# A Feasible Intervention to Reduce Fatigue in Rapidly Rotating Shift Nurses

Mariève Cyr

Department of Psychiatry

McGill University, Montreal

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Abstract

Nearly half of nurses in Canadian hospitals work rotating shifts. Although necessary, shift work is associated with various short- and long-term health consequences such as cancer, cardiovascular disease, and gastrointestinal problems. These negative effects are partly caused by circadian misalignment (i.e., when one's body clock is not aligned with the demands of the environment). While previous research has found that controlling light exposure can improve circadian alignment in individuals working permanent night shifts, light-based interventions are rarely adapted for and tested in rapidly rotating shift workers. In this field study, we developed and tested a light-based intervention to reduce fatigue, errors, and sleepiness in rapidly rotating shift nurses. A total of 33 nurses completed daily self-report measures during two separate weeks: they followed their usual routine during the first week and completed the intervention during the second week. The intervention involved 40 minutes of light exposure from a portable light box before night shifts, light avoidance using sunglasses after night shifts, and suggestions regarding the ideal times to sleep and nap. As predicted, nurses complied with the intervention and experienced reductions in fatigue and work-related errors during the intervention phase. However, their sleepiness was unaffected. Although more controlled studies are needed to assess the long-term efficacy of this intervention, our results suggest that such feasible and cost-effective interventions may help minimize some of the adverse effects associated with working rapidly rotating shifts.

*Keywords:* shift work, rapidly rotating shifts, fatigue, nurses, circadian misalignment, light exposure

Résumé

Près de la moitié des infirmières travaillant dans les hôpitaux canadiens effectuent un travail en rotation. Bien que nécessaire, le travail posté est associé à plusieurs effets néfastes sur la santé, tel le cancer, les maladies cardiovasculaires et les problèmes gastro-intestinaux. Ces conséquences sont partiellement causées par le désalignement circadien (lorsque l'horloge biologique n'est pas alignée avec les exigences de l'environnement). Plusieurs études antérieures ont démontré que l'exposition contrôlée à la lumière peut améliorer l'alignement circadien chez les travailleurs de nuit; ces interventions sont toutefois rarement adaptées et testées auprès des travailleurs effectuant un travail en rotation rapide. Lors de cette étude, nous avons développé et testé une intervention basée sur l'exposition à la lumière afin de réduire la fatigue, les erreurs et la somnolence chez les infirmières qui travaillent en rotation rapide. Au total, 33 infirmières ont complété des questionnaires, matins et soirs, durant deux semaines distinctes: elles ont suivi leur routine habituelle durant la première semaine et ont complété l'intervention durant la deuxième. L'intervention comprenait 40 minutes d'exposition à la lumière avant les quarts de nuit, un évitement de la lumière en portant des lunettes fumées après les quarts de nuit ainsi que des suggestions sur les heures idéales pour dormir et faire une sieste. Comme prévu, les infirmières ont suivi l'intervention et ont noté une réduction de la fatigue et des erreurs au travail durant la semaine d'intervention. Cependant, leur somnolence n'a pas été affectée. Bien que des études plus contrôlées soient nécessaires pour évaluer l'efficacité à long terme de cette intervention, nos résultats suggèrent que de telles interventions réalisables et peu coûteuses peuvent aider à minimiser certains des effets indésirables associés au travail posté en rotation rapide.

*Mots-clés:* travail posté, travail en rotation rapide, fatigue, infirmier(ère)s, désalignement circadien, exposition à la lumière

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Contributions

Two other graduate students (at the time), Jay Olson and Despina Z. Artenie, and I designed the study, obtained approval from the McGill University Health Centre's IRB, recruited and screened participants, collected the data, performed the statistical analyses, and wrote the resulting publication. I wrote the thesis. Jean Nahas, Denis Chmoulevitch, Alice Leclercq, Victoria De Braga, and Claire Suisman helped with data transcription. Dr. Virginia Lee provided overall support and guidance, and helped with the design, recruitment, ethics, and the institutional logistics. Dr. Amir Raz helped with the overall guidance and provided advice for the project.

A Feasible Intervention to Reduce Fatigue in Rapidly Rotating Shift Nurses

Shift work is common among many occupations (Oexman, Knotts, & Koch, 2002; Williams, 2008). For example, healthcare and protective service professions (e.g., nurses, doctors, police officers) require around-the-clock operations; industry workers, truck drivers, miners, and pilots also take part in shift work. In 2005, approximately 28% of Canadian workers did shift work; this comprises permanent evening and night shifts, irregular shifts, on-call jobs, and rotating or split shifts (i.e., a combination of day, evening, and night shifts; Williams, 2008). Since then, shift workers have been growing in numbers as they enable individuals to receive appropriate care and services, and help maintain public safety; their availabilities also benefit industries by fostering economic growth (Oexman et al., 2002). Additionally, working night shifts is often associated with a higher salary, which is attractive for many workers (Culpepper et al., 2010; Oexman et al., 2002). Although shift work is necessary and has some benefits, it is also linked with numerous physical and psychological consequences that can impact workers in both the short and long term.

**Short-term Effects**

One of the main side effects associated with shift work is sleep deprivation (Akerstedt, 1990). Indeed, sleep is affected in the majority of shift workers (Akerstedt, 1988); many experience difficulties sleeping after their night shifts for instance. It is estimated that such disruptions result in up to 4 hours of sleep debt per day (Akerstedt, 1998; Akerstedt, 2003; Akerstedt & Wright, 2009; Juda, Vetter, & Roenneberg, 2013). The sleep quality of shift workers is also often impaired. Studies using EEG have observed disruptions in stage 2 and REM sleep (Akerstedt, 1998). This accumulation of sleep loss during the work week in turn results in a number of negative consequences including increased fatigue and sleepiness, impaired cognitive performance, irritability, mood disturbances, altered appetite, impaired metabolic function, disturbed functioning of the HPA axis, and inflammation (Akerstedt, 1998; Dawson & Reid, 1997; Harrington, 2001; Herman & Cullinan, 1997; James, Honn, Gaddameedhi, & Van Dongen, 2017).

Another important side effect of shift work is fatigue. In fact, it has frequently been cited as one of the main reasons why workers struggle to tolerate shift work (Harrington, 2001). Fatigue is a multifaceted phenomenon which includes emotional, physiological, cognitive, and sensory components, and has been defined as weariness, weakness, and depleted energy (Shen et al., 2006). Studies have shown that fatigue is significantly higher among shift workers than day workers (Yuan et al., 2011). Rotating shift nurses, for example, are at a high risk of developing acute or chronic fatigue (Smith-Miller et al., 2014). In a recent survey, the majority of Canadian nurses reported feeling fatigued “almost always” or “all the time” (Canadian Nurses Association, 2010). Additionally, shift work fatigue is associated with an increased risk of work-related injuries (e.g., needle stick injuries), musculoskeletal disorders, burnout, and employee turnover (Cottini, Kato, & Westergaard Nielsen, 2009; Smith-Miller et al., 2014; Wisetborisut et al., 2014). Given its numerous adverse effects, reducing fatigue in shift workers has become a priority in the healthcare sector. For example, the 2010 report on nurse fatigue and patient safety produced by the Canadian Nurses Association recommends that organizations educate nurses on fatigue management through knowledge of circadian rhythms and sleep. Many other institutions, such as the Institute of Medicine, the Joint Commission, and other professional nursing organizations, have also put forward similar recommendations (Smith-Miller et al., 2014).

An additional side effect of shift work is sleepiness, defined as drowsiness, sleep propensity, and decreased alertness (Shen et al., 2006). Unsurprisingly, working night shifts has been linked to increases in objective and subjective sleepiness at work, particularly in the early morning hours (Akerstedt, 1998; Schweitzer, Muehlbach, & Walsh, 1992; Smith & Eastman, 2012). Many workers even report unintentionally falling asleep at work due to severe sleepiness (Akerstedt, 1988; Gold et al., 1992). In fact, the sleepiness levels recorded in shift workers are similar to those observed in patients suffering from clinical insomnia (Akerstedt, 1998). Such levels of sleepiness further result in lower vigilance, which increases the risk of work-related accidents (Akerstedt & Wright, 2009; Gold et al., 1992; Eastman et al., 1995). Sleepiness can also have a major influence on workers' safety during their commute home; after a night shift, individuals are more likely to engage in drowsy driving—one of the most prevalent causes of preventable road accidents in the world—and to be involved in near-crash driving events (Lee et al., 2016). In a study conducted by Novak and Auvil-Novak (1996), over 95% of the surveyed nurses reported being involved in driving-related injuries and near accidents while commuting from work. Studies additionally indicate that medical residents, who also work rotating schedules, have high rates of fatigue-related motor vehicle accidents (Barger et al., 2005; Kowalenko, Kowalenko, Gryzbowski, & Rabinovich, 2000). Once workers are home, sleepiness continues to be problematic: it is observed on days off and negatively influences workers' daily lives (Akerstedt, 1998). Sleepiness is thus another significant concern for shift workers.

In addition to putting workers at risk, shift work fatigue and sleepiness can compromise public safety. Both phenomena are associated with slower reaction time, decreased short-term memory, impaired cognitive processing and problem-solving abilities, and increased variability in work performance (Akerstedt, 1998; Harrington, 2001). In hospital settings, these in turn lead to increased work-related errors, near-errors, and falls, as well as irregular monitoring and assessment of patients (Canadian Nurses Association, 2010; Kenyon, Gluesing, White, Dunkel,

& Burlingame, 2007; Smith-Miller et al., 2014). Indeed, nurse fatigue was found to be one of the three main causes of medication errors and has also been linked with increased errors of omission; that is, failing to provide appropriate care such as forgetting to ambulate a patient (Kalisch & Xie, 2014; Kenyon et al., 2007; Mayo & Duncan, 2004). Moreover, shift work has been linked with workplace inefficiency (Harrington, 2001). Nurses working rotating shifts, for instance, report lower job performance than daytime workers (Coffey, Skipper, & Jung, 1988). As a result, such effects increase the financial burden of institutions. In 1999, it was estimated that medical errors alone costed between $17 and $29 billion annually to American hospitals (Thomas et al., 1999); this number is likely even greater today. A more recent study estimated the annual cost of fatigue-related productivity loss to be nearly $2000 per employee (Rosekind et al., 2010). Minimising the side effects associated with shift work is thus also beneficial from a financial perspective.

**Long-term Effects**

In the longer term, shift work is associated with even greater adverse effects for workers. These include an increased risk of cardiovascular disease, ischemic stroke, compromised immune function, metabolic syndrome, obesity, alterations in the composition of the gut microbiome, gastrointestinal tract dysfunction, Type II diabetes, altered cellular metabolism, and increased DNA damage (James et al., 2017**)**. Shift work is also associated with complications during pregnancy (i.e., spontaneous abortion, low birth weight, and prematurity) as well as an increased risk for cancer; it is considered a probable carcinogen by the World Health Organization (Harrington, 2001; James et al., 2017; Straif et al., 2007). Additionally, shift work has been associated with mental health problems such as anxiety, depression, and increased neuroticism (Harrington, 2001; James et al., 2017).

