease Control and Prevention reported that absenteeism costs employers $225.8 billion per year (CDC Foundation, 2015). Healthcare organizations value low absenteeism because of the positive effect on patient care and safety when a consistent caregiver is present. The absence rate in healthcare practitioner/ technical occupations is 3.2% as compared to the 2.9% absence rate among fulltime wage and salary employees in the country (Bureau of Labor Statistics, 2015). Nurses represent the largest proportion of healthcare workers, and nurse absenteeism, estimated to cost $3.5 billion per year (Forbes, 2013), has an adverse effect on the delivery of high quality patient care.

Ricci and colleagues (2007) estimated that the annual cost of absenteeism for fatigued U.S. workers alone was $37.7 billion (Ricci et al., 2007). Work-related fatigue, a daily experience in nurses, becomes an alarming chronic condition when accompanied by insufficient rest, sleep and leisurely activities. Chronic fatigue can create physical and psychosocial health problems and consequently lead to absenteeism from the workplace (Sluiter et al., 2003). Nurses’ SA disrupts the workflow on nursing units. It leads to temporary staff shortage and causes unit nurses to work overtime or shorthanded in order to cover the absent worker. This situation creates a cycle where on duty nurses experience higher fatigue levels and consequently feel a need to miss work.

As early as the 1940s, the occupational literature emphasized the relationship between fatigue and SA in the working population (Medical Research Council, 1943). From the epidemiologic Maastricht cohort study on “Fatigue at Work”, where 12161 Dutch workers were followed over three years, Janssen et al. reported that with a 1 standard deviation (SD) increase in chronic fatigue scores, workers were 1.40 times more likely to take long-term SA over 6 months of follow-up (Janssen et al., 2003). A Swedish national study reported that fatigue significantly predicted both intermediate (14-89 days) and long-term (≥90 days) SA after adjusting for disturbed sleep, socio-demographic and work characteristics (Akerstedt et al., 2007). Only a few studies were conducted in hospital nurses (Roelen et al., 2013; Sluiter et al., 2003) despite fatigue being cited as a common reason for nurse absenteeism (Hackett et al., 1989; Zboril-Benson, 2002). After 1-year of follow up, Norwegian nurses’ (n=2059) physical fatigue and total fatigue, measured by Chalder’s Fatigue Questionnaire, predicted SA after adjusting for demographic, health, lifestyle and work related variables (Roelen et al., 2013). Similarly, end-of-shift (i.e. acute) fatigue, measured by the Need for Recovery scale, was significantly related to hospital nurses’ increased duration of SA (Sluiter et al., 2003).

Factors associated with SA in nurses can be classified into four domains: work-related, personal, social and organizational factors. Work schedules, overtime and work intensity are work-related factors. In a systematic review on shift work and sick leave, Merkus and colleagues concluded that there was strong evidence for a positive relationship between permanent evening shifts and SA in female healthcare workers (Merkus et al., 2012). A cross-sectional study from the Netherlands showed that female nurses who worked overtime had a significantly higher number of sick days (Schreuder et al., 2010). A number of studies have focused on job strains and reported conceptually similar findings despite differences in measures. Nurses who had high work strain with low social support (Bourbonnais & Mondor, 2001; Trybou et al., 2014) and with higher work efforts (Schreuder et al., 2010) were more likely to take SA. Increased nursing workloads above the optimal level (Rauhala et al., 2007) and high physical work demands (Trinkoff et al., 2001) increased the likelihood of SA in hospital nurses.

Personal factors include both health-related and socio-demographic characteristics. There is cumulative evidence of nurses' psychological and physical ill health being associated with absenteeism. Research has shown that depressed, emotionally exhausted and psychologically distressed nurses were more likely to be absent from work (Anagnostopoulos & Niakas, 2010; Davey et al., 2009; Schreuder et al., 2010; Siu, 2002). Poor sleep quality and sleep disorders such as sleep apnea or insomnia are common in nurses (An et al., 2016; Portela et al., 2015). Although there is occupational literature that supports the relationship between SA and sleep impairment (Akerstedt et al., 2007; Kucharczyk et al., 2012; Nakata et al., 2004), these studies did not include nurses as study participants.

Certain demographic factors have also played a role in SA, however, the evidence has been inconsistent. A few studies reported that younger nurses were more likely to take sick days when compared to their older peers (Davey et al., 2009; Trinkoff et al., 2001) while others did not find any significant differences in SA by age (Davey et al., 2009; Siu, 2002). Social factors such as family obligations can lead to absenteeism in nurses. A Scottish study reported that work-family conflict was a significant predictor of SA in telephone helpline nurses (Farquharson et al., 2012).

Supportive work cultures are important organizational factors that influence nurse absenteeism. On nursing units where nurse managers scored higher on relationship-oriented leadership styles, nursing staff were less likely to have short-term SA episodes (Schreuder et al., 2011). In the absence of encouragement, supportive work cultures (Eriksen et al., 2003), and respect from peers and supervisors (Schreuder et al., 2010), nurses were more likely to be absent from work. Moreover, perceived absence norms on nursing units and prior history of absence predicted future absenteeism from work (Davey et al., 2009).

In summary, there is little evidence on the proposed relationship between work-related fatigue and SA in nurses. Moreover, certain work (e.g., shift rotations, long work hours and high workloads), personal (e.g., health problems and sleep disturbances), or organizational (e.g., unsupportive work environments) factors related to SA are fatiguing in nature, too. The knowledge we gain in studying this phenomenon can provide a better understanding of SA that has a complex etiology and contribute to the development of SA preventive measures. Thus, the purpose of this study was to explore the association between occupational fatigue and SA in 12-hour shift nurses in a pediatric hospital over 12 months of follow-up. A secondary aim was to explore other work-related and personal factors that predicted SA in this cohort.

3.3. Methods

3.3.1. Design and sample

The study used a 1-year retrospective cohort design. Nurses' baseline data (n=40) were from the Fatigue Risk Assessment Management Effectiveness (FRAME) pilot study (R21OH009979). The goal of the FRAME study was to evaluate fatigue reduction interventions including napping in two hospital settings (Geiger-Brown et al., 2012, 2016). The main study enrolled 88 nurses from eight nursing units and collected data on demographics, sleep and health problems, sleepiness, occupational fatigue and work-related factors using a number of validated instruments.

The present study focused on one of these hospital settings where 12 months of absenteeism data were available. The sample included 40 female nurses enrolled from four nursing units in a pediatric hospital between February and April 2012. Data on absenteeism were extracted from the time and attendance system by a system analyst and then linked to nurses' baseline data. The attendance system stores time details for every work day (date, clock-in and clock-out hours), and pay codes that indicate an employee's presence or absence from work on a specific day. The follow-up data period was 12 months, which resulted in 6057 work shifts (range= 36-228 shifts per nurse). The majority of the shifts were for 12 hours; however we also included shifts where nurses worked 6 hours or more.

3.3.2. Measures

SA. In this study, SA was defined as being absent from work when a nurse was expected to be working. The pay codes indicating absence from work were: SICK, Accrued Sick and Safe Leave Act (ASSLA)-sick, Family Medical Leave Act (FMLA)-sick or UNPAID LEAVE. We did not consider the pay codes that represented scheduled vacation days, holidays or family bereavement. None of the participants were on maternity leave during the study period. Based on the work schedules, daily pay codes indicating sick days and leaves were classified as absences. Each day of work was considered a single event where a nurse had an equal probability of being present or absent.

Work-related fatigue. At baseline, nurses' chronic fatigue (CF), acute fatigue (AF) and intershift recovery (IR) were measured by the Occupational Fatigue Exhaustion Recovery (OFER 15) scale. The instrument consists of 15 items divided equally into three subscales. The items are on a 7-point Likert scale from strongly disagree (0) to strongly agree (6). The scores range from 0 to 100 where higher values represent more of the measured constructs: higher fatigue and better intershift recovery that were experienced in the past few months. Respondents' scores can be interpreted as low (0-25), low-moderate (26-50), moderate-high (51-75) and high (76-100). OFER 15 subscales had good internal consistency (Cronbach's alpha=0.84–0.89), and evidence of construct (convergent and discriminant) and factorial validity established in nurses. The items were reported to be free of gender bias (Winwood et al., 2005; Winwood et al., 2006). The reliability coefficients for the three subscales in the FRAME study were ≥ 0.81.

Covariates

Workload. Perceived workload during work shifts was measured by the National Aeronautical and Space Administration-Task Load Index (NASA-TLX). The scale consists of six items on a 10-point visual analogue scale from "low" to "high. Each item represents a single dimension of workload: mental, physical and temporal demands, applied effort, performance satisfaction, and frustration during work. Overall workload represents the sum of the raw scores from the 6 items, where higher scores represent greater workload (Hart, 2006). The NASA-TLX has been administered to ICU nurses and was found to have an acceptable reliability coefficient of 0.72. Psychometric properties were established through convergent and discriminant validity (Hoonakker et al., 2011).

