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Bio-mathematical fatigue models predict sickness absence in hospital nurses: An 18 months retrospective cohort study

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ABSTRACT

This study examined the associations between bio-mathematical fatigue-risk scores and sickness absence (SA) in hospital nurses over 18 months. Work schedules and SA data were extracted from the hospital's attendance system. Fatigue-risk scores were generated for work days using the Fatigue Audit InterDyne (FAID) and Fatigue Risk Index (FRI). Over the study period, 5.4% of the shifts were absence shifts. FAID-fatigue ranged from 7 to 154; scores for a standard 9–5 work schedule can range from 7 to 40. Nurses with high FAID-scores were more likely to be absent from work when compared to standard FAID-scores (41–79, OR = 1.38, 95%CI = 1.21–1.58; 80–99, OR = 1.63, 95%CI = 1.37–1.94 and ≥ 100, OR = 1.73, 95%CI = 1.40–2.13). FRI-fatigue ranged from 0.9 to 76.8. When FRI-scores were > 60, nurses were at 1.58 times (95%CI = 1.05–2.37) at increased odds for SA compared to scores in the 0.9–20 category. Nurse leaders can use these decision-support models to adjust high-risk schedules or the number of staff needed to cover anticipated absences from work.

1. Introduction

Sickness absence 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, sickness absence 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, sickness absence 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 et al., 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.

Sickness absence also known as "absenteeism" 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 sickness absences in shift workers (Akerstedt et al., 2007; Bultmann et al., 2013; Janssen et al., 2003). Only a few studies have focused on nurses. One study conducted in Norway measured fatigue subjectively by its physical and mental components, and showed that nurses' elevated physical and total fatigue levels were related to self-reported long-term (> 30 days) sickness absence 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 h shifts found that elevated acute fatigue levels (above one standard deviation), increased the odds for sickness absence by 29% (Sagherian et al., 2017b).

From an occupational standpoint, fatigue is commonly described as an individualized experience of lack of energy or tiredness with physical, cognitive and/or psychological manifestations (Beurskens et al., 2000; Sagherian and Geiger Brown, 2016). This condition that is related with the desire to rest and sleep (Dorrian et al., 2007) can be viewed in terms of acute states or chronic traits. Acute fatigue is short-lived when individuals adjust their tasks or work activities, and attain periods of rest and sleep. On the contrary, chronic fatigue is more of a permanent condition where compensatory mechanisms used in managing acute

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fatigue become ineffective (Beurskens et al., 2000; Winwood et al., 2007).

Fatigue presents 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 and Clarke, 2010; Sagherian et al., 2017a; Scott et al., 2006; Wolf et al., 2017). Most of the fatigue in nurses results from non-standard work schedules and increased temporal and job demands (Akerstedt and Kecklund, 2017; Dorrian et al., 2011; Yuan et al., 2011). While 12-h 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 et al., 2011). A recent Swedish study showed that individuals who worked more than 10 h per shift, had rest periods of less than 11 h between two shifts, worked during the night, or had early day starts closer to 6 a.m., had increased odds of being fatigued when compared with other work schedule characteristics (Akerstedt and 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 review of the literature on fatigue and sickness absence showed that fatigue was consistently assessed via subjective fatigue measures (i.e., survey questionnaires) in workers. While surveys are instrumental in observational and experimental human subject research, they are neither designed nor practical to capture fatigue in day-to-day operations on nursing units. 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 et al., 2011; Lerman et al., 2012; Tucker and Folkard, 2012). Fatigue in these models often means sleep opportunity (Dawson et al., 2017) and is generally defined as a "biological drive to rest and sleep because of a days' work" (Williamson et al., 2011). 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 other 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 et al., 2004; Moore-Ede et al., 2004; Roach et al., 2004); however published data in healthcare workers are scarce. A prospective cohort study by McCormick et al. (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 night-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 a.m. during the night shift, 12-h rather than 24 h 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 and Pinekenstein, 2016).

To date, bio-mathematical fatigue models are rarely used by hospitals despite being user-friendly and commercially available. Although these models have embedded algorithms that aim to evaluate the safety of work settings by predicting incidents/accidents associated with risk of being fatigued during a working shift, they have not been tested or used in relation to sickness absence in healthcare or 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 sickness absence over 18 months of follow-up. We hypothesized that increased fatigue-risk scores will increase nurses' odds of future sickness absence from the workplace. Consequently, this proposed relationship will be an initial step to test the predictive validity of bio-mathematical fatigue models in relation to sickness absence within the healthcare arena, one of the largest 24/7 service industries in the US.

2. Methods

2.1. 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-h shifts. A total of 197 nurses from four nursing units in a mid-Atlantic Metropolitan 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 h 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.

2.2. Measures

2.2.1. Sickness absence

The outcome variable was defined as "being absent from scheduled 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 daily pay codes marked as: SICK, Accrued Sick and Safe Leave Act (ASSLA)-sick, Family Medical Leave Act (FMLA)-sick and 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