**Circadian Misalignment**

Many of these negative consequences have been linked to the disruption of shift workers' circadian rhythms (Minors and Waterhouse, 1981; Moore-Ede, Czeisler, & Richardson, 1983). Circadian rhythms are approximately 24-hour physiological rhythms that are endogenously generated in mammals, including humans. These rhythms regulate various internal processes such as hormone production (e.g., melatonin), cell division, body temperature, alertness/sleepiness, brain activity, feeding patterns, and more (Harrington, 2001). Interestingly, alertness, which is linked with the release or suppression of melatonin, and performance efficiency run in parallel with the circadian rhythm of body temperature (Akerstedt & Gillberg, 1982). As a result, body temperature is often used as an indicator of one's circadian phase. In individuals who follow a regular day schedule, body temperature and alertness typically reach their minimum (Tmin) between 4:00 AM and 6:00 AM (Akerstedt, 1988; Mitler et al., 1988). However, when individuals engage in shift work, their working, sleeping, and eating patterns are altered and no longer align with their circadian rhythms; this is known as circadian misalignment and is associated with the previously discussed adverse health and performance outcomes.

**Circadian Modulation**

Fortunately, decades of research have demonstrated that circadian rhythms can be modulated by various exogenous elements or "zeitgebers" (Eastman, 1990). These zeitgebers include the light-dark cycle, which typically results from the presence or absence of sunlight, as well as other elements such as the sleep-wake cycle and one's lifestyle (e.g., social and work-related activities; Harrington, 2001). In most animals, the light-dark cycle is the strongest zeitgeber (Moore-Ede et al., 1982); in other words, manipulating the light-dark cycle is one of the most effective ways of shifting circadian rhythms in the desired direction. Studies have shown that bright light exposure specifically is key; indeed, only very bright light (> 2500 lux) can fully suppress the nocturnal secretion of melatonin, and thus modulate the rhythms that influence alertness and sleep **(**Lewy, Wehr, Goodwin, Newsome, & Markey, 1980; Thorington, 1985). In fact, the sleep-wake cycle is strongly linked to the melatonin one (Zisapel, 2001). For example, individuals' propensity to fall asleep at night typically occurs approximately 2 hours after the onset of melatonin production in the brain (Lavie, 1997; Zisapel, 2007). Melatonin levels also tend to be elevated during the night and lower during the day (Zisapel, 2018). As melatonin acts as an endogenous sleep regulator, suppressing its production via bright light exposure can thus alter sleep onset (Zisapel, 2018).

The timing of bright light exposure is very important as it will determine the direction of the shift: in general, light in the morning, after the Tmin, advances circadian rhythms (i.e., the Tmin will occur earlier during the night), light in the middle of the day has little effect, light in the evening delays circadian rhythms (i.e., the Tmin will occur later during the night), and light in the middle of the night, right before the Tmin, elicits the largest delays (De Coursey, 1960; Pittendrigh, 1981). Theoretically, individuals who work night shifts would benefit from delaying their circadian rhythms in order to push their Tmin (and peak sleepiness) later in the morning, outside of their work hours and during their sleep episode (Smith & Eastman, 2012). Conversely, individuals who rotate back to day shifts, after a set of night shifts, would benefit from advancing their rhythms. In optimal conditions, when both light-dark and sleep-wake cycles were absolutely controlled, Wever, Polasek and Wildgruber (1983) were able to shift individuals' circadian rhythms by roughly 6 hours per day. In more typical conditions, circadian rhythms can shift by approximately 1 to 4 hours per day, with most individuals shifting by 1 to 2 hours per day (Eastman, 1990; Smith & Eastman, 2012). However, abrupt changes in environmental demands, such as when travelling across time zones or working rotating shifts, lead to slower shifts in circadian rhythms (Aschoff, Hoffmann, Pohl, & Wever, 1975). This, in turn, may limit the potential for circadian alignment or partial alignment in rapidly rotating shift workers. Notably, evidence also suggests that delaying circadian rhythms is typically easier than advancing them (Eastman, 1990). This has led to recommendations regarding more adaptive shift schedules such as transitioning from day shifts to evening shifts to night shifts for example (Eastman, 1990; Smith & Eastman, 2012).

**Permanent Night Shift Work**

Laboratory and field studies focusing on permanent night shift workers further demonstrate that it is possible to manipulate workers' circadian rhythms via timed bright light exposure and avoidance; this enables workers to better align their circadian rhythms with the demands of their work schedules and, thus, minimise the adverse effects associated with circadian misalignment. Some studies have shown that bright light exposure during night shifts (e.g., using a portable light box), light avoidance after night shifts (e.g., wearing sunglasses during the commute home), and sleeping in on days off can reduce fatigue (Waterhouse, Reilly, Atkinson, & Edwards, 2007), and improve sleep quality and performance at work (Smith, Fogg, & Eastman, 2009). For example, Eastman and colleagues (1994) studied 50 healthy subjects who took part in eight consecutive 8-hour simulated night shifts (2:30 AM to 10:30 AM). Half of the group was exposed to bright light (≈ 5000 lux) during the first 6 hours of the first two night shifts (using light boxes and a ceiling fixture), whereas the other half was only exposed to dim light (< 500 lux). To block light in the morning, half of each group wore welder's glasses (black opaque frames, 1% transmission in baseline, 0.35% transmission in intervention) when going outside. Participants also spent 8 hours in bed in a dark room (windows covered with black plastic) exactly 2 hours after the end of each simulated night shift. Participants were only allowed caffeine during the first 4 hours after waking. Their results indicate that using bright light exposure at night in combination with bright light avoidance in the morning elicited the largest total phase shift (*M* = 7.9 hours) as measured by body temperature. On the other hand, participants in the dim light and no goggle condition experienced the smallest total phase shift (*M* = 3.2 hours). The results also indicate that delays in circadian phase did not occur in participants who did not wear the light-blocking goggles. Further, participants who experienced the largest delays in circadian phase reported longer sleep durations, more vigor, lower fatigue levels, and less overall mood disturbances. The authors thus concluded that combining bright light during the first few night shifts and light avoidance during the "travel-home window" is most effective at shifting circadian rhythms. Further, starting the light and dark manipulations before the first night shift can increase the associated benefits. Finally, comparing their findings to a previous study in which participants received bright light during 8 or more night shifts and also used goggles, they concluded that bright light exposure during a larger number of night shifts elicits larger circadian phase shifts.

In a subsequent study, Eastman, Liu and Fogg (1995) compared the effects of bright light duration (6, 3, and 0 hours) on circadian phase shift, fatigue, sleep, vigor, and mood. Their results indicate that 6 hours and 3 hours of bright light exposure during night shifts led to similar changes in circadian phase whereas individuals who were not exposed to bright light experienced significantly smaller phase shifts. Consistent with the findings of the previously discussed study, larger phase shifts correlated with less fatigue, longer sleep duration, more vigor at work, and reduced mood disturbances. The authors thus concluded that shorter durations (≈ 3 hours) of nocturnal bright light exposure can also elicit meaningful circadian phase shifts and that large phase shifts can minimise the detrimental effects of shift work. They additionally concluded that little effect is expected if light exposure takes place too far from participants' Tmin. Since then, several other studies have also demonstrated the effectiveness of sustained and intermittent bright light exposure during night shifts, light avoidance during the commute home, and dark sleeping environments in shifting the circadian rhythms of permanent night shift workers (Boivin & James, 2002; Eastman et al., 1994; Martin & Eastman, 1998; Smith & Eastman, 2012).

**Rotating Shift Work**

Although the effectiveness of such circadian-based and sleep hygiene interventions is well established for permanent night shift workers, many shift workers rotate between day, evening, and night shifts. Indeed, nearly half (48%) of Canadian nurses who work in hospital settings report working rotating shifts (Shields & Wilkins, 2006). More recent studies have investigated the effectiveness of circadian-based interventions in rotating shift workers; the available evidence suggests that rotating shift workers may also benefit from implementing sleep hygiene and circadian principles into their daily routine. For example, in a study conducted by Boivin and colleagues (2012), 16 police officers working rotating shifts, including 7 consecutive night shifts, followed a circadian-based intervention. They were exposed to intermittent bright light during the first 6 hours of their night shifts (using portable light boxes), wore orange-tinted glasses from sunrise until the start of their daytime sleep period, and slept in dark environments (opaque material covered their bedroom windows). The authors reported that participants who followed the intervention experienced larger phase delays than those who did not, though only partial circadian alignment was observed. Participants who followed the intervention were also more alert. Another study, focusing on rotating shift nurses suffering from clinical insomnia, demonstrated that short durations ($\geq$ 30 minutes) of intense bright light (7000–10,000 lux) exposure during the first half of night/evening shifts combined with light attenuation in the morning can improve insomnia, depression, and anxiety (Huang, Tsai, Chen, & Hsu, 2013).

Other interventions for shift workers based on improving sleep hygiene (e.g., sleeping in a dark and quiet environment) as well as other fatigue countermeasures have also resulted in similar benefits (Bonnet & Arand, 1994; Ker, Edwards, Felix, Blackhall, & Roberts, 2010; Schweitzer, Randazzo, Stone, Erman, & Walsh, 2006; Walsh et al., 1990). For example, a study by Scott and colleagues (2010) demonstrated that using fatigue countermeasures such as napping before night shifts and on breaks, drinking coffee to maintain alertness, and maximising sleep duration on days off can result in increased sleep duration, sleep quality, and alertness in nurses working rotating shifts.

However, the studies discussed above (and those found in the literature) do not necessarily apply to shift workers who rotate rapidly between day shifts and night shifts (e.g., 3 night shifts, 2 days off, 3 day shifts) as is common for many shift workers in hospital settings (Smith & Eastman, 2012). Very few studies have tested circadian-based interventions in rapidly rotating shift workers as experts in the field suggest that it is not possible to improve circadian alignment in such workers. For example, in a recent review, Smith & Eastman (2012) stated that there was “no way to reduce circadian misalignment for a rapid rotation that includes both night shifts and day shifts” and that this type of rotation “should be abolished” given its effects on performance, safety, and health. Still, many shift workers continue to work rapidly rotating shifts; thus, we believed it would be worth attempting to alleviate some of the side effects of circadian misalignment using the principles discussed earlier.