Depression. The Center for Epidemiologic Studies Depression scale- Revised (CESD-R) was administered to screen for nurses' depression. The scale consists of 20 items addressing sadness, loss of interest, appetite, sleep, fatigue, thinking, guilt, movement and suicidal ideation experienced in the past week. The responses are: "not at all/less than one day", "1-2 days", "3-4 days", "5-7 days" and "nearly every day for 2 weeks". The summative score can range from 0 to 60, and a cutoff score of ≥ 16 indicates clinical symptoms of depression (Eaton et al., 2004; Radloff, 1977). The CESD-R has shown to have good internal consistency reliability with a Cronbach's alpha= 0.923 to 0.928. The scale had good psychometric properties in the general population (Van Dam & Earleywine, 2011). The Cronbach's alpha in the FRAME study was 0.89.

Sleepiness. Nurses' daytime sleepiness was measured by the Epworth Sleepiness Scale (ESS). The ESS is composed of 8 items, each representing a real life situation. The items are on a 4-point scale where responses range from "no chance of dozing" to "high chance of dozing". The sum of the items can range from 0 to 24, where a cutoff score of ≥ 10 indicates excessive daytime sleepiness. The ESS had a good reliability coefficient of 0.88, and was moderately correlated with the Multiple Sleep Latency Test in adults thus establishing its construct validity (Johns, 1992, 2000). In the FRAME study, the Cronbach's alpha=0.74.

Symptoms suggestive of sleep disorders

The Cleveland Sleep Habits Survey (CSHS) was administered to screen for obstructive sleep apnea (OSA), and other symptoms such as insomnia, restless leg syndrome (RLS) and periodic limb movement disorder (PLMD). This self-report measure consists of three parts: the Berlin questionnaire (BQ), sleep-related questions and a list of comorbidities.

OSA. The BQ consists of 10 items divided into three categories. In category 1, five items address snoring history and episodes of witnessed sleep apneas. In category 2, four items address daytime fatigue and sleepiness while driving a vehicle. The third category relies on the person's history of hypertension (>140/90 mmHg) or obesity (BMI $\geq$ 30kg/m^2). Respondents who scored positive on $\geq$ 2 of the categories were considered at high risk for OSA. Reliability coefficients were 0.86 to 0.92. The BQ had a sensitivity=0.86, specificity=0.77, and positive predictive value=0.89 in detecting high-risk OSA patients with an Respiratory Distress Index of > 5, thus establishing its predictive validity (Netzer et al., 1999).

Insomnia. This disorder was assessed by three items in the CSHS: "I've used sleeping pills or alcohol to help me sleep", "it takes me more than half an hour to fall asleep" and "I wake up 3 times or more during my sleep". Each item was scored as either positive or negative. A positive score was assigned if a nurse answered yes to using alcohol/sleeping pills and responded "3-4 times per week" or "nearly every time" to the other two items that indicated persistence of these symptoms. Nurses screened positive for insomnia if they scored positive on two of the three items.

RLS. This was assessed with the item "in the evening, I get a strange crawling sensation in my legs along with an urge to move them". A response of "3-4 times per week" or "nearly every time" was considered positive screen for RLS.

PLMD. This was assessed with the item "has anyone told you that your legs/arms move or jerk during sleep?" A response of "3-4 times per week" or "nearly every time" was considered positive screen for PLMD.

The scoring for insomnia, RLS and PLMD were based on the persistent experience of these symptoms (Mustafa et al., 2005).

Personal characteristics included age, marital status, race, educational level, caring for dependents on a regular basis, and being a student. Health variables included 16 comorbidities from the CSHS (e.g., diabetes, hypertension, congestive heart failure, and asthma), cigarette smoking and alcohol use. Work-related variables were nursing unit of practice, type of shiftwork, years of nursing experience, having a second job, and number of breaks.

3.3.3. Ethical approval

The study qualified as non-human subjects research by the University of Maryland and Children's National Medical Center Institutional Review Boards.

3.3.4. Statistical analysis

Descriptive statistics were used to describe the characteristics of the sample. Prior to model fitting, the assumptions associated with specific models such as linearity and outliers were examined. Five variables had missing observations with average missingness 8.5% (range= 5.0-10.0%). Little's MCAR test was not significant (X^2 (67)=64.66, p=.558) indicating that the missingness in observations was completely at random and no imputation was necessary.

Generalized linear mixed models (GLMMs) were used to examine the association between fatigue and SA while accounting for the nonindependence in repeated measures (intraclass correlation coefficient [ICC] = .096). This statistical approach accounts for the nesting effect of multiple shifts (level 1 variable) within the individual nurse (level 2 variable). The crude and adjusted odds ratios (ORs) and the corresponding 95% confidence interval (CI) were estimated. Continuous variables (AF, CF, IR, workload and depression scores) were standardized, and the ORs represented the odds of being absent for 1SD increase or decrease in scores. A series of GLMMs were fitted and predictors with $p \leq .25$ in bivariate association were retained in multiple models. Variables in the categories work-related, health and personal were entered in blocks in hierarchical multivariable models. The final random intercept model was parsimonious and adjusted for four covariates and time (in months). All analyses were performed in STATA 14.1 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP).

3.4. Results

A descriptive summary of baseline personal characteristics is presented in Table 5. The study sample was predominately white (78.9%), single (72.5%), baccalaureate prepared (82.5%) with a mean age of 30.90 ± 7.86 (range= 22-52) years. One in five (20.0%) reported caring for children or elderly on regular basis. Almost one-quarter of the sample were overweight/obese (27.0%) and reported health problems (27.5%). Ten nurses (25.0%) exceeded the cutoff score for depression of ≥ 16. Daytime sleepiness was common, with 32.5% of the nurses scoring ≥ 10 on the Epworth Sleepiness scale. Nurses commonly reported symptoms of sleep disorders including insomnia (27.5%), OSA (17.5%), PLMD (10.0%) and RLS (5.0%), with 19 nurses reporting symptoms of at least one or more sleep disorder.

A descriptive summary of work characteristics, fatigue scores and SA is presented in Table 6. Nurses had a median 3.40 years of nursing experience (interquartile range= 1.78-7.20 years). More than half the sample were on 12-hour rotating shifts (60.0%) followed by the night shift (25.0%). The majority had on average 35.91 ± 10.35 minutes of meal breaks, while eight nurses (20.0%) reported not taking any break during work. Nurses on average perceived themselves to have moderate levels of workload (34.00 ± 6.07, range: 18.96-50.23) during a working shift. They experienced low-to-moderate levels of CF (41.67 ± 24.45) and moderate-to-high levels of AF (66.11 ± 18.66). IR was considered low-to-moderate (43.89 ± 21.15) in between two consecutive shifts. During the 12 months of follow-up which resulted in 6057 work shifts, 5.2% of the shifts were SA episodes.

Table 5. Nurses' personal characteristics at baseline (n=40).

Study variables	*n (%)*
Age, *M (SD)*	30.90 (7.86)
Race	
White	30 (78.9)
Black	4 (10.5)
Others (Asian, more than one race)	4 (10.5)
Marital status,	
Married (or with partner)	11 (27.5)
Unmarried (single, divorced)	29 (72.5)
Dependents (children, elderly)	8 (20.0)
Education	
Baccalaureate	33 (82.5)
Master	4 (10.0)
Others (AD, diploma)	3 (7.5)
Being a student	5 (12.5)
Body mass index (kg/m^2)	
Normal (< 25)	27 (73.0)
Overweight (25-29.9)	4 (10.8)
Obese (≥ 30)	6 (16.2)
Smoking cigarettes	2 (5.0)
Drinking alcohol	32 (80.0)
Health problems	11 (27.5)
CESD-R depression *M (SD)* (range=0-60)	10.68 (7.63)
Daytime sleepiness (ESS ≥ 10)	13 (32.5)
Sleep disorder symptoms	
Insomnia	11 (27.5)
Obstructive sleep apnea	7 (17.5)
Periodic limb movement disorder	4 (10.0)
Restless leg syndrome	2 (5.0)

Note. CESD-R=Center for Epidemiologic Studies Depression scale-Revised; ESS, Epworth Sleepiness Scale.

Table 6. Nurses' baseline fatigue and perceived workload, work characteristics and sickness absence (n=40).