**Feasibility**

In addition to the paucity of studies on rapidly rotating shift workers, for the most part, previous studies present interventions that are not feasible in many work settings (e.g., controlled light exposure in the workplace) or would require major institutional changes (e.g., modifying scheduling practices, providing adequate staffing to allow workers to take breaks, and providing sleeping accommodations). In the case of nurses for example, napping during 2 hours at night to reduce sleepiness (Matsumoto & Harada, 1994) or receiving 3 hours of bright light exposure at work may interfere with patientcare and disrupt the sleep of patients. Indeed, at night, nurses often work in dim light conditions to allow patients to sleep (Nilsson, Campbell, & Andersson, 2008); bright light exposure is thus less feasible unless it occurs in an isolated area (e.g., a break room). However, nurses are typically assigned more patients during night shifts relative to day shifts and often do not leave the bedside to take breaks (Kemp, 1984; Sarna et al., 2009). It is thus unlikely that nurses would be able to receive multiple hours of bright light exposure during their night shifts. Further, the glasses used in previous studies (e.g., welder's goggles) to prevent morning light exposure are typically bulky and odd-looking, making it improbable for nurses to wear them outside of a study setting. Finally, because "top-down" (administrator- or management-driven) approaches are often slow and expensive (Mistlberger, 2004), we wanted to develop a feasible intervention that would not require any institutional buy-in nor impede on participants' work responsibilities. We hoped that such "bottom-up" (end-user driven) approaches would help nurses take control of their own fatigue and foster uptake.

**Knowledge Translation**

Shift workers typically receive little or no training on circadian rhythms or general fatigue management. In 2004, Mistlberger conducted a survey of 178 organisations in British Columbia and concluded that 82% of the organisations provided no training on how to cope with shift work; the remaining 18% generally gave a single training session or infrequent workshops.

Similarly, in a recent survey from the Canadian Nurses Association, less than 10% of the 6,000 nurses reported that their institution had procedures to address fatigue (Canadian Nurses Association, 2010). We thus wanted to create a simple intervention based on principles that would be easy to disseminate in order to eventually contribute to the implementation of circadian-based knowledge into practice.

**Goal**

As a result, the goal of this study was to improve knowledge translation of circadian rhythms research by (1) developing a feasible and scalable intervention to reduce fatigue, sleepiness, and work-related errors among rapidly rotating shift workers and (2) collect initial evidence regarding its effectiveness and feasibility in a field study of rapidly rotating shift nurses. We chose to focus on nurses as they work in environments that are not typically conducive to previously validated interventions, they commonly rotate rapidly between day, evening, and night shifts, and their work directly impacts the safety of the public.

As part of a larger project, we were also interested in assessing the effects of our intervention on participants' sleep quality, duration and latency, as well as their mood. However, these outcomes will not be discussed in the context of this thesis but are available in the published article (Olson et al., 2020).

**Hypotheses**

We had three primary outcomes and two secondary outcomes. The primary outcomes included fatigue, sleepiness, and work-related errors; the secondary outcomes included compliance and feasibility. Consistent with the literature, we expected that nurses would experience improvements in all primary outcomes when they followed our intervention relative to when they did not. Specifically, we expected reductions in fatigue, sleepiness, and work-related errors during the intervention phase relative to the baseline observation phase. Further, we expected high compliance with the intervention and its individual components. We also expected that participants would find our intervention feasible.

# Methodology

**Participants**

Participants were recruited from three units (Intensive Care, Emergency Room, and Internal Medicine) of the Montreal General Hospital (MGH) and the Glen site of the McGill University Health Centre (MUHC). We first received permission from the Director of Nursing and the Associate Directors of Nursing at the MUHC to recruit nurses working in their hospitals. The Nurse Managers of each unit posted recruitment posters (see Appendix 1) on their unit (e.g., at the nurse station) and emailed them to their nurses. We also gave a total of 12 recruitment presentations to small groups of nurses on the units. We additionally presented the study during two nurse education days to facilitate recruitment. In total, 65 nurses contacted us to take part in the study.

All prospective participants first completed a phone screening with a research assistant. Nurses included in the study worked full-time or part-time (i.e., at least 60% of a full-time workload), worked rotating schedules with 2 to 4 consecutive night shifts, worked directly with patients (e.g., Nurse Managers were not eligible), had worked at the same hospital for at least 6 months, owned a smartphone, and were between 18 and 65 years old.

We excluded nurses who did not meet our inclusion criteria ($n$ = 6) as well as one nurse who may have experienced an adverse reaction to the light exposure due to a sun allergy. We also excluded nurses who had been diagnosed with a sleep disorder ($n$ = 5), had been diagnosed with medical or psychological conditions or took medication that could influence fatigue (n =

10), had been involved in a car accident or near-accident related to fatigue (n = 3), had experienced an acute stressor (e.g., divorce or the death of a loved one) within the past 12 months or anticipated one in the upcoming weeks (*n* = 1; since increases in psychological stress levels have been shown to influence fatigue; Pawlikowska et al., 1994), had travelled across multiple time zones in the past 4 weeks (*n* = 0; to minimise the influence of additional circadian disruptions; Waterhouse et al., 2007), or had donated blood within the previous week (*n* = 0; since donating blood may also influence fatigue levels; Nilsson Sojka & Sojka, 2003). Further, we excluded nurses who could potentially experience unintended consequences of the light exposure or intervention (e.g., increases in fatigue): specifically, nurses who were pregnant or breastfeeding, or intended to get pregnant during the study (*n* = 3), since higher fatigue levels during pregnancy have been associated with a higher probability of caesarean deliveries as well as higher rates of anxiety and premature births (Chien & Ko, 2004; Hall et al., 2009; Mamelle, Laumon, & Lazar, 1984). We also excluded nurses who had glaucoma (*n* = 1), retinopathy, or cataracts. Finally, two participants dropped out of the study due to personal reasons prior to the beginning of the baseline phase.

A total of 33 participants completed both the baseline and the intervention phase; there was no additional attrition. Participants were evenly distributed across hospitals (Glen site: *n* = 16; MGH: *n* = 17), were mostly women (76%) and were between 22 to 58 years old (*M* = 32.8, *SD* = 8.5). Detailed participant demographics are reported in Table 1.

## Procedure

**Intervention Development.** The first step in conducting this study was to develop the fatigue-reduction intervention for nurses. We conducted a literature review of field and laboratory-based interventions aimed at reducing fatigue and outcomes associated with fatigue,

Table 1

*Participant Characteristics at Baseline*

| Demographics | M (SD) / n (%) |
|---|---|
| N | 33 |
| Age | 32.73 (8.59) |
| Sex (female) | 76% |
| Years nursing | 7.67 (7.30) |
| Job satisfaction (1 to 7) | 5.73 (0.45) |
| Drive to work (yes) | 58% |
| Exercise per week (days) | 2.73 (1.91) |
| **Fatigue (MFI)** | **M (SD)** |
| General (4 to 20) | 13.09 (2.90) |
| Physical (4 to 20) | 16.06 (2.76) |
| Motivation (4 to 20) | 16.67 (2.16) |
| Activity (4 to 20) | 16.36 (2.43) |
| Mental (4 to 20) | 14.61 (3.91) |
| **Stress (PSS)** | **M (SD)** |
| Stress (0 to 40) | 13.73 (5.41) |
| **Workload (NASA-TLX)** | **M (SD)** |
| Mental (5 to 100) | 78.33 (20.72) |
| Physical (5 to 100) | 63.26 (24.13) |
| Temporal (5 to 100) | 71.14 (19.52) |
| Performance (5 to 100) | 36.67 (24.23) |
| Effort (5 to 100) | 65.61 (19.72) |
| Frustration (5 to 100) | 48.49 (23.86) |
| **Chronotype (MEQr)** | **M (SD)** |
| Chronotype (4 [evening] to 25 [morning]) | 14.49 (3.50) |
| **Menstruation** | **M (SD) / n (%)** |
| Regular | 71% |

| | |
|---|---|
| Cycle length (days) | 31.18 (15.83) |

*Note*. Fatigue was measured using the Multidimensional Fatigue Inventory (MFI); stress was measured using the Perceived Stress Scale (PSS); workload was measured using the NASA Task Load Index (NASA-TLX); and chronotype was measured using the Reduced Morningness-Eveningness Questionnaire (MEQr).

such as circadian alignment, sleep duration, alertness, and work performance, using timed bright light exposure. This was completed using academic search engines including PubMed and Google Scholar. Key search words included “shift work”, “light exposure”, “nurse fatigue”, “circadian rhythms”, and “sleep hygiene” among others. We initially reviewed a total of 34 related laboratory studies, 24 field studies, and 3 systematic reviews, ranging from 1989 to 2017, focusing on techniques that have been shown to effectively improve circadian alignment, sleep quality, latency and duration, and other consequences associated with working night or rotating shifts. We focused on light intensity, timing, and duration of exposure, timing and duration of light avoidance, timing and duration of naps, and sleep hygiene recommendations. We then synthesised the literature into a set of feasible evidence-based suggestions that could be applied to varying shift schedules.

**Study Design.** To gather initial evidence regarding the effectiveness and feasibility of our intervention, we completed a field study with rotating shift nurses. We used a within-participants design in which all participants completed a baseline observation phase followed by an intervention phase. Both phases of the study lasted approximately one week, including 2 to 4 consecutive night shifts as well as the 1 or 2 days before and after those night shifts. The phases were completed non-consecutively, with a minimum of one week between each phase. The timing of the phases was determined in collaboration with each participant to ensure they had the same work schedule during both phases (i.e., the same number of night shifts and days off). During each phase, participants completed questionnaires assessing fatigue, sleepiness, and caffeine and alcohol consumption on their smartphones every morning and evening. On work days, they also reported work-related errors, sleepiness during the night shift, overtime, and level of physical activity (using a pedometer). During the intervention phase, nurses additionally reported compliance for each component of the intervention (e.g., light exposure, sunglasses). The study was approved by the Research Ethics Board of the McGill University Health Centre.

After the initial phone screening and before the beginning of the baseline observation phase, eligible participants individually met with a research assistant to sign the consent form and complete 5 paper-and-pencil questionnaires assessing individual differences (i.e., demographics, fatigue, stress, workload, and chronotype; see "Measures of Individual Differences"). After completing the questionnaires, nurses were told that they would receive a text message containing a link to an online questionnaire every morning (7:30AM) and evening (6:30 PM) of the baseline phase. These times coincided with nurses' work schedules since 12-hour night shifts began at 7:30 PM and ended at 7:30 AM. Thus, data collection did not interfere with their work. Further, nurses were instructed to complete the morning questionnaires when they naturally woke up on days off. In total, the questionnaires required 10 to 15 minutes per day. Nurses also received a pedometer; they were instructed to wear it during their night shifts and to report their step count in the appropriate section of the daily questionnaires. Finally, each nurse received a practice online questionnaire to complete the night before the beginning of the baseline observation phase. This first meeting took place in participants' respective workplace, before or after a work shift and lasted approximately 30 minutes.

After the end of the baseline phase (but prior to the intervention phase), a research assistant met with each nurse to provide partial compensation ($60), instructions regarding the intervention phase, and the required materials. Participants received a personalised fatigue-reduction plan, which was tailored to their specific work schedule, as well as a portable light box and a sleep mask. The researcher then explained the fatigue-reduction plan to the participants, answered any questions they may have had, and instructed them to follow the recommendations as closely as possible while making accommodations for their own lifestyle (e.g., taking their kids to school after a night shift). To ensure appropriate use of the light box, the researcher demonstrated it to each nurse. Finally, nurses were asked to complete the online questionnaires and to wear the pedometer as they did during the baseline phase.