Study variables	*M (SD)*
Unit of practice *n (%)*	
Medical-surgical	12 (30.0)
Intensive care	11 (27.5)
Hematology-oncology	11 (27.5)
Heart-kidney	6 (15.0)
Second job *n (%)*	5 (12.5)
Shift work *n (%)*	
7am-7pm	6 (15.0)
7pm-7am	10 (25.0)
Rotating shifts	24 (60.0)
Breaks *n (%)*	
No breaks	8 (20.0)
1 break/shift	19 (47.5)
2 or more breaks/shift	13 (32.5)
Break duration (min.)	35.91 (10.35)
OFER subscales (range: 0-100)	
Chronic fatigue	41.67 (24.45)
Acute fatigue	66.11 (18.66)
Intershift recovery	43.89 (21.15)
NASA TLX workload (range=0-60)	34.00 (6.07)
Sickness absence in shifts *n (%)*	
Absent (yes)	312 (5.2)
Present (no)	5745 (94.8)

Note. NASA TLX= NASA task load index. OFER=Occupational Fatigue Exhaustion Recovery Scale

In Table 7, we present the odds ratios for fatigue and SA while controlling for possible covariates and the effects of time. At the bivariate level, the variables marital status, depression, OSA, AF, and workload were considered in building the final model ($p \leq .25$). CF and IR that represented the two other domains of the OFER 15 were retained because of their conceptual importance to the study. In the final model, AF significantly predicted SA in pediatric nurses. With 1 SD increase in AF scores, nurses were 1.29

times more likely to be absent from work. As well, IR, workload, OSA and marital status were significant predictors of SA. Interestingly, IR had a suppression effect in the final model. With 1SD increase in IR scores, nurses were 1.32 times more likely to be absent from work. In other words, more intershift recovery was associated with more days away from work. With 1SD increase in perceived workload scores, nurses were 1.23 times more likely to be absent from work. Nurses with OSA symptoms had 2.05 times higher odds of taking sick leave. SA was 1.53 times more likely to occur when nurses were married or living with a partner.

Table 7. Odds ratios for sickness absence (yes/no) in nurses.

Parameter	**Crude OR (95% CI)**		**Adjusted OR (95% CI)**	
	Bivariate level	***p***	Final model**	***p***
Acute fatigue*	1.25 (0.99, 1.57)	.057	1.29 (1.02, 1.63)	.036
Chronic fatigue*	1.14 (0.90, 1.45)	.272		
Intershift recovery*	1.07 (0.85, 1.36)	.546	1.32 (1.03, 1.69)	.027
Workload*	1.18 (0.96, 1.46)	.116	1.23 (1.03, 1.48)	.024
Unit of practice				
Hematology-oncology	(ref)			
Medical-surgical	0.81 (0.45, 1.44)	.472		
Intensive care	1.44 (0.81, 2.56)	.220		
Heart-kidney	1.07 (0.54, 2.11)	.850		
Number of breaks				
No breaks	(ref)			
1 break/shift	1.38 (0.76, 2.49)	.286		
≥ 2 breaks/shift	0.95 (0.50, 1.81)	.881		
Nurse experience (yrs.)	1.00 (0.96, 1.03)	.876		
Shift work				
7a-7p	(ref)			
7p-7a	1.11 (0.54, 2.27)	.772		
Rotating	1.04 (0.55, 1.97)	.898		
Depression*	1.17 (0.94, 1.47)	.166		
Sleep apnea				
No	(ref)		(ref)	
Yes	1.51 (0.87, 2.63)	.142	2.05 (1.29, 3.25)	.002
Insomnia				
No	(ref)			
Yes	1.09 (0.67, 1.79)	.731		
Daytime sleepiness				
No	(ref)			
Yes	0.98 (0.61, 1.58)	.947		
Health problems				
No	(ref)			
Yes	0.92 (0.56, 1.52)	.757		
Age	1.01 (0.99, 1.04)	.363		
Marital status				
Single/divorced	(ref)		(ref)	
Married/with partner	1.67 (1.06, 2.62)	.027	1.53 (1.01, 2.31)	.045
BMI (kg/m^2)				
Normal weight	(ref)			
Overweight/obese	1.12 (0.69, 1.82)	.642		
Dependents				
No	(ref)			
Yes	0.94 (0.54, 1.63)	.828		
Drinking alcohol	(ref)			
No	0.95 (0.55, 1.64)	.840		
Yes				

Note. BMI=body mass index. *For standardized variables, the OR represents 1 SD increase in scores. ** The final model is adjusted for covariates, marital status and the effects of time (months).

3.5. Discussion

This retrospective cohort study showed that baseline AF, measured by the OFER 15 subscale, significantly predicted SA in female pediatric nurses. Our findings also indicated that nurses' perceptions of increased workload, more intershift recovery between shifts, having OSA and being married were significant predictors of SA.

Hospital nurses, similar to other shift working populations, experience AF after work. This expected and short-lived condition can become a health concern when repeatedly coupled with poor IR. Researchers hypothesize that the combined effect of the two can lead to a more permanent type of fatigue (i.e., chronic) and the development of health problems (McEwen & Seeman, 1999; Sluiter et al., 2003; Winwood et al., 2007). Interestingly in our study, IR had a suppression effect on AF when added into the predictive model. A suppressor variable increases the predictive validity of another variable when included in the statistical model. Together, high AF and greater IR increased the odds of being absent from work. When compared to the occupational literature, our results are conceptually in line with de Croon et al. (2003) despite differences in fatigue measurement and in the operationalization of the outcome. In truck drivers, end-of-shift fatigue (i.e., acute fatigue) as measured by the Need for Recovery scale predicted future SA (>14 work days) at 2 years of follow-up (de Croon et al., 2003). Our results suggest the importance of managing early stages of fatigue and the role of recovery during off days in decreasing the incidence of SA at work.

In addition to AF, certain work-related and personal factors predicted SA in our nurses. On nursing units, nurses' perceptions of increased workload during work hours increased the odds of being absent. Using the RAFAELA patient classification system , Rauhala et al. (2007) found that when Finnish nurses encountered work overload that was 30% higher than the optimal workload on the units, they had 1.44 and 1.49 times higher rates of self (1-3 days) and medically certified (>3 days) sickness episodes (Rauhala et al., 2007). When the number of physical work demands increased, Trinkoff et al. reported that nurses were at higher odds of being absent from work (Trinkoff et al., 2001). In a recent study from the Danish general workforce, Andersen et al. (2016) found that high physical workloads such as bending, standing in the same place long hours, squatting or lifting/carrying objects significantly predicted long-term (>3 consecutive weeks) SA. Moreover, when these physical activities were combined, workers had an increased risk (Hazards Ratio=1.94, 95%CI=1.56-2.41) of SA (Andersen et al., 2016). Staff nurses are often not in a position to address high unit workloads. It is incumbent upon nurse managers and executes to manage nurse workload, in order to decrease absenteeism rates, and indicator of work-life imbalance.

Having symptoms of OSA was also a significant predictor where pediatric nurses were two times more likely to skip work. A Finnish study showed that when compared to their controls, female employees diagnosed with OSA were at 1.9 and 1.8 times higher risk for short (> 9 days) and long (≥ 90 days) term SAs during six years of follow up after adjusting for age, socioeconomic status, employment and organization type, and comorbid factors (Sjösten et al., 2009). The results from a large national sample of Norwegian workers (n=6892) showed that having symptoms of insomnia and OSA were both independent and combined predictors of SA. Those with OSA were 1.43 times at higher odds of taking 4-weeks duration of sick leave when compared to their peers (Sivertsen et al., 2013). In addition to work absenteeism, OSA increases the risk of occupational injuries and negatively impacts cognitive performance (Hirsch Allen et al., 2015), all of which are highly relevant to nurses working with patients at the bedside. Hospitals as part of the pre-employment medical examination process, may offer nurses sleep disorders screening to promote sleep health and decrease the risk of SA.

Among demographic characteristics, being married or living with a partner increased the odds of being absent from work. During the validation process of a prognostic model for long-term (>30 days) SA, Roelen et al. found that married Norwegian nurses were more likely take long-term SA (Roelen et al., 2015). It is possible that our married nurses encountered family/social obligations that compelled them to skip work. Additional support from family members or friends may also contribute to decreased incidence of absenteeism.

3.5.1. Strengths and Limitations

Several features of our study's design contributed to our ability to interpret the results with confidence. Baseline nurse fatigue scores preceded the outcome that helped establish the temporality and directionality of events. There is no recall bias as absenteeism data were extracted from the hospital's time and attendance system. This approach is advantageous over self-reported data that could underestimate the number of reported sick leaves (Gaudine & Gregory, 2010). We also adjusted for a number of covariates previously addressed in the occupational and nursing literature.

We acknowledge some study limitations. One limitation may be related to the FRAME study's napping intervention that was initiated on the night shifts. The 30-minutes naps could have alleviated fatigue and decreased nurses' need for being absent. However, napping in the hematology-oncology unit where the actual naps successfully occurred had little effect on the final outcome of SA. Another limitation may be related to nurses' absenteeism because of family obligations that might have inflated the outcome. This is a limitation in interpreting secondary administrative data. As for the external validity, we are cautious in generalizing our findings where the sample was from one hospital setting with four units that primarily provides pediatric care. Moreover, since this is not an etiology study, future studies addressing the causal effect of fatigue on SA are warranted.

3.6. Conclusion

The current study provided evidence that high AF increased the odds of SA in US nurses for the first time. Our results add insight to the phenomenon of SA that is complex in nature. In practicality, most of these identified factors are modifiable and can be addressed both by nursing management and nurses' personal efforts. Nursing management can monitor nurse fatigue and unit workloads in order to decrease this unfavorable outcome and consequently maintain safe practice environments. Nurses should seek medical attention, be screened for OSA and other sleep disturbances, and explore treatment options that will improve their overall sleep health and decrease the incidence of SA.

There are multiple avenues for future research in this area. One recommendation is to study the mediating role of recovery on short- and long-term SA over time, and utilize fatigue measures that capture the multidimensionality of the construct. Since differences exist in fatigue and SA based on gender in the general workforce, future studies should be conducted in male nurses which are a growing segment of the US nursing workforce.

4. Bio-mathematical fatigue models predict sickness absence in hospital nurses: An 18 months retrospective cohort study[1]

4.1. Abstract

Background. Sick days are often taken by fatigued employees. In occupations that require 24/7 coverage, one person's sickness absence cascades into more work days and longer shift durations for those that remain. A major challenge for hospital administrators is how to monitor employee fatigue. Bio-mathematical fatigue models may be a solution as these models can generate fatigue-risk scores using time card and task activity information.

Objective. To explore the associations between bio-mathematical fatigue-risk scores and sickness absence over 18 months of follow-up.

Methods. This is a retrospective cohort design study of 12-hour shift bedside nurses (n=197) representing four specialty units from a major pediatric hospital. For the study period 2012-13, nurses' work schedules and sickness absence data were extracted from the hospital's attendance (clock-in, clock-out hours) system. Fatigue-risk scores were generated for work days using the Fatigue Audit InterDyne (FAID) and Fatigue Risk Index (FRI) software programs with higher scores indicating greater fatigue, and linked to sickness absence data. Generalized linear mixed models were used to test the associations between the fatigue-risk scores and sickness absence, while accounting for the non-independency of repeated measures.

Results. The study period resulted in 43,893 work shifts of which 5.4% were sickness absence episodes. Nurse FAID fatigue-risk scores ranged from 7 to 154; fatigue scores

[1] K. Sagherian, S. Zhu, C. Storr, P.S. Hinds, J. Geiger-Brown (under review, *Chronobiology International)*

from standard 9-5 work schedule range from 7-40. Nurses with high FAID scores were more likely to be absent from work when compared to those with low FAID scores (scores 41-79, OR=1.38, 95%CI=1.21-1.58, $p<.001$ and scores 81-150, OR=1.67, 95%CI=1.42-1.95, $p<.001$). The FRI estimates fatigue and risk scores separately. Nurse scores ranged between 0.9-76.8 for fatigue and 0.7-3.8 for risk. When FRI-fatigue scores were greater than 60, nurses were at 1.58 times (95%CI=1.05-2.37, $p=.028$) at increased odds for sickness absence compared to scores in the 0.9-20 category. Nurses were 1.87 times (95%CI=1.37-2.56, $p<.001$) more likely to be absent from work for every one point increase in their FRI-risk scores.

Conclusion. Bio-mathematical fatigue-risk scores significantly predicted nurses' sickness absence. For nursing management, these models may be a practical solution to monitor for day-to-day fatigue changes in the workplace.

Key words: sickness absence, fatigue, FAID, FRI, bio-mathematical models, nurse

4.2. Introduction

Sickness absence (SA) is an anticipated event in the workplace and is often related to ill-health. Yet when the time spent in recovery becomes frequent and long-term, SA costs billions of dollars for the economy (CDC Foundation, 2015) and affects institutions' work productivity and team morale. In hospital nurses who spend most of their time in patient care, SA can disrupt the workflow on nursing units by creating a temporary shortage in staff as well as adding work days and longer shift durations for the unit nurses that remain. This can lead to elevated fatigue and unsafe nursing practices, and increased risk for patient mortality (Arakawa, Kanoya, & Sato, 2011; Duffield et al., 2011; Trinkoff et al., 2011). Moreover, nurses are prone to develop chronic health problems and stress-related illnesses (Kane, 2009; Nagai et al., 2011; Whang et al., 2009), which can result in frequent absences from work.

SA is multifactorial in etiology being attributed to a number of work, organizational and personal factors (Alexanderson, 1998). Several high quality epidemiologic studies from Europe have reported subjective fatigue as a predictor of future long-term SAs in shift workers (Akerstedt, Kecklund, Alfredsson, & Selen, 2007; Bultmann, Nielsen, Madsen, Burr, & Rugulies, 2013; Janssen, Kant, Swaen, Janssen, & Schröer, 2003). Only a few studies have focused on nurses. One study done in Norway split fatigue into components and showed that nurses' elevated physical and total fatigue levels were related to self-reported long-term (>30 days) SA after 12 months of follow up (Roelen et al., 2013). Moreover, the results of a recent retrospective cohort study from the United States on a sample of pediatric nurses working 12 hour shift found that elevated acute fatigue levels (above 1SD), increased the odds for SA by 29% (Sagherian et al., 2017).

Fatigue experiences are generally reversible with countermeasures such as adequate sleep, naps, and leisure activities (Sagherian & Geiger Brown, 2016). However in the absence of countermeasures, fatigue can become prolonged (Winwood, Bakker, & Winefield, 2007) and present a safety hazard in the workplace. Research has shown that when fatigued and sleep deprived, nurses experience reductions in job performance putting patients at risk for medical errors that may jeopardize their health (Dorrian et al., 2008; Olds & Clarke, 2010; Sagherian, Clinton, Abu-Saad Huijer, & Geiger-Brown, 2016; Scott, Rogers, Hwang, & Zhang, 2006; Wolf, Perhats, Delao, & Martinovich, 2017). Most of the fatigue in nurses results from non-standard work schedules and increased temporal and job demands (Torbjörn Akerstedt & Kecklund, 2017; Dorrian, Baulk, & Dawson, 2011; Yuan et al., 2011). While 12-hour shifts are the norm for nurses in US hospitals, the problems of fatigue and sleepiness partially lie in shortened rest and sleep periods that occur between two consecutive shifts, and subsequently trying to remain vigilant during the work shift the following night (Geiger-Brown, Trinkoff, & Rogers, 2011). A recent Swedish study showed that individuals who worked more than 10 hours per shift, had rest periods of less than 11 hours between two shifts, worked during the night, or had early day starts closer to 6 AM, had increased odds of being fatigued when compared with other work schedule characteristics (Akerstedt & Kecklund, 2017).

Nurse fatigue should be monitored in order to maintain a safe working environment for patient care, lower absenteeism rates and overall well-being of the nursing staff. A systematic review of the literature on work-related fatigue and SA found employee fatigue was consistently assessed via subjective fatigue measures (i.e., survey questionnaires) in all of the studies (Sagherian, Geiger Brown, Rogers, & Ludeman, 2017). While surveys are instrumental in observational and experimental human subject research, they are neither designed nor practical to capture day-to-day operations on nursing units for the purpose of monitoring elevated fatigue levels. An alternative and practical approach to surveys is the use of bio-mathematical fatigue models that can estimate fatigue and by inference performance decrements based on laboratory and field research, the science of homeostatic sleep drive and circadian rhythms, and sleep inertia (Dawson, Ian Noy, Härmä, Åkerstedt, & Belenky, 2011; Lerman et al., 2012; Tucker & Folkard, 2012). These models use sleep-wake prediction algorithms, display different outputs and units of measurement (i.e., fatigue-risk, alertness, or neurobehavioral performance), and have been validated against different instruments such as subjective alertness, EEG, psychomotor vigilance tests and accident data in different subgroups (Dawson et al., 2011; Moore-Ede et al., 2004).

A number of bio-mathematical fatigue models are used in aviation, transportation and safety-sensitive industrial settings such as the Fatigue Audit InterDyne (FAID), the Circadian Alertness Simulator (CAS), the Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) and the Fatigue Risk Index (FRI) (Dawson et al., 2011; Mallis, Mejdal, Nguyen, & Dinges, 2004; Moore-Ede et al., 2004; Roach, Fletcher, & Dawson, 2004); however published data in healthcare workers are scarce. A prospective cohort study by McCormick and colleagues (2012) used the SAFTE model to examine orthopedic surgical residents' fatigue and risk of medical errors associated with their sleep-work schedules over a period of two weeks. Results showed that surgical residents were fatigued almost half of the time when awake and had a 22% increased risk of making medical errors when compared to the well-rested control group. Also, residents on nigh-shifts were significantly more fatigued and had greater risk of making errors when compared to day-shift rotations (McCormick et al., 2012). The authors also conducted an experimental study over 28 days where they used four types of surgical resident rotations: day and night shifts, trauma shifts, and pre-work hour restriction with overnight call every third night (the historical control group) to simulate fatigue impairment scores using the SAFTE model. The results showed that most of the fatigue occurred during night shifts where residents would be impaired 50% of the time at work. However, when fatigue countermeasures that consisted of 30-min naps before the first night shift, and at 3 AM during the night shift, 12-hour rather than 24 hour shifts, sleeping during off days, practicing sleep hygiene and one additional hour of sleep per day for one week were uploaded in the model, scores decreased dramatically from 50% to ~2% (McCormick et al., 2013).