After the intervention phase, a research assistant individually met with participants to complete the post-intervention questionnaire and to provide the final compensation ($80). In total, nurses received $140 in compensation.

**Materials**

**Fatigue-Reduction Plan.** The fatigue-reduction plans were based on the guidelines we isolated from the literature review which we then tailored to each nurse's specific shift schedule (see Appendix 2 for an example). The plans suggested ideal times to seek bright light (using the portable light box), avoid light (using their own sunglasses and curtains), and sleep (wearing the sleep mask). Specifically, to boost alertness (Badia et al., 1991; Daurat et al., 1993) and to promote circadian phase delay (Badia et al., 1991; Daurat et al., 1993), we recommend seeking 40 minutes of bright light exposure as late as possible before each night shift (e.g., 6;15 PM) as well as in the evening (e.g., 10 PM) of the day before the first night shift. We recommended 40 minutes to ensure a minimum of 30 minutes of exposure since this duration (with a similar light intensity) has been shown to improve sleep and mood in nurses who do shift work (Huang, Tsai, Chen, & Hsu, 2013). To further promote circadian phase delay (Smith & Eastman, 2012) and improve sleep (Sasseville, Benhaberou-Brun, Fontaine, Charon, & Hébert, 2009), we suggested avoiding light as soon as possible after night shifts using dark sunglasses (except after the final night shift), during the return home (except when driving), and closing the curtains when arriving home and until bedtime. To promote sleep quality (Smith & Eastman, 2012) and duration (Åkerstedt and Wright, 2009; McKenna & Wilkes, 2018), we recommended waking up later in the morning the day before the first night shift, going to bed as soon as possible after night shifts, sleeping as long as possible during the day (except after the final night shift), and sleeping in a dark and quiet environment. As noted, exceptions were made after the final night shift to facilitate the transition back to a day-oriented schedule (Smith & Eastman, 2012) and when driving to minimise safety risks (Weisgerber, Nikol, & Mistlberger, 2017).

**Light Box.** To seek bright light exposure, participants were provided with a portable light box (TRAVelite Desk Lamp, Northern Lights Technologies, Inc., QC, Canada). The light box nominally emits 10,000 lux (25–30 cm away from the eye) and has the following dimensions: 34 x 20 x 6 cm. We instructed participants to place the light box within one arm's length away from them (approximately 60 cm), pointing towards their face, but without looking directly at the light. Following these instructions resulted in a light intensity of approximately 5,500 lux as measured by a light meter (Universal Photometer, Optikon Corp. Ltd., ON, Canada). This illuminance is comparable to the light levels used in similar interventions (Bjorvatn et al., 2007; Boivin, Boudreau, James, & Kin, 2012; Kakooei et al., 2010). To promote compliance, nurses were reminded two hours before the beginning of their night shift, via a text-message, to seek bright light exposure. In the morning questionnaires, participants were asked to report whether they used the light box before their night shift, the times at which they began and finished using the light box, and their distance from the light box (i.e., under 30 cm, 30 to 60 cm, 60 to 100 cm, or over 100 cm); this allowed us to track compliance.

**Sunglasses.** To avoid light, participants were instructed to wear their darkest pair of sunglasses; we provided a pair to one participant who did not own sunglasses. Although this prevented us from controlling the quality of the sunglasses, it likely increased the feasibility of this recommendation and compliance. In the evening questionnaires, participants were asked to report whether or not they wore their sunglasses in the morning after their night shift.

**Sleep Mask.** To maximise the darkness of the sleep environment, participants were provided with a sleep mask (Ultralight Comfortable 3D Contoured Eye Blindfold, JJ Autumn, USA). They were instructed to wear it when sleeping, but to remove it if it impaired their sleep in any way. In the evening questionnaires, participants were also asked to report whether or not they wore their sleep mask.

## Measures of Individual Differences

Participants completed the following paper-and-pencil questionnaires during the first meeting (see Appendix 3).

**Demographics.** To collect demographic information, we designed a 22-item questionnaire focusing on basic demographics (e.g., age, sex, marital status, children), work-related demographics (e.g., job satisfaction, work experience, commute time), and lifestyle demographics (e.g., exercise, smoking). The job satisfaction item was derived from the Job Satisfaction Scale (Warr, Cook, & Wall, 1979) and is considered a valid and reliable measure of overall job satisfaction (Dolbier, Webster, McCalister, Mallon, & Steinhardt, 2005). Other items were derived from previously used demographic questionnaires and chosen based on their potential link with fatigue.

**Fatigue.** To measure individual levels of fatigue, participants completed the Multidimensional Fatigue Inventory (MFI; Smets, Garssen, Bonke, & De Haes, 1995). This 20-

item measure assesses five dimensions of fatigue: general fatigue (e.g., “I feel tired”), physical fatigue (e.g., “Physically, I feel only able to do a little”), reduced motivation (e.g., “I dread having to do things”), reduced activity (e.g., “I get little done”), and mental fatigue (e.g., “It takes a lot of effort to concentrate on things”). All items are rated on a 5-point Likert scale ranging from 1 (“No, that is not true”) to 5 (“Yes, that is true”). Participants were asked to rate the degree to which each statement applied to them “lately”. Total scores are computed for each subscale and range from 4 to 20; higher scores designate higher levels of fatigue. This questionnaire generally has good internal consistency (average Cronbach’s $a$ = .84; Smets et al., 1995), though it was higher in our sample ($a$ = .88).

**Stress.** To measure individual levels of stress, participants completed the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). This 10-item questionnaire assesses the frequency with which each statement applied to participants in the past month. Example items include the following: “In the last month, how often have you found that you could not cope with all the things that you had to do?” and “In the last month, how often have you felt that you were unable to control the important things in your life?”. All items are rated on a 5-point Likert scale ranging from 0 (“Never”) to 4 (“Very Often”). A total score is computed for the scale and ranges from 0 to 40; higher scores designate higher levels of stress. The internal consistency of this validated scale generally ranges from fair to good (Cronbach’s $a$ = .74 to .91; Lee, 2012) and was considered good in our sample ($a$ = .81).

**Workload.** To measure individual levels of perceived workload, participants completed the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988). This 6-item measure has previously been used with nurses (Hoonakker et al., 2011; Young, Zavelina, & Hooper, 2008) and assesses six dimensions of perceived workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. Sample items include the following: "How physically demanding was the task?" and "How successful were you in accomplishing what you were asked to do?". All items are rated on a 20-point scale ranging from 0 ("Very Low") to 100 ("Very High"). Participants are asked to rate their experience of a specific task; in this case, nurses were instructed to reflect on their job in general. A total score is computed for this index and ranges from 30 to 600; higher scores designate higher perceived workload. This index generally has good test–retest reliability (r = .77; Hoonakker et al., 2011) and fair overall internal consistency (*a* = .72; Hoonakker et al., 2011), though it was considered good in our sample (*a* = .81).

**Chronotype.** To assess chronotype, the preference for mornings (i.e., morning birds) versus evenings (i.e., night owls), participants completed the Reduced Morningness-Eveningness Questionnaire (MEQr; Adan & Almirall, 1991). This 5-item measure classifies chronotype along a morningness dimension. Sample items include the following: "Approximately what time would you get up if you were entirely free to plan your day?" and "At approximately what time of day do you usually feel your best?". For each item, participants selected the answer, among the 4 or 5 options available, that best reflects them. A total score is computed and falls within one of the following categories: "definitely evening type" (4–7), "moderately evening type" (8–11), "neither type" (12–17), "moderately morning type" (18–21), and "definitely morning type" (22–25). This questionnaire generally has good external validity (Natale et al., 2006) and fair internal consistency (*a* = .70; Chelminski, Petros, Plaud, & Ferraro, 2000), though it was lower in our sample (*a* = .52).

**Menstrual Cycle.** Since menstrual cycle phase can affect sleep quality and fatigue (Baker & Lee, 2018), female participants completed 3 items of the Indices of Estrogen Exposure questionnaire (Lord, Duchesne, Pruessner, & Lupien, 2009) on the first day of the baseline and intervention phase of the study. The full 13-item questionnaire assesses four elements that can influence lifelong estrogen exposure: menstrual cycle, motherhood, menopause, and hormone therapy. We selected the 3 items that were relevant to our study (i.e., those assessing regularity and length of the menstrual cycle, and number of days since onset of the last menstruation).

**Daily Measures**

Participants completed the following daily measures directly on their smartphones every morning and evening during the baseline and intervention phase (see Appendix 4).

**Fatigue.** To measure daily fatigue, defined as a feeling of physiological or pathological strain or exhaustion (Piper et al., 1989), participants completed the Daily Fatigue Short Form (Christodoulou, Schneider, Junghaenel, Broderick, & Stone, 2014). This 7-item questionnaire has been validated in multiple populations, including healthy and clinical ones (Christodoulou et al., 2014). Items relate to participants' feelings in the previous day (e.g., "In the last day, how often did you feel tired?"), but were modified to say "In the last 12 hours, …" since participants had to complete the questionnaire twice per day. All items are rated on a 5-point Likert scale ranging from 1 ("Never") to 5 ("Always"). A total score is computed and ranges from 7 to 35; higher scores designate higher fatigue levels. This scale generally has good reliability ($a > .90$; Christodoulou et al., 2014) and it was similar in our sample ($a = .92$).

**Sleepiness.** To measure state sleepiness—the increased propensity to fall asleep (Curcio, Casagrande, & Bertini, 2001)—participants completed the Karolinska Sleepiness Scale (Akerstedt & Gillberg, 1990). This single-item scale correlates with objective measures of sleepiness (i.e., physiological and behavioural) and has been used extensively in shift work and sleep studies (Akerstedt, Anund, Axelsson, & Kecklund, 2014). Participants were asked to rate their current sleepiness (“in the pas five minutes”) using a 9-point Likert scale that ranges from 1 (“Extremely alert”) to 9 (“Very sleepy, great effort to keep awake, fighting sleep”). Higher scores designate high levels of sleepiness.

On work days, nurses were also asked to complete this questionnaire during their night shift (in addition to completing it in the morning and evening). To minimise interferences with nurses’ work, they were instructed to complete it at any point during their shift (e.g., during a break), after having received the online link. They received the questionnaire at 2:00 AM during 8-hour shifts and at 12:00 AM during 12-hour ones. We excluded the sleepiness measure that participants completed during their night shifts from the analyses because nurses completed the questionnaire at very different times each night (e.g., 1:00AM and 6:00AM), making it impossible to assess variations in state sleepiness during night shifts.

**Work-related Errors.** To assess work-related errors or near-errors, participants were asked to report any errors or near-errors they made at work after every night shift. Based on a previous study, work-related errors were defined as “any perceived variation from current standards of practice” (Scott, Rogers, Hwang, & Zhang, 2006). For each error or near-error, participants were asked to report the approximate time of occurrence, the type (medication, transcription, charting, procedural, slip/fall, or other), and the degree of severity (minor, moderate, serious); they were also asked to include a brief description (Dorrian et al., 2006). Such error reports have been shown to be as accurate or potentially more accurate than typical incidence reports (O’Neil et al., 1993).