It is also important to note that bio-mathematical fatigue models are but one component of a fatigue risk management system (FRMS), defined as a data-driven comprehensive approach to fatigue management rather than following a traditional prescriptive approach of restricting employees' work hours (Lerman et al., 2012). The goal of these models is to provide objective assessment of fatigue-risk associated with work schedules in order to make informed decisions regarding the design of shift schedules and prevention of fatigue-related incidents or accidents during a shift. Other parts of a FRMS include having a fatigue management policy; fatigue risk management where efforts are geared to identifying, studying, and controlling the risks associated with fatigue; employee reporting systems; incident investigation; employee education and training to manage high fatigue levels; sleep disorder treatment options and audits within an organization (Lerman et al., 2012; Steege & Pinekenstein, 2016).

To date, bio-mathematical fatigue models are rarely used by hospitals despite being user-friendly and commercially available. Although these models have been developed to evaluate the safety of work settings and predict incidents/accidents associated with work-related fatigue, they are not used in relation to SA in healthcare nor in shift working groups. Thus, the purpose of this study was to explore the associations between fatigue-risk scores that were generated from two bio-mathematical fatigue models and SA over 18 months of follow-up. We hypothesized that increased fatigue-risk scores will increase nurses' odds of future SA from the workplace.

4.3. Methods

4.3.1. Design and study sample

The study used a retrospective cohort design over a period of 18 months. The population of interest was hospital nurses who worked traditional 12-hour shifts. A total of 197 nurses from four nursing units in a pediatric hospital were included in the sample: 32% medical-surgical, 31% intensive care, 24% hematology-oncology and 12% heart-kidney.

Nurses' work-rest schedules and absenteeism data were extracted from the hospital's time and attendance system (Kronos, Inc.) by a system analyst. The system stores the date, clock-in and clock-out times, codes that indicate vacation and bereavement days, holidays and absences, and some manually entered notes by nurse managers for every single work shift. During the data cleaning process, shift durations that were less than 4 hours were considered as administrative responsibilities and were excluded from further analyses. The follow-up period which included 43 893 shifts was from January, 2012 to June, 2013.

4.3.2. Measures

SA. The outcome variable was defined as "being absent from work when an individual was expected to be working". The absence may be related to an illness, lack of motivation, family or social responsibilities. Absence data were extracted from the pay codes marked as: SICK, Accrued Sick and Safe Leave Act (ASSLA)-sick, Family Medical Leave Act (FMLA)-sick or UNPAID LEAVE. The pay codes that indicated scheduled vacation days, holidays or family bereavement were considered rest/off days and were not part of the outcome. Sickness absence was operationalized as a daily event of being absent from (yes) or present at (no) work over 18 months. The absence rate was 5.4% over the study period.

Fatigue estimates. In our study, fatigue was defined as "a biological drive for recuperative rest" (Williamson et al., 2011) from work. Nurses' fatigue scores were generated using the Fatigue Assessment Tool by InterDynamics (FAID®) and Fatigue Risk Index (FRI) software programs. The bio-mathematical fatigue models produced fatigue-risk estimates per shift based on the input of clock-in and clock-out data (i.e., actual work hours) and certain determinants of fatigue that came embedded in each software. For the FRI, the software generates fatigue and risk estimates separately associated with the work schedules and requires additional input about nurses' commute, breaks and workload.

Fatigue Assessment Tool by InterDynamics. The FAID® (InterDynamics Pty Ltd.) is a 2-process bio-mathematical model that estimates peak fatigue-risk scores based on the input of work schedules (i.e., actual worked hours). The prediction process has two steps: 1) estimates sleep-wake patterns from the input of work-rest schedules and 2) then generates fatigue. The model is based on the science of homeostatic pressure (i.e., sleep debt) and diurnal circadian rhythm. It also accounts for the time and duration of work shifts, non-work hours where recovery happens, and the cumulative impact of fatigue based on the previous seven days of an employee's work schedule as major determinants of work-related fatigue. The algorithms were developed based on the sleep and fatigue research conducted by Drs. Dawson and Fletcher. They have been validated against subjective measures of sleep, fatigue and alertness, and psychomotor vigilance performance tests in laboratory settings and field studies of shift workers from different occupations (Roach et al., 2004).

High FAID scores indicate higher fatigue exposures; high fatigue and less alertness. The scale is calibrated such that a fatigue score of 40 represents a standard work schedule of 40 hours per week, Monday to Friday from 9 AM to 5 PM. Scores of 80 to 100 represent work-related fatigue derived from 23-24 hours of continuous sleep deprivation (Dean, Fletcher, Hursh, & Klerman, 2007; FAID InterDynamics, 2017). Extreme fatigue scores of more than 120 represent permanent night schedules of six consecutive 12-hour night shifts and one day off.

Fatigue and Risk Index. The FRI (QinetiQ and Simon Folkard Associates Ltd.) estimates fatigue and risk scores separately based on the algorithms generated from shiftwork and aviation research. The models have a cumulative component that accounts for the effect of the previous shift that immediately preceded the current work shift, a duty time component that accounts for the effects of start times, shift length and the time of day during a work shift, and a job type / breaks component that incorporates workload and rest breaks during a working shift (Folkard, Robertson, & Spencer, 2007).

The FRI software has a default setting that requires being set prior to the upload of work schedules and generation of fatigue and risk scores. It consists of seven questions related to commutes, workload, attention, and breaks and where each question was answered based on previous research and the expert opinion of Dr. Simon Folkard. The following are the default settings that were used for the current study:

1. What is the typical commuting time of employees to or from work (to the nearest 10 minutes)? Answer: 40 minutes
2. Type of job/workload: the workload and/or work pace of the job is typically? Answer: moderately demanding, little spare capacity.
3. Type of job/attention: the job typically requires continuous attention? Answer: all or nearly all the time.
4. How frequently (to the nearest 15 minutes) are rest breaks typically provided or taken? Answer: every 6 hours
5. What is the typical average length of these breaks (to the nearest 5 minutes) that are provided or taken? Answer: 30 minutes
6. What is typically the longest (to the nearest 15 minutes) period of continuous work before a break? Answer: 5 hours 45 minutes
7. What is typically the length of the break taken after this longest period of continuous work (to the nearest 5 minutes)? Answer: 30 minutes

Scores from the FRI 'Fatigue Index' can range between zero and 100. They represent the average probability multiplied by 100 of high levels of sleepiness on the Karolinska Sleepiness Scale (KSS). The KSS is a nine-point rating scale that ranges from one being extremely alert to nine being extremely sleepy or fighting sleep. For example, a fatigue score of 40 indicates a 40% probability of scoring 8 or 9 on the KSS. The 'Fatigue Index' scale is calibrated such that a value of 20.7 for a 12 hour shift schedule corresponds to the average of DDNNRRRR work pattern (i.e. 2 days, 2 nights followed by 4 rest days) with typical values on the job type and breaks (Folkard et al., 2007; Spencer, Robertson, & Folkard, 2006). However, there is no reported consensus on fatigue scores that represent good practices or the level at which users should intervene and adjust work schedules to reduce the risk of fatigue in the workplace.

Scores from the FRI 'Risk Index' indicate the relative risk of an incident or an error occurring during a specific work shift. The scale is calibrated such that a score of 1.0 is the average risk of an incident for a 12 hour shift schedule of a DDNNRRRR, and a score of 2.0 could be interpreted as twice the risk on that specific shift. Like the Fatigue Index, there is no specific threshold for the Risk Index and users are encouraged to keep the risk as low as reasonably practicable, and develop their own thresholds (Folkard et al., 2007; Spencer et al., 2006). It is worth noting that the main difference between the fatigue and risk indexes is the effect of time of day, where the peak in risk occurs closer to midnight, whereas the peak in fatigue occur some five hours later, in the early morning.

Covariates. The current study had data available from four units of practice used as covariate. For descriptive purposes, variables named shift type and shift durations were computed. While most shifts followed the traditional 7 AM or 7 PM start times, a shift with a 4 AM start time was considered a day shift and with 5 PM start time was considered a night shift.

4.3.3. Statistical analysis

Descriptive statistics were used to describe the characteristics of the sample. Continuous variables were examined for normality based on skewness (acceptable range: ±1.5) and graphic representations (histogram and box-plot). Skewness values were acceptable, histograms showed non-normal distribution for the FRI-fatigue, and boxplots yielded outliers on the FRI-risk and FAID-fatigue only. For our study, FAID-fatigue and FRI-fatigue scores were divided into categories in order to compare to standard work schedules for reference. The FAID scores were divided into three categories of 0 to 40 (standard), 41 to 79 (medium risk) and ≥ 80 (high-risk). The FRI-fatigue scores were divided into four categories of 20 point increments: 0 to 20, 21 to 40, 41 to 60 and 61 to 80 (all values were less than 80). For the FRI-risk, no transformation was necessary. Prior to model building, Spearman *rho* correlations were used to assess for the collinearity between FRI-risk, FRI-fatigue, and FAID-fatigue scores. The correlations between FRI-risk with FRI-fatigue and FAID-fatigue were strong ($r_{s1,2} = 0.95$, $r_{s1,3} = 0.86$). As a result, the FRI-risk was built in a separate model.