**Caffeine and Alcohol Consumption.** To track caffeine and alcohol consumption, participants reported the number of “cups/drinks” of coffee, caffeinated tea, cola drinks, energy drinks, and alcohol drinks they consumed in the previous 12 hours. These questions were also taken from a validated daily logbook (Rogers, Hwang, & Scott, 2004).

**Level of Physical Activity.** To estimate nurses' physical activity levels at work, nurses were asked to wear a pedometer and report their step count at the end of each night shift. However, we excluded this measure from the analyses as the pedometer was often reset, dropped (and broken), or forgotten. Complete data was only obtained from one participant. Thus, this measure was deemed unreliable and was excluded from the analyses.

**Overtime.** To assess paid and unpaid overtime, participants were asked to answer the following question after every night shift: "How much overtime did you work?". Participants selected an answer among 15-minute intervals ranging from "none" to "more than 4 hours". This item was taken from a previously validated logbook (Rogers et al., 2004).

**Final Measure**

**Post-intervention Questionnaire.** To assess the feasibility, effort, ease of implementation, and perceived effectiveness of the fatigue-reduction intervention, participants completed a post-intervention questionnaire (see Appendix 5). In this 37-item questionnaire, participants rated the intervention globally as well as each of the individual components (e.g., sunglasses) on a 7-point Likert scale ranging from 1 (e.g., "not at all feasible") to 7 (e.g., "very feasible"). The final 7 items were open-ended questions regarding the easiest and hardest components of the intervention, potential impacts of the intervention on nurses' personal and work life, suggested improvements, and whether nurses experienced any difficulties adjusting back to day shifts. Participants were asked to verbally explain their reasoning for each answer and a research assistant noted their exact explanations. This served as the basis for a semistructured interview in which nurses were encouraged to share their thoughts regarding the intervention and study generally; this allowed us to gather additional qualitative data.

**Statistical Analyses**

**Data Cleaning and Transformations.** First, we visually checked the data for extreme scores and impossible values. Duplicate entries of the online questionnaires (e.g., if the participant clicked the "submit" button twice) were removed (4% of the submissions). We only included the first submission of each questionnaire in the analyses. We also excluded data from questionnaires that were submitted over one hour before the submission time, as this was likely a participant error (0.31% of the data). We excluded state measures of fatigue and sleepiness that were submitted over 6 hours after the questionnaires were sent to participants (6.23% of the data); we excluded measures of errors, and caffeine and alcohol consumption that were submitted over 24 hours late (0.52% of the data). Both cut-off times were determined to allow participants who worked overtime to complete the questionnaires after the end of their shift (e.g., 4 hours later than expected) while minimising the risk of recall bias (e.g., recalling how sleepy they felt 10 hours earlier). In total, we thus excluded 7.06% of the submitted data.

We then transformed the remaining data for fatigue and sleepiness into normalised data to control for individual differences before the beginning of each set of night shifts. For each participant, day, and phase (i.e., intervention or baseline), we subtracted the average morning and evening scores during the two days before the first night shift from the corresponding values on the rest of the days. For participants who only had one day before their first night shift, the morning and evening scores of that specific day were used to normalise the subsequent data. This resulted in a set of normalised values for each participant, time (morning or evening), day, and phase (baseline or intervention). Errors and near-errors were not normalised since participants could not commit errors during their days off.

**Confirmatory Analyses.** We had three primary outcomes (fatigue, sleepiness, and errors). We predicted that during the intervention phase, nurses would be less fatigued, be less sleepy, and make fewer work-related errors and near-errors. We used directional tests for all hypotheses.

To determine whether our intervention elicited the expected effects, we conducted mixed-effect linear regressions to individually predict fatigue and sleepiness, given the phase (baseline or intervention), day, and time (morning or evening); the participant was used as a random variable. We set an alpha threshold of .05 for all tests. This statistical analysis enabled us to use data from multiple time points for each participant, which increased our statistical power. Statistical assumptions were reasonable except for the lack of specification error: in the context of an exploratory study, it was not feasible to measure all (and only) relevant variables.

To determine whether our intervention had an influence on work-related errors and near errors, we used a Wilcoxon–Mann–Whitney test comparing the mean number of errors per participant between each phase. Since the normality assumption was violated, we conducted this non-parametric equivalent of a paired-samples *t* test.

**Exploratory Analyses.** To better understand our data, we also performed several exploratory analyses. We used non-directional tests for all exploratory analyses and an alpha of .05.

First, we wanted to examine whether daily fatigue and sleepiness levels were associated with the occurrence of work-related errors and near errors. To do so, we conducted a paired-samples *t* test comparing nurses' fatigue levels on days when they reported errors compared to days when they did not report any. We conducted a similar analysis for sleepiness. The statistical assumptions for both tests were reasonable.

Second, we were interested in investigating the association between nurses' daily fatigue and sleepiness levels across both phases. We thus conducted Pearson's correlation to assess the degree of association between these two variables. The statistical assumptions for this test were also reasonable.

Third, we were interested in the association between certain individual differences and changes in daily fatigue levels from the baseline phase to the intervention phase. In other words, we wanted to determine whether some individuals experienced greater reductions in fatigue than others. As a result, we conducted Spearman's rank correlations to assess the degree of association between three individual difference variables (i.e., MFI score, age, and chronotype) and changes in participants' daily fatigue. We used the nonparametric equivalent of Pearson's correlation for these three correlations since the fatigue data was not normally distributed.

# Results

## Confirmatory Results

**Fatigue.** We hypothesized that nurses would report feeling less fatigued during the intervention phase compared to the baseline observation phase. Our results support this hypothesis: during the intervention phase, average fatigue levels ($M$ = 13.54, $SD$ = 4.74) were lower than during the baseline phase ($M$ = 15.30, $SD$ = 5.27), $B$ = -0.37, $t$(375.20) = -4.39, $p$ < .001. This corresponds to a change in participants' fatigue ratings from "rarely" and "sometimes" to "never" and "rarely". Descriptive statistics are reported in Table 2; test statistics are reported in Table 3.

As illustrated by Figure 1, nurses reported similar fatigue levels during their days off (day

Table 2

*Descriptive Statistics*

| Measure | | Baseline | | Intervention | |
|---|---|---|---|---|---|
| | n | *M* | *SD* | *M* | *SD* |
| Fatigue | 33 | 15.3 | 5.27 | 13.54 | 4.74 |
| Sleepiness | 33 | 4.04 | 2.14 | 3.61 | 2.04 |
| Errors | 33 | 13 | - | 5 | - |
| Caffeine consumption | | | | | |
| Coffee | 33 | 0.55 | 0.68 | 0.49 | 0.68 |
| Tea | 33 | 0.05 | 0.27 | 0.05 | 0.23 |
| Cola | 33 | 0.14 | 0.40 | 0.09 | 0.35 |
| Energy drink | 33 | 0.03 | 0.20 | 0.03 | 0.19 |
| Alcohol consumption | 33 | 0.10 | 0.48 | 0.12 | 0.56 |
| Overtime (minutes) | 33 | 35.20 | 80.90 | 36.30 | 84.00 |

Table 3

*Results of the Regression Model (Summary Statistics)*

| Fatigue | | N | *B* | *SE* | *df* | *T* | *p* |
|---|---|---|---|---|---|---|---|
| Predictor | | | | | | | |
| | Day | 33 | 0.14 | 0.045 | 394.90 | 3.02 | 0.003 |
| | Time | 33 | 0.075 | 0.083 | 374.90 | 0.90 | 0.37 |
| | Phase | 33 | -0.37 | 0.083 | 375.20 | -4.39 | <0.001 |
| Sleepiness | | N | *B* | *SE* | *df* | *T* | *p* |
| Predictor | | | | | | | |
| | Day | 33 | 0.11 | 0.046 | 398.60 | 2.32 | 0.021 |
| | Time | 33 | -0.31 | 0.086 | 376.20 | -3.65 | <0.001 |
| | Phase | 33 | -0.071 | 0.086 | 376.60 | -0.83 | 0.21 |

*Note.* Results of regression models predicting the dependent measures given day (reference level: first day of shift), time (reference: morning), and phase (reference: baseline). *B* shows the standardised slope, which can be interpreted as analogous to a standardised mean difference when controlling for the other predictors. *p* values are based on directional hypotheses.

1–2) in both phases, while they reported significantly lower fatigue levels during their night shifts in the intervention phase (day 3–5) relative to those reported in the baseline phase. Finally, nurses' fatigue levels during their final days off (day 6–8) were similar in both phases.

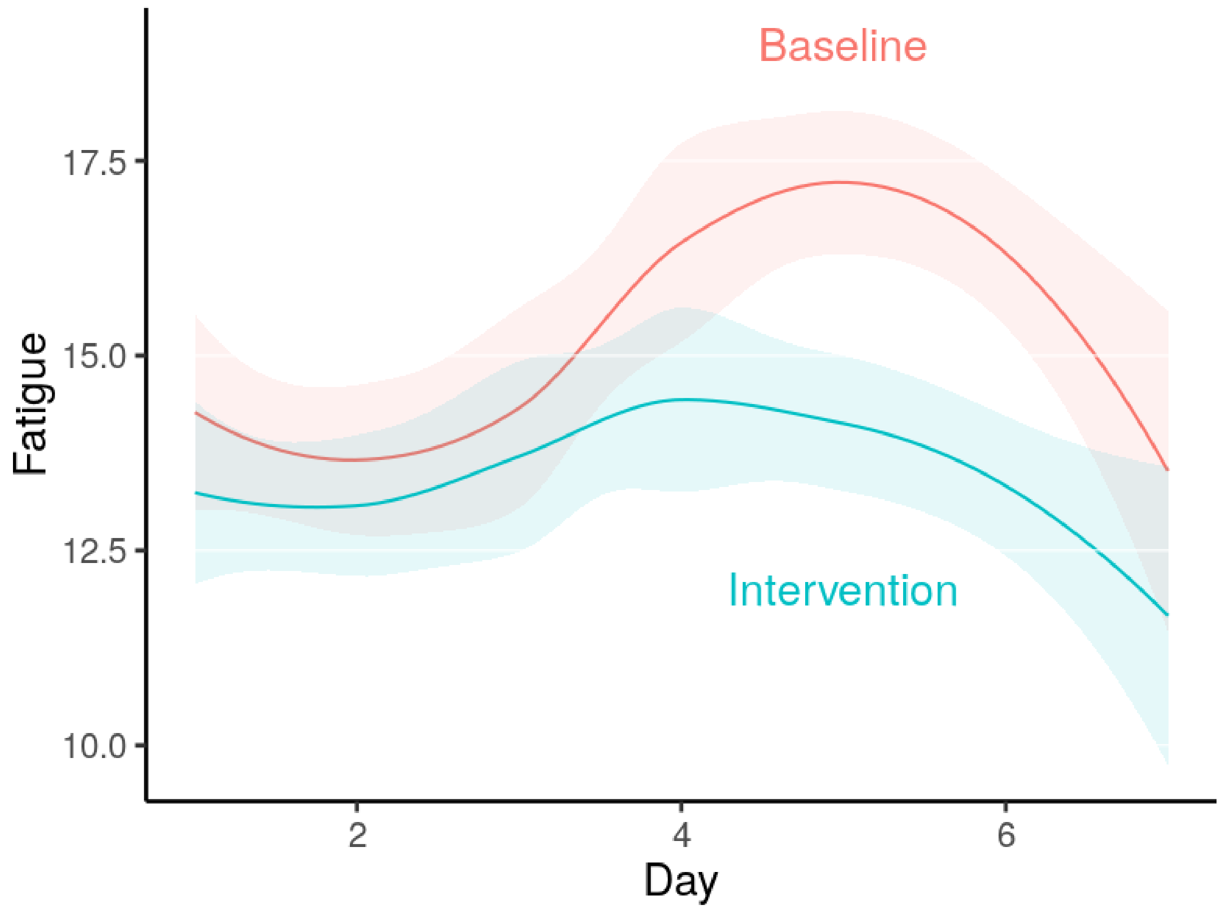


*Figure 1*. Fatigue was lower during the intervention phase relative to the baseline phase. Average fatigue levels by day are depicted across both phases of the study. Shaded areas represent 95% confidence intervals.