Generalized linear mixed models (GLMMs) were used to examine the association between fatigue estimates and sickness absence while accounting for the nonindependence in repeated measures (intraclass correlation coefficient [ICC] =0.114). The crude and adjusted odds ratios (ORs) and 95% confidence interval (CI) were estimated. The GLMM models were controlled for unit of practice and time (in months).

All analyses were performed in STATA 14.1 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP).

4.3.4. Ethical approval

The current study qualified as non-human subjects research by the University of Maryland Baltimore and Children's National Medical Center Institutional Review Boards.

4.4. Results

The 18 months of follow-up resulted in 43,893 work shifts (range= 38-313 shifts per nurse), of which 5.37% (n=2,355) were sickness absence episodes. Most nurses worked typically 12.5 hours per shift. However, 5.67% (n=2,248) of the shifts were between 4 and 11.5 hours, and less than 1% (n=314) were between 16 and 23.5 hours. On average, the FAID-fatigue score was 58.38 (SD=26.63, range=7-154) indicating fatigue risk at the moderate level. As shown in Table 8, 22.89% (n=9390) of the FAID-fatigue scores were ≥ 80 of which 97.66% (n=9170) were night shifts. The median score on the FRI-fatigue was 18.63 (*M*=31.71, SD=20.09, range=0.87-76.83). Moreover, nurses who scored ≥61; had more than 60% probability of scoring 8 to 9 on the KSS, and were working during the night.

Table 8. Nurses' shiftwork characteristics, fatigue estimates and sickness absence.

Variables	N (%)
Shift type	
Day	22 042 (53.06)
Night	19 496 (46.94)
FAID-fatigue*	
0 to 40	12 295 (29.97)
41 to 79	19 333 (47.13)
≥ 80	9390 (22.89)
FRI-fatigue	
0 to 20	21323 (51.33)
21 to 40	1175 (2.83)
41 to 60	18561 (44.68)
≥ 61	479 (1.15)
FRI-risk	
M (*SD*) (range: 0.70-3.75)	1.12 (0.17)
Sickness absence	
Absent (yes)	2355 (5.37)
Present (no)	41 538 (94.63)

Note. *The sum does not add to 41 538 since the software considers past seven days as history for cumulative fatigue.

Table 9 presents odds ratios for FAID-fatigue and sickness absence while controlling for unit of practice and the effects of time. When FAID-fatigue risk scores were between 41 and 79, nurses were 1.38 times more likely to be absent from work when compared to the standard (i.e., ≤ 40) group. Sickness absence was 1.67 times more likely to occur when nurses' FAID-fatigue risk scores reached 80 or more when compared to the standard group.

Odds ratios for FRI-fatigue and sickness absence are presented in Table 10 and odds ratios for FRI-risk and sickness absence in Table 11, while adjusting for unit of practice and the effects of time. Nurses with FRI-fatigue scores of more than 60, were 1.58 times more likely to be absent from work when compared to the reference group. When the FRI-risk scores increased by one point (e.g., from a score of one to a score of two), nurses were 1.87 times more likely to occur to be absent from work.

Table 9. Nurses' FAID-fatigue estimates predict sickness absence (yes/no).

Parameter	**Crude OR (95% CI)**	***p***	**Adj. OR (95% CI)**	***p***
FAID-fatigue				
0 to 40	ref			
41 to 79	1.38 (1.21-1.58)	<.001	1.38 (1.21-1.58)	<.001
≥ 80	1.67 (1.42-1.95)	<.001	1.67 (1.42-1.95)	<.001
Unit of practice				
Hematology-oncology			ref	
Medical-surgical			1.28 (1.03-1.59)	.027
Intensive care			1.51 (1.22-1.87)	<.001
Heart-kidney			1.51 (1.15-1.99)	.003
Time (in months)			1.01 (1.00-1.02)	.016

Table 10. Nurses' FRI-fatigue estimates predict sickness absence (yes/no).

Parameter	**Crude OR (95% CI)**	***p***	**Adj. OR (95% CI)**	***p***
FRI-fatigue				
0 to 20	ref		ref	
21 to 40	1.08 (0.78-1.48)	.657	1.05 (0.76-1.44)	.783
41 to 60	1.10 (0.97-1.25)	.138	1.11 (0.98-1.26)	.113
≥ 61	1.61 (1.07-2.41)	.022	1.58 (1.05-2.37)	.028
Unit of practice				
Hematology-oncology			ref	
Medical-surgical			1.28 (1.04-1.58)	.022
Intensive care			1.49 (1.21-1.84)	<.001.0
Heart-kidney			1.48 (1.13-1.94)	04
Time (in months)			1.01 (1.00-1.02)	.032

Table 11. Nurses' FRI-risk estimates predict sickness absence (yes/no).

Parameter	**Crude OR (95% CI)**	***p***	**Adj. OR (95% CI)**	***p***
FRI-risk	1.91 (1.39-2.61)	<.001	1.87 (1.37-2.56)	<.001
Unit of practice				
Hematology-oncology			ref	
Medical-surgical			1.29 (1.04-1.59)	.021
Intensive care			1.48 (1.20-1.83)	<.001
Heart-kidney			1.47 (1.21-1.93)	.005
Time (in months)			1.01 (1.00-1.02)	.029

4.5. Discussion

The findings from this retrospective cohort study provide preliminary evidence about the predictive validity of bio-mathematical fatigue models in relation to sickness absence. Elevated fatigue, as measured by the FAID and FRI fatigue scores, significantly increased the odds of being absent from the workplace. We also found a strong correlation between the FAID and FRI fatigue scores, $r_s = 0.88$ that suggested commonalities in prediction algorithms regardless of differences in software features as mentioned in the literature (Van Dongen, 2004). The few published studies that examine nurses' subjective fatigue experiences with sickness absence report similar results to those that we found using a bio-mathematical model (Roelen et al., 2013; Sagherian, Unick, et al., 2017). On the other hand, the fatigue captured by bio-mathematical models has been defined as sleepiness or decreased alertness after extended periods of wakefulness because of a work shift (Darwent, Dawson, Paterson, Roach, & Ferguson, 2015; Dawson et al., 2011). A Finnish study by Lallukka et al. showed that the risk for sickness absence was lowest when sleep duration was 7.6 hours for female and 7.8 hours for male workers (Lallukka et al., 2014).

When examining our high fatigue scores that infer to extended periods of wakefulness (i.e., extreme sleepiness), they mostly occurred during the night and when shifts were on average between 12.76 (SD=0.76, FAID) and 14.57 (SD=1.72, FRI) hours. Interestingly, in separate analyses, we found that when nurses worked night shifts, they were 1.19 times (95%CI=1.05-1.35; p=.005) more likely to be absent from work compared to the day shifts. Evidence of an association between shift types and sickness absence in the occupational literature is inconclusive. A systematic review by Merkus and colleagues found strong evidence for the relationship between fixed evening shifts and sickness absence in female healthcare workers only (Merkus et al., 2012). A recent 5-year retrospective cohort study showed that airline employees who switched from fixed day shifts to three-shift rotations were 1.31 times at increased odds for long-term sickness absence, whereas fixed night shift workers were not (van Drongelen, Boot, Hlobil, van der Beek, & Smid, 2017).

The FRI has a unique feature of estimating the relative risk of an error that may result in an accident/injury during a particular shift (Folkard et al., 2007). In our study, when the risk scores increased, nurses were 1.87 times more likely to be absent from work. It is probable that an episode of sickness absence played a protective role where nurses needed to recover away from the exposure of work and when the risk of making medical errors was high. However, in the absence of a risk threshold of what is considered safe or normal, interpretation of risk scores or even the hazard associated with work-related fatigue is best kept within the context of the institution and the tasks in hand (Dawson et al., 2011). A hospital is a hazardous setting where the rate of work-related injuries/illnesses in healthcare workers is almost double than the rate in the US industry (Bureau of Labor Statistics, 2014). Nurses operate in high-risk environments, execute direct and indirect nursing care activities with varying level of complexities, and are required to maintain vigilance through their shifts. From this standpoint and in order to eliminate threats to patient safety, a lower risk threshold may be set, possibly around a score of one, where nurses would spend the greatest proportion of their time within that safety-zone.

4.5.1. Strengths and Limitations

The strengths of this study are in the longitudinal design where time-varying fatigue estimates preceded the outcome of sickness absence. The use of bio-mathematical fatigue models was advantageous and innovative, as they captured elevated nurse fatigue levels on daily basis where it would have been unlikely to capture this degree of detail with surveys. Moreover, shortcomings such as social desirability, boredom effects, or drop outs that are anticipated in longitudinal survey research are not potential threats here. In addition to nurses' work schedules, the data on sickness absence were retrieved from the hospital's attendance system that eliminated the risk for recall bias over 18 months.