Qualitative evidence further supports this finding. For example, one participant claimed that after using the light box, "[she] would arrive at work feeling like it was [her] first night".

**Sleepiness.** We hypothesized that nurses would report feeling less sleepy during the intervention phase compared to the baseline observation phase. Contrary to our expectations, nurses reported similar sleepiness levels during the intervention phase ($M$ = 3.61, $SD$ = 2.04) relative to the baseline phase ($M$ = 4.04, $SD$ = 2.14), $B$ = -0.071, $t$(376.60) = -0.83, $p$ = .21. Both of these values were closest to the "rather alert" label on the sleepiness scale. Although there were statistically significant effects of time and day, this simply means that nurses' morning sleepiness scores were significantly different than their evening sleepiness scores, and that their sleepiness levels were significantly different from one day to another. These effects are unrelated to the intervention. Descriptive statistics are reported in Table 2; test statistics are reported in Table 3.

**Work-related Errors.** We hypothesized that nurses would report fewer work-related errors and near-errors during the intervention phase. Our results also support this hypothesis: during the baseline phase, nurses reported a total of 13 errors; during the intervention, they reported a total of 5 errors (Wilcoxon–Mann–Whitney z = 1.80, $p$ = .036). The majority of reported errors were considered minor in severity (83%); the rest were considered moderate. Overall, nurses primarily reported errors in charting and transcription ($n$ = 8), such as "charted on the wrong patient" and "ordered a different blood test than the [intended] one". Other errors included procedural errors ($n$ = 7), medical errors ($n$ = 2), and other ($n$ = 1). These included errors that may have affected patient safety, such as giving medication late, mislabelling tubes when sending them to the lab, ordering the wrong blood test, and losing track of additives in dialysis bags. Other errors may have affected nurse safety; for example, one nurse reported poking herself with a needle. Descriptive statistics are reported in Table 2.

**Caffeine and Alcohol Consumption.** We measured caffeine and alcohol consumption to verify that the effects observed on fatigue, sleepiness, and errors were not influenced by other factors such as the consumption of psychostimulants or depressants. Relative to the baseline phase, participants consumed similar levels of coffee, tea, cola, energy drinks, and alcohol (see Table 2 for descriptive statistics). Therefore, there were no meaningful differences in caffeine and alcohol consumption between the two study phases.

**Overtime.** We asked participants to report their paid and unpaid overtime for similar reasons. We found that participants worked practically the same amounts of overtime during the baseline phase ($M$ = 35.20) and the intervention phase ($M$ = 36.30).  See Table 2 for descriptive statistics.

**Compliance.** We expected that the majority of nurses would comply with our intervention and this is what we observed. First, nurses reported wearing the sleep mask during 73% of their sleep episodes. Most participants always used it when sleeping ($n$ = 18) while others wore it on at least half of the study days ($n$ = 11); only 4 participants did not wear it at all. Second, nurses reported wearing their sunglasses 89% of the recommended times (i.e., after their night shifts). Most participants always wore them after work ($n$ = 24) while others used them on at least half of the mornings ($n$ = 8); only one nurse one did not wear them at all. Third, nurses reported using the light box before 98% of their shifts. Nearly all of them used it every day ($n$ = 32); one person reported forgetting to use it on two of the intervention days. Duration of the light exposure ranged from 30 minutes to 235 minutes and the average duration was approximately 10 minutes longer than the suggested duration ($M$ = 50.10, $SD$ = 29.14). Most participants (66%)

placed the light box between 30 cm and 60 cm away from their face or under 30 cm away (19%). Before night shifts starting at 7:30 PM, nurses commonly used the light box around 5:00 PM and 6:00 PM; before those starting at 11:30 PM, nurses usually used the light around 10 PM.

**Feasibility.** On average, nurses rated the intervention and its various components as feasible, minimally effortful, easy to implement, and somewhat effective. They also reported that they would likely implement it in the long term if they had access to the equipment. Wearing the sunglasses was considered the most feasible ($M$ = 6.61, $SD$ = 0.83), least effortful ($M$ = 1.45, $SD$ = 0.83), easiest to implement ($M$ = 6.52, $SD$ = 1.06), and most likely to implement in the long term ($M$ = 6.42, $SD$ = 1.03); interestingly, participants rated the intervention as most effective to reduce sleepiness ($M$ = 5.03, $SD$ = 1.05). Further details are presented in Table 4.

**Adverse Effects.** Participants reported almost no adverse effects. Only two nurses reported minor side effects from using the light box: one reported eye strain during the light exposure and another reported a headache. No other adverse effects were reported.

**Exploratory Results**

**Daily Fatigue and Work-related Errors.** We further wanted to determine whether daily fatigue levels were different when participants reported work-related errors or near-errors compared to when they did not. We conducted a two-tailed paired-samples *t* test which revealed that fatigue levels were higher when participants committed one or more errors at work ($M$ = 5.59, $SD$ = 8.40) than when they did not commit any ($M$ = 1.39, $SD$ = 5.79), $t(147) = -2.23$, $p$ = .027. See Figure 2.

**Daily Sleepiness and Work-related Errors.** We also wondered whether there was a similar relation between daily sleepiness and errors at work. A two-tailed paired-samples *t* test revealed that sleepiness was not significantly different when participants reported errors at work

Table 4.

*Descriptive Statistics of the Post-intervention Questionnaire*

| Feasible | *M* | *SD* |
|---|---|---|
| Intervention (in general; 1 to 7) | 5.91 | 0.91 |
| Light (1 to 7) | 5.55 | 1.09 |
| Sunglasses (1 to 7) | 6.61 | 0.83 |
| Sleep mask (1 to 7) | 6.00 | 1.85 |
| Sleep/nap (1 to 7) | 5.36 | 1.75 |
| Effortful | *M* | *SD* |
| Intervention (in general; 1 to 7) | 2.76 | 1.58 |
| Light (1 to 7) | 2.97 | 1.61 |
| Sunglasses (1 to 7) | 1.45 | 0.83 |
| Sleep mask (1 to 7) | 1.94 | 1.82 |
| Sleep/nap (1 to 7) | 2.38 | 1.31 |
| Ease of Implementation | *M* | *SD* |
| Intervention (in general; 1 to 7) | 5.55 | 1.56 |
| Light (1 to 7) | 5.21 | 1.76 |
| Sunglasses (1 to 7) | 6.52 | 1.06 |
| Sleep mask (1 to 7) | 5.97 | 1.85 |
| Sleep/nap (1 to 7) | 5.56 | 1.5 |
| Effectiveness | *M* | *SD* |
| Fatigue (1 to 7) | 4.70 | 1.29 |
| Sleepiness (1 to 7) | 5.03 | 1.05 |
| Mood (1 to 7) | 4.45 | 1.56 |
| Sleep (1 to 7) | 4.64 | 1.34 |
| Errors (1 to 7) | 3.70 | 1.57 |
| Long-term Use | *M* | *SD* |
| Intervention (in general; 1 to 7) | 5.55 | 1.12 |
| Light (1 to 7) | 5.24 | 1.62 |
| Sunglasses (1 to 7) | 6.42 | 1.03 |
| Sleep mask (1 to 7) | 5.61 | 2.21 |
| Sleep/nap (1 to 7) | 5.36 | 1.65 |

*Note.* All nurses ($n = 33$) completed each item of the post-intervention questionnaire.

($M = 2.36$, $SD = 2.68$) compared to when they did not ($M = 0.93$, $SD = 2.04$), $t(147) = -1.73$, $p = .085$.