As well, we acknowledge several limitations to our study. One is related to lack of data on nurses' socio-demographic and health characteristics that may influence the relationship between fatigue and sickness absence. Another limitation is related to the assumptions in the FRI software, where we did not have data on commutes, meal breaks or workload that would have individualized the fatigue and risk scores. Even though our input was based on expert opinion and previous research experiences, the risk of researcher bias in assigning our default settings is still probable where commutes, workload perceptions and meal breaks vary at the individual level. On the other hand, the FRI was developed to evaluate and compare work schedules in groups rather than on individual basis which was a tedious process in our sample.

As outlined in the literature, bio-mathematical fatigue models themselves have several inherent limitations that influenced the external validity of our findings, where lack of interindividual variability in fatigue estimates may hinder the generalizability of fatigue across shift working populations (Dawson et al., 2011) and in our case to hospital nurses across different healthcare settings. However, our data showed that there were negligible differences in the risk for sickness absence when adjusted for nursing units where fatigue parameters remained relatively stable. Another limitation is related to the construct of fatigue that is used interchangeably with sleepiness, as these models estimate sleep opportunity (Dawson, Darwent, & Roach, 2017). Fatigue is a subjective experience where performance decrements are manifested in physical and/or cognitive activities. It is also probable to have some misclassification bias as nurses may implement strong fatigue countermeasures, or on the contrary, may work second jobs or fulfill family obligations that hinder the recovery process during non-work hours and off days, which are not part of the fatigue estimates.

4.6. Conclusion

The present study provided evidence that high fatigue estimates are associated with sickness absence in 12-hour shift pediatric hospital nurses. Compared to survey questionnaires, bio-mathematical fatigue models may be a practical solution for nursing management to monitor fatigue in the workplace. Moreover, these software programs generate decision support data for nurse leaders to utilize in their fatigue and sickness management initiatives, and in efforts to maintain safe working time arrangements (i.e., work-rest schedules) for nurses.

As for future research, our FAID or FRI cut points may be used to establish fatigue tolerance levels on nursing units and to examine the generalizability of these models to other healthcare settings. It is possible that these fatigue estimates may need calibration in nurses since validations studies have used work schedules and empirical data from truck drivers, train drivers or flight crew. In this study, we found strong correlations between nurses' fatigue and risk estimates, thus prospective studies are warranted to evaluate these relationships within the context of patient safety, including medical errors and near misses.

5. Discussion, Implications and Recommendations

The dissertation titled *"Nurse Fatigue Increases the Risk of Sickness Absence"* examined the prospective associations between work-related fatigue, bio-mathematical fatigue-risk, and sickness absence in 12 hour shift hospital nurses. The chapters 2, 3 and 4 that encompassed three manuscripts addressed the specific aims of the dissertation. This final chapter provides a summary of major findings, overall strengths and limitations of the retrospective studies, implications for nursing practice, and future research directions.

5.1. Summary of Findings

Aim 1. To systematically review and synthesize the existing literature on the relationship between fatigue and sickness absence in the working population.

The systematic review identified 17 longitudinal studies that examined the relationship between fatigue and sickness absence in workers. Fifteen studies were of high methodological quality, and results demonstrated strong evidence on the prospective associations between chronic fatigue and fatigue as a symptom, and long-term sickness absence in the general workforce. The duration of long-term sickness absence differed both by study and country. Gender influenced the relationship between fatigue and sickness absence, where there was strong evidence in men only.

Aim 2. To explore the association between work-related fatigue and sickness absence in hospital nurses over 12 months of follow-up.

Hypotheses: 1) Nurses with elevated chronic fatigue scores at baseline will have increased odds of sickness absence, and 2) Nurses with elevated acute fatigue scores at baseline will have increased odds of sickness absence; however the strength of the *relationship between acute fatigue and sickness absence will be lower than that of chronic fatigue and sickness absence.*

The results failed to reject the null hypothesis regarding the relationship between chronic fatigue and sickness absence. Conversely, acute fatigue significantly predicted nurses' sickness absence from the workplace. With 1SD increase in baseline acute fatigue scores, nurses were 1.29 (95%CI=1.02-1.63, p=.036) times more likely to be absent from work. As a secondary aim, the study explored additional work-related and personal factors that predicted sickness absence. The results showed that intershift recovery (OR=1.32, 95%CI=1.03-1.69; p=.027), perceived workload (OR=1.23, 95%CI=1.03-1.48; p=.024), having obstructive sleep apnea (OR=2.05, 95%CI=1.29-3.25; p=.002), and being married (OR=1.53; 95%CI=1.01-2.31; p=.045) increased the odds for sickness absence.

Aim 3. To explore the associations between bio-mathematical fatigue-risk scores and sickness absence in hospital nurses over 18 months of follow-up.

Hypothesis: Nurses' elevated fatigue-risk scores will increase the odds of sick absence.

Two software programs; Fatigue Audit InterDyne (FAID) and Fatigue Risk Index (FRI) were used to generate nurses' fatigue-risk scores. The results rejected the null hypothesis and showed significant associations. Compared to standard work schedules (FAID scores=7- 40), nurses were 1.38 (95%CI=1.21-1.58, p<.001) and 1.67 (95%CI=1.42-1.95, p<.001) times more likely to be absent from work when FAID scores were between 41-79 and 81-150 respectively. The FRI estimates fatigue and risk scores separately. Similarly, when FRI-fatigue scores were greater than 60, nurses were at 1.58 increased odds (95%CI=1.05-2.37, p=.028) for sickness absence compared to scores in the 0.9-20 category. With one unit increase in FRI-risk scores, nurses were 1.87 times (95%CI=1.37-2.56, *p*<.001) more likely to be absent from work.

5.2. Strengths and Limitations

The strengths of the dissertation are in its longitudinal design where nurses' subjective fatigue experiences and time-varying fatigue estimates preceded the outcome of sickness absence that helped establish the temporality and directionality of events. Second, the data on sickness absence were retrieved from the hospital's time and attendance system that eliminated the risk for recall bias during the study period. This approach is advantageous over self-reports that could under or overestimate the number of reported sick leaves (Gaudine & Gregory, 2010). Third, the risk for mono-method bias was reduced in the dissertation where fatigue was assessed through subjective (OFER-15) and objective (FAID and FRI) measures. Finally, the three studies contributed substantially to the literature through novel findings and innovation.

Besides the limitations specified in each study, one overall limitation is embedded in the absenteeism data extracted from the hospital's time and attendance system. Sickness absence episodes might have been related to nurses' social or family obligations that could have inflated the outcome, however this effect is unknown. It is also probable that the dissertation had threats to external validity where the data were from one hospital that provides care to the pediatric population, and nurses were primarily from the younger generation and worked 12 hour shifts. This limits the generalizability of the findings to the aging nursing workforce, nurses working outside 12 hour shifts, other nursing units and health care organizations in the country.

5.3. Implication for nursing practice

Research studies have supported the implementation of fatigue risk management strategies for hospital nurses to decrease the safety hazards related to patient care and personal well-being. Mostly, fatigue countermeasures have consisted of restricted nursing work hours, education and training on sleep hygiene, relieved meal/rest breaks and planned naps during the night (Geiger-Brown et al., 2016; Scott, Hofmeister, Rogness, & Rogers, 2010) that encompass a nurse-driven component. However, the American Nurses Association had a position statement emphasizing the shared responsibilities between nurses and nursing administration in reducing nurse fatigue levels and creating safe practice environments (ANA, 2014).

Recently, Steege and Pinekenstein (2016) proposed a *multilevel fatigue risk management in nursing work systems model* that consisted of robust data collection from multiple sources and nurse fatigue monitoring, decision support tools to assist in decision processes, risk management responsibilities and safety controls (e.g., workloads, scheduling practices, education and training) (Steege & Pinekenstein, 2016). In this dissertation research, the results from the two retrospective studies direct nurse executives, nurse managers and nurses to consider and initiate changes in the workplace within the scope of their responsibilities. Acute fatigue, intershift recovery and sleep apnea were related to sickness absence. These findings inform nurses to seek medical attention for sleep disturbances, practice sleep hygiene and recover during non-work hours to resume pre-fatigued states. Nursing administration can also offer nurses sleep disorders screening and treatment options as part of their pre-employment screening, and ongoing occupational health program. Additionally, high workloads as perceived by nurses increased the odds of sickness absence, which informs nurse managers to re-evaluate current workloads on nursing units. In the dissertation, fatigue was measured by the OFER-15 scale and two bio-mathematical fatigue software programs. Acute fatigue and fatigue induced by work-rest schedules that are modifiable in nature predicted nurses' sickness absence. The gained knowledge can assist nurse managers to evaluate and modify current work schedule practices and provide adequate rest/sleep opportunities between work shifts, which is a major challenge for them. However, the dissertation provides supportive evidence on the integration of bio-mathematical fatigue software programs such as the FAID or FRI in day-to-day operations, and in keeping fatigue estimates within safe zones to lower sickness absences rates in the workplace. Nurse executives can support this process by acquiring bio-mathematical fatigue software programs and dedicating personnel to examine past work schedules that are stored in the time and attendance system in order to establish acceptable thresholds on nursing units.