**Daily Fatigue and Sleepiness.** To determine whether there was an association between

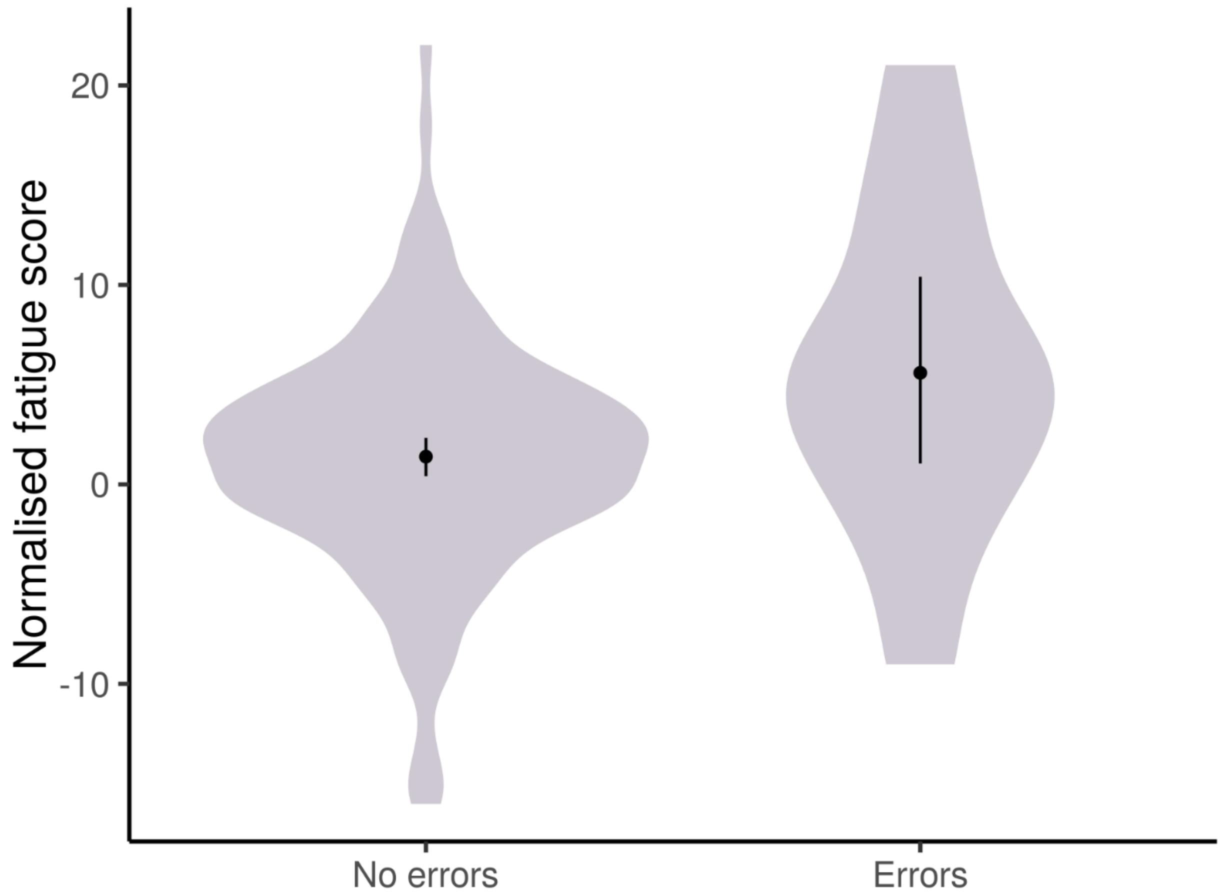


*Figure 2.* Daily fatigue levels were higher when nurses reported errors at work relative to when they did not report any errors. Fatigue levels are depicted across conditions (no errors vs. errors). Shaded areas represent the distribution of scores; the width is proportional to the number of scores.

participants' daily fatigue and sleepiness levels, we conducted a correlation between the two variables. Pearson's correlation revealed a positive association; higher fatigue levels were associated with higher sleepiness scores, $r(407) = .39$, $R^2 = .15$, $p < .001$. See Figure 3.

**Multidimensional Fatigue and Fatigue Reduction.** To determine whether there was an association between participants' initial fatigue levels (MFI) and changes in their daily fatigue levels across both phases of the study, we conducted correlations between each subscale of the MFI and the difference in fatigue levels (intervention phase - baseline phase). Spearman's correlation did not reveal any statistically significant associations between the MFI subscales and the difference in daily fatigue levels, general: $\rho = .016$, $p = .93$, motivation: $\rho = -.14$, $p = .43$, physical: $\rho = .19$, $p = .29$, mental: $\rho = .046$, $p = .80$, and activity: $\rho = -.16$, $p = .37$.

**Age and Fatigue Reduction.** We additionally wanted to determine whether participants' age was associated with changes in their daily fatigue levels across both phases of the study. Spearman's correlation revealed no association between the two variables, $\rho = -.0069$, $p = .97$.

**Chronotype and Fatigue Reduction.** Finally, we were interested in examining whether chronotype (MEQr) was associated with changes in participants' daily fatigue levels across the baseline and intervention phases. Spearman's correlation revealed a strong negative association, $\rho = -.46$, $R^2 = .21$, $p = .007$. Specifically, lower scores on the MEQr (i.e., more "evening type" individuals) were associated with greater reductions in fatigue during the intervention phase relative to the baseline phase (see Figure 4).

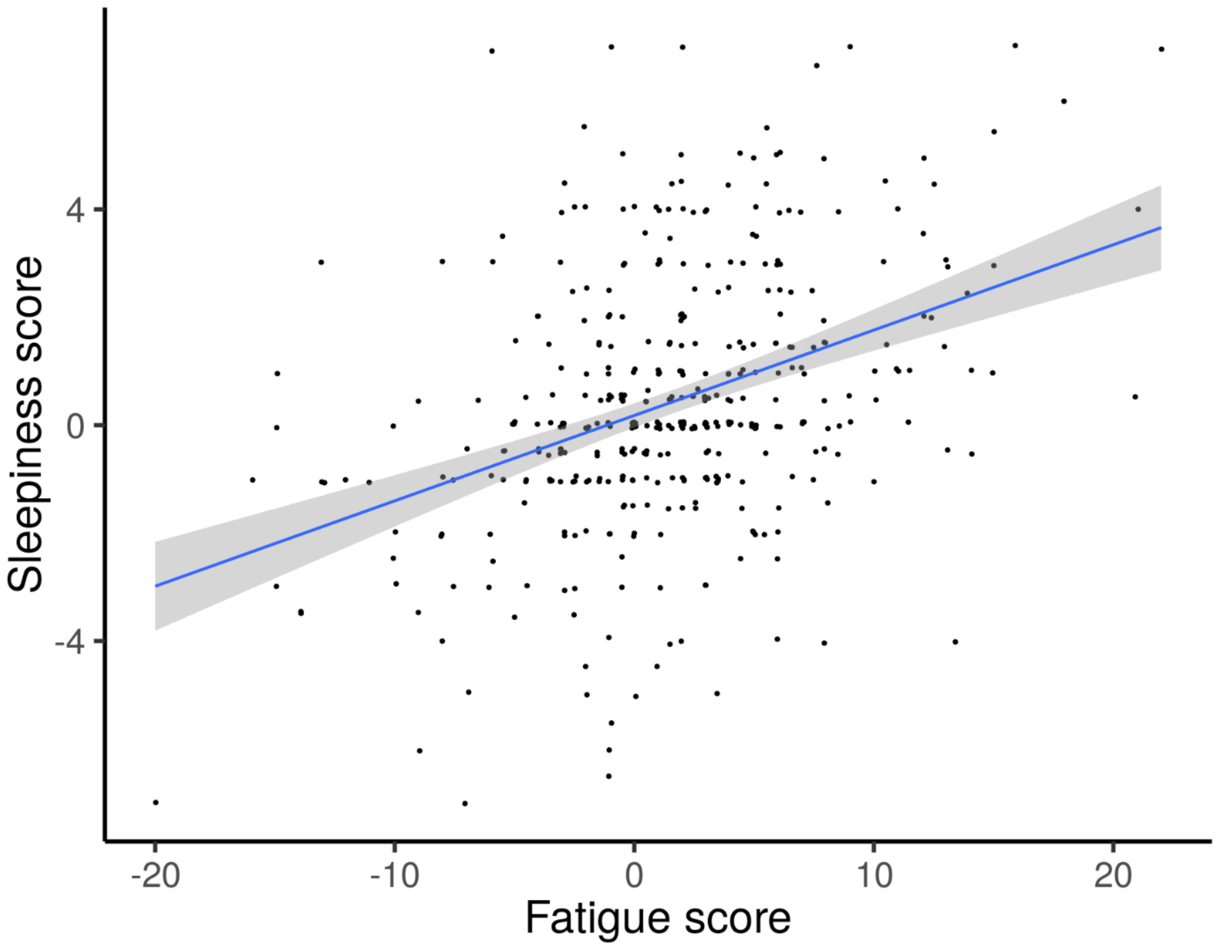


*Figure 3.* Daily fatigue scores are positively associated with daily sleepiness scores. Shaded areas represent 95% confidence intervals.

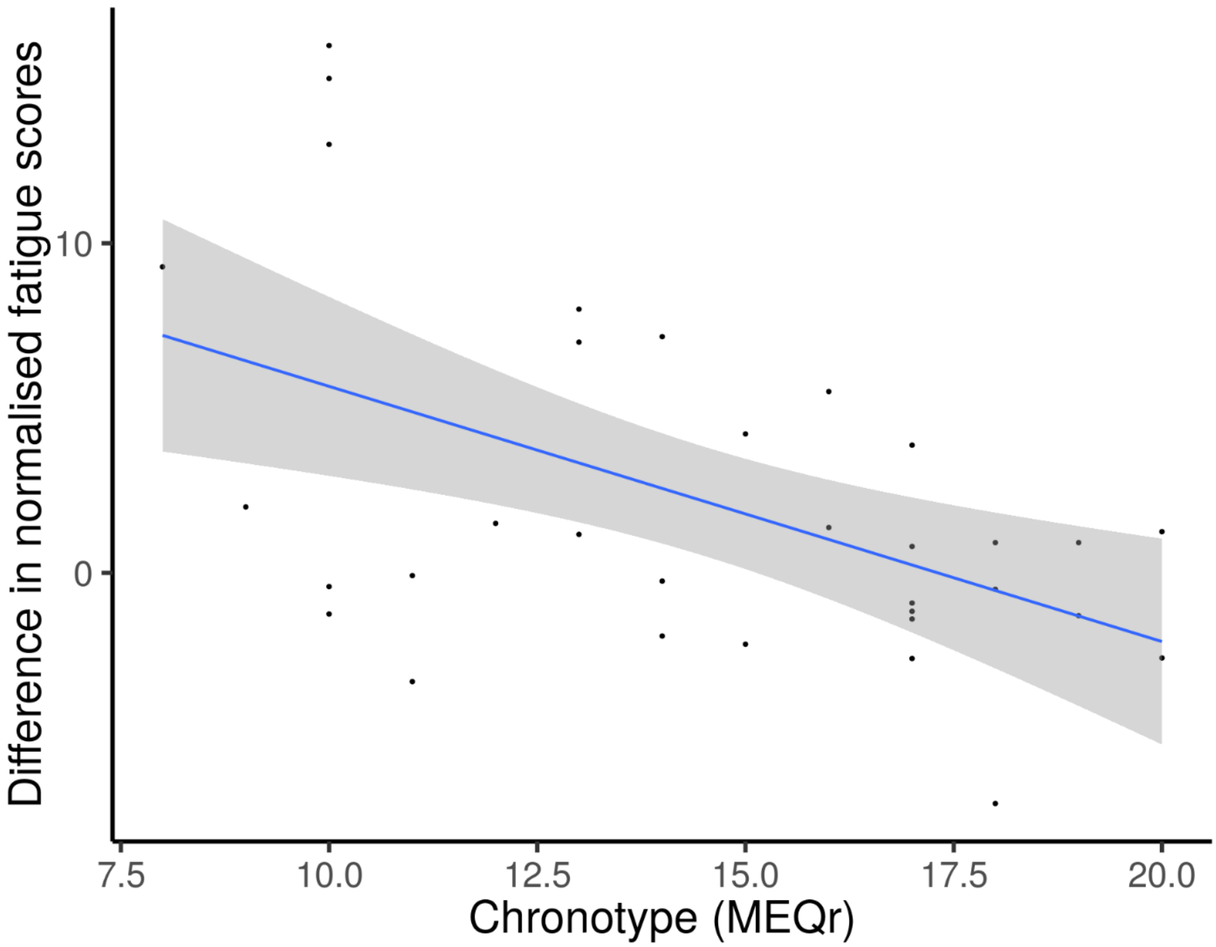


*Figure 4.* Chronotype was negatively associated with the difference in fatigue scores during the intervention phase relative to the baseline phase; that is, evening types experienced greater reductions in fatigue during the intervention phase. Shaded areas represent 95% confidence intervals.