One of the recommendations of Institute of Medicine committee was to limit nurses' total work hours to 12 hours per shift and no more than 60 hours per week (Page, 2004). In the bio-mathematical fatigue study, secondary data analyses showed that 314 shifts exceeded 16 hours in a 24 hour period, which limits opportunities for rest and sleep. In the United States, insufficient sleep costs the economy between $280 and $411 billion dollars annually (Hafner, Stepanek, Taylor, Troxel, & van Stolk, 2016). For nurse managers who are faced with administrative and temporal demands, bio-mathematical fatigue software programs that model sleep-wake cycles from work-rest schedules can serve as safety guards against sleep deprivation in volatile nursing units.

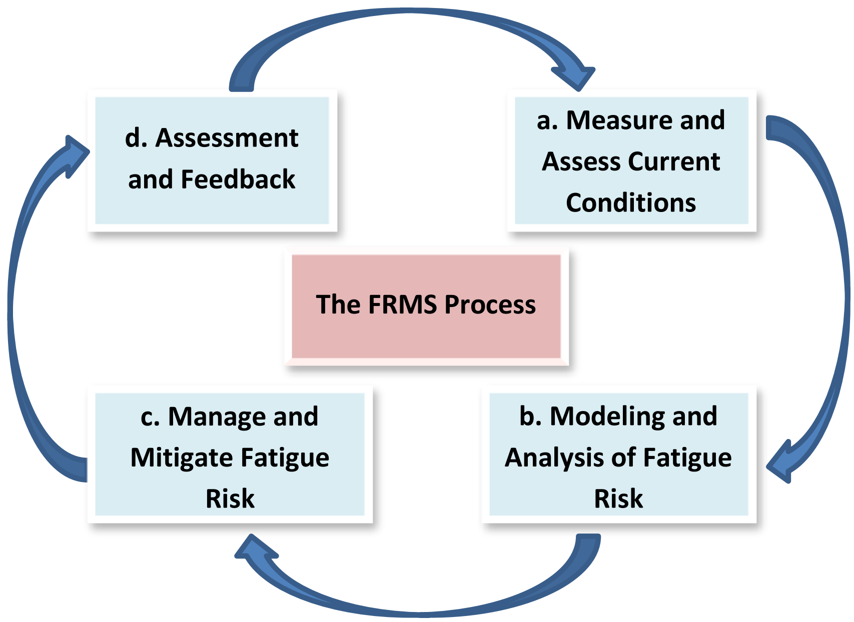
5.4. Conclusion and Implications for future research

In conclusion, acute fatigue experiences and bio-mathematical fatigue estimates increased the odds of sickness absence in 12 hour shift pediatric nurses. In addition, greater intershift recovery, increased perceptions of workload, having symptoms of sleep apnea and being married significantly predicted sickness absence too. The dissertation findings contributed to better understanding of sickness absence in nurses that is complex in nature. It is worth noting that most of these factors are modifiable and can be addressed both by nursing management and nurses' personal efforts.

Based on the systematic review (aim 1), the authors recommend measuring multidimensional components of fatigue in sickness absence studies that could help in tailoring sickness absence prevention strategies. Another potential area is to explore acute and chronic fatigue patterns on sickness absence, and to identify work and non-work factors that contribute to this relationship. The systematic review also showed that gender influenced the relationship between fatigue and sickness absence, thus more research is needed in male nurses, who represent around 10% of the US nursing workforce.

In addition to the use of a subjective fatigue measure, the dissertation used bio-mathematical fatigue models to estimate nurses' fatigue-risk during work shifts. As mentioned previously in chapter 4, these models are one component of a fatigue risk management system (FRMS) that aims to manage fatigue-risk and enhance safe work environments. As shown in Figure 3, the FRMS is a cycle that continuously assesses and measures the status quo in the workplace, models the risk of being fatigued, manages and mitigates fatigue through fatigue countermeasures and reassesses fatigue-risk and safety outcomes such as incidents and accidents. Interestingly, the second and third aims of the dissertation supported the first and second steps in the FRMS model. Within the context of sickness absence, one potential area of research is to conduct intervention studies that incorporate fatigue mitigation plans such as planned naps and safe work time arrangements and monitor trends in sickness absences and medical errors on nursing units. Moreover, feasibility studies are needed that identify facilitators and barriers in adopting these software programs on nursing units.

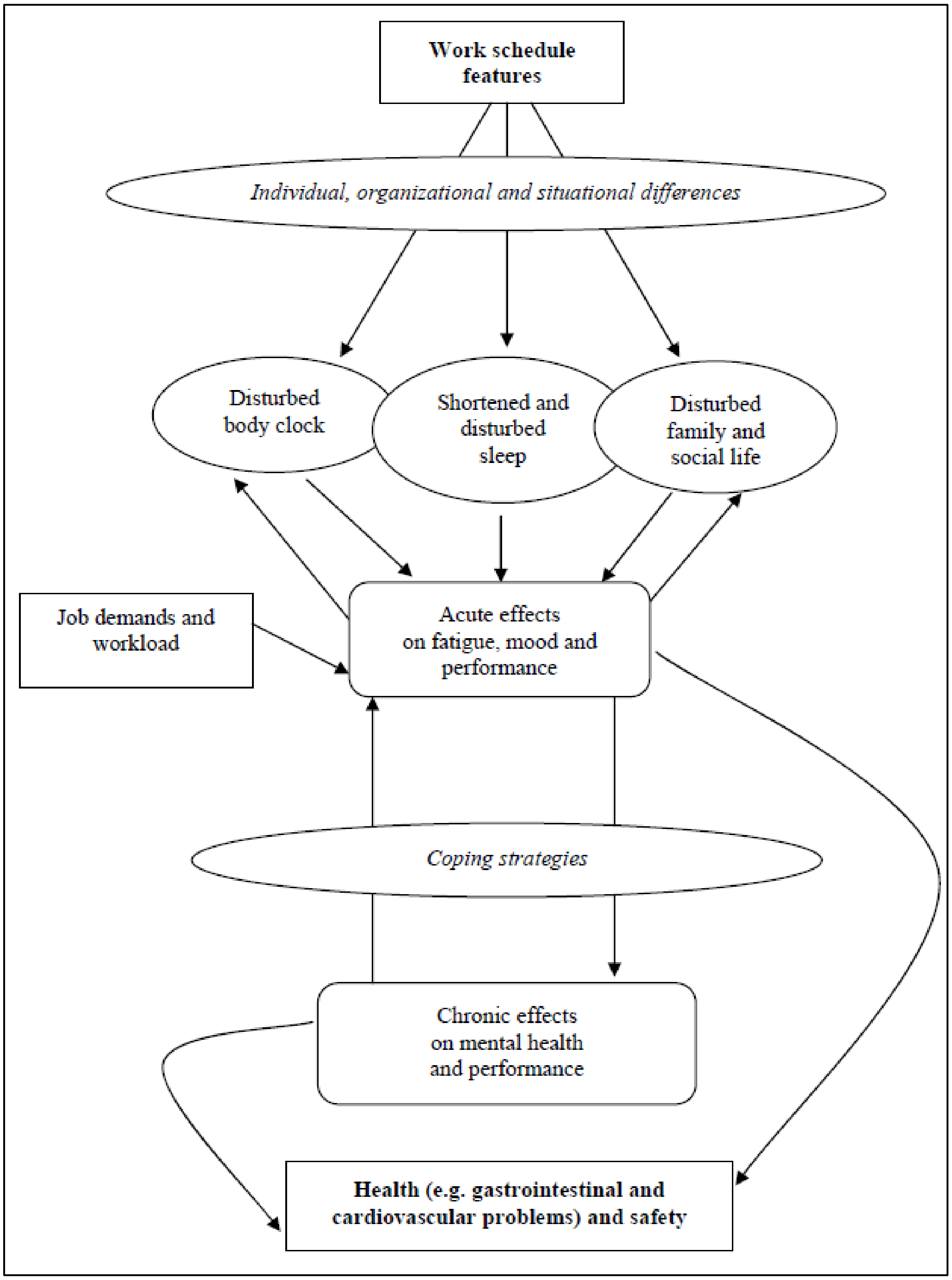
Figure 3. Fatigue Risk Management System Process



Source: European Organization for the Safety of Air Navigation (EUROCONTROL, 2012).

In the bio-mathematical study, subgroup analyses have shown that 12 hour night shifts increased the odds of sickness absence too. Research reports that only a small percentage of night shift workers show adaptations to the night (Folkard, 2008; Gamble et al., 2011). Consequently, prospective studies are needed that systematically examine nurses' work schedule characteristics in relation to sickness absence that are currently lacking in the literature. On a final note, sickness absence has poor indications on personal and professional well-being; however fatigue may be the key to prevent their occurrence in the workplace.

Appendix A. "Problems associated with abnormal work schedules" conceptual model developed by Philip Tucker and Simon Folkard.



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