# Discussion

Many rotating shift workers experience numerous negative short- and long-term health and performance outcomes due to circadian misalignment. In the healthcare sector, these have health and safety implications for both workers (e.g., nurses) and patients. Although circadian-based interventions (e.g., timed bright light exposure and avoidance) have been shown to improve circadian alignment and its associated effects in permanent night shift workers, few are feasible in hospital settings or have been tested in rapidly rotating shift workers. Further, nurses rarely receive any training on the circadian principles that can be used to better cope with shift work and manage their fatigue. As a first step towards translating circadian rhythms' knowledge into practice, we aimed to develop a feasible intervention to reduce fatigue, sleepiness, and work-related errors among rapidly rotating shift nurses and collect initial evidence regarding its effectiveness and feasibility. Relative to the baseline observation phase, nurses who followed our intervention reported lower levels of daily fatigue as well as fewer work-related errors and near errors, though their daily sleepiness levels remained similar. The majority of nurses complied with the intervention and rated it as feasible. Interestingly, nurses' fatigue levels were higher when they made errors at work compared to when they did not; this association was not observed in daily sleepiness levels. Still, daily fatigue and sleepiness correlated strongly; specifically, higher daily fatigue levels were associated with higher sleepiness levels. Finally, although nurses' multidimensional fatigue scores and age did not correlate with their experienced fatigue reduction, chronotype was strongly associated with it; in particular, "evening" type individuals experienced greater reductions in fatigue during the intervention phase while "morning type" individuals experienced smaller reductions in fatigue.

Overall, these findings suggest that our intervention may be effective at reducing subjective fatigue and work-related errors in rapidly rotating shift nurses. These results also suggest that our intervention may be a feasible and sustainable method for rapidly rotating shift workers to minimise some of the consequences associated with circadian misalignment. These findings further suggest that certain individuals (i.e., “evening types”) may experience larger benefits from such interventions than others (i.e., “morning types”). Future research is needed to assess the long-term effectiveness of this intervention using more objective measures of fatigue, sleepiness, sleep (e.g., using actigraphy), and light exposure, as well as to assess compliance over time. Further, future studies should compare the intervention to a control group. It may also be interesting to continue the intervention during day shifts and during the transition between day shifts and night shifts (or vice-versa), to attempt to tailor the intervention to participants’ chronotype, and to test similar interventions in other types of shift workers (e.g., physicians, police officers).

**Daily Fatigue**

We expected that nurses’ daily fatigue levels would be lower during the intervention phase relative to the baseline phase and this is what our results suggest. Indeed, nurses reported less fatigue during the intervention phase than during the baseline phase, particularly during night shifts. This finding is consistent with previous literature demonstrating that bright light exposure in the evening and light avoidance in the morning can lead to significant reductions in fatigue among shift workers (Smith et al., 2009; Smith & Eastman, 2012). This finding also provides further support for the idea that even short durations of bright light exposure combined with light avoidance can reduce some of the adverse effects associated with circadian misalignment (Eastman et al., 1995; Huang et al., 2013). On the other hand, this partly contradicts the theoretical framework suggesting that it may not be worthwhile to attempt to reduce circadian misalignment in rapidly rotating shift workers (Smith & Eastman, 2012). Although we did not directly assess circadian misalignment, we measured the outcomes that are typically associated with it. Assuming that the observed reductions in fatigue result from improvements in nurses' circadian alignment, this finding would challenge the views reported by Smith and Eastman in their 2012 review; specifically, that rapidly rotating shift workers may not benefit from circadian-based interventions. On the other hand, the decrease in fatigue may simply be caused by an increase in sleep duration and quality. Indeed, although these findings are beyond the scope of this thesis, nurses who followed our intervention also reported longer sleep duration and better sleep quality. These improvements may be partially or entirely caused by the sleep hygiene components of our intervention (e.g., wearing a sleep mask). This is also a plausible explanation as sleep duration and sleep quality have been associated with changes in fatigue in previous studies (Boissard et al., 2003; Dorrian et al., 2008; Gómez-García et al., 2016; Russell, Wearden, Fairclough, Emsley, & Kyle, 2016). In this case, our findings would not contradict the above-mentioned theoretical framework, but instead suggest that fatigue levels can be positively influenced through other mechanisms. However, given the measures used in this current study, it is not possible to determine what is/are the underlying mechanism(s) driving the observed effects. Future studies should thus include an objective measure of circadian phase (e.g., body temperature, melatonin) in order to determine whether or not this intervention has an influence on circadian rhythms.

Though mechanistic explanations are not possible, it is important to nonetheless note the positive impacts of our intervention on fatigue. Many factors other than rotating shift work can influence nurse fatigue. For example, one group of researchers conducted a national survey of Canadian nurses and found that increases in workload and working short-staffed were factors that nurses believed highly impacted their fatigue levels (Canadian Nurse Association, 2010). Of course, nurses have little control over how busy their shift is or whether their colleagues were able to make it to work that day. As a result, providing nurses with interventions that target other factors that also influence fatigue, such as circadian misalignment and sleep deprivation, enables them to at least partially control their fatigue. Given the individual nature of our intervention, each worker has the option of including it into their routine without having to wait for the implementation of related institutional practices. This is a key advantage of our intervention as shift workers vary in their levels of fatigue and degree of tolerance to rotating shift work (Ritonja, Aronson, Matthews, Boivin, & Kantermann, 2019). Flexible interventions that can be implemented at the individual level are thus preferred over general institutional changes that are costly and do not necessarily address the specific needs of each worker (Ritonja et al., 2019; Smith & Eastman, 2012). Our simple, flexible, and accessible intervention satisfies this need.

**Daily Sleepiness**

We expected that nurses' daily sleepiness would generally be lower during the intervention phase relative to the baseline observation phase. However, this is not what we observed: although there was a small reduction in daily sleepiness levels during the intervention phase, the difference between the two phases of the study was not meaningful. This finding is surprising since it is inconsistent with the majority of the literature. In most studies, sleepiness improves as a result of interventions that target circadian alignment and sleep hygiene (Babkoff et al., 2002; Crowley et al., 2004; Daurat et al., 2000). For example, numerous studies have shown that napping before or during the night shift as well as using bright light exposure at night can reduce objective and subjective measures of night-shift sleepiness and can also boost alertness (Babkoff et al., 2002; Rogers, Spencer, Stone, & Nicholson, 1989; Schweitzer et al., 1992; Wright et al., 1997). Interestingly, studies have demonstrated that even partial circadian alignment can result in important improvements in sleepiness and alertness, similar to those observed in individuals with complete realignment (Chapdelaine, Paquet, & Dumont, 2012; Crowley, Lee, Tseng, Fogg, & Eastman, 2004).

Still, this is not what the participants in our study reported. This lack of difference observed in sleepiness reports may be due to the fact that we assessed subjective sleepiness which is not the most representative measure of objective sleepiness. Indeed, some researchers have demonstrated that subjective sleepiness measures do not necessarily strongly correlate with objective sleepiness measures (Chervin & Aldrich, 1999). Although the measure we used in this study has been validated against objective measures of performance and EEG variables (Kaida et al., 2006), its test-retest reliability is difficult to assess as it varies based on the time of day, earlier sleep episodes, and other factors (Shahid, Shen, & Shapiro, 2010). Interestingly, in the post-intervention questionnaire, nurses reported that the intervention was most effective at reducing their sleepiness; yet, this is not what was reflected in their daily sleepiness reports. This discrepancy speaks to the limitations of such subjective measures. Thus, even though the Karolinska Sleepiness Scale was a reasonable choice in the context of a feasibility study, since it is valid, short, and simple to use, our results may have been different if we had included a more objective measure of sleepiness (e.g., sleep latency). Overall, although our intervention seemed to improve nurse fatigue, it did not meaningfully influence participants’ daily reports of sleepiness.

**Work-related Errors**

In addition to reporting reductions in fatigue, as expected, nurses also reported significantly less work-related errors and near errors during the intervention phase compared to the baseline phase. Further, nurses rated the majority of their errors and near errors as minor in severity, and most errors were classified into one of the three following categories: charting, transcription, and procedural.

The reduction in work-related errors is consistent with our hypothesis; it is not surprising since multiple studies have shown that work performance is reduced during night shifts (Canadian Nurses Association, 2010; Kenyon et al., 2007; Smith-Miller et al., 2014) and that interventions designed to minimise fatigue, sleep deprivation, or sleepiness can improve the performance of shift workers (Babkoff, French, Whitmore, & Sutherlin, 2002; Campbell & Dawson, 1990; Czeisler et al., 1990; Daurat, Foret, Benoit, & Mauco, 2000; Gillberg, Kecklund, Axelsson, & Akerstedt, 1996; Harma, Knauth, & Ilmarinen, 1989; Kretschmer, Schmidt, & Griefahn, 2012; Wright, Badia, Myers, & Plenzler, 1997).

On the other hand, not all interventions using bright light exposure significantly reduced the frequency of errors and near errors in rapidly rotating shift workers. Indeed, in a randomised cross over study conducted with rapidly rotating shift nurses, Tanaka and colleagues (2011) found no difference in adverse events and near misses when nurses received morning bright light exposure relative to when they did not. However, it is important to note that the duration of bright light exposure was very short (i.e., 10 minutes) and that errors were assessed during day shifts. The differences between their intervention and the one used in our study are thus large enough to explain this discrepancy.

Importantly, although the majority of errors and near errors were considered minor, they could still have had a significant impact on patients and nurses. For example, giving medication late and losing track of additives in dialysis bags influences the quality of patientcare that nurses provide and can lead to adverse medical events. In Australia, for example, it has been estimated that 230,000 patients every year suffer from preventable adverse medical events, including 12,000 preventable deaths (Dorrian et al., 2006; Wilson et al., 1996). On the other hand, nurse safety can also be jeopardized; indeed, studies show that shift workers are at a higher risk of work-related injuries than day workers (Wong, McLeod, & Demers, 2011). In our study, one nurse for instance reported poking herself with a needle, which is a common injury among nurses (Trinkoff et al., 2007).

In addition to impacting workplace safety, a large portion of the reported errors, which included ordering the wrong blood test and mislabelling tubes when sending them to the lab, likely influenced work efficiency and productivity by requiring additional time and resources to correct them (e.g., having the laboratory redo the appropriate blood test). Indeed, both workplace performance and safety in healthcare settings have large financial implications. Over time, reducing medical errors can translate into millions of dollars in savings for hospitals (Thomas et al., 1999; Wilson et al., 1996). The effectiveness of our intervention in reducing errors at work is thus beneficial for a number of parties including patients, workers, and institutions.

Moreover, the errors and near errors reported in this study only include the ones that were caught by workers. As a result, these reports may represent a subset of the errors that nurses made during their shifts; a greater number of errors may in fact be prevented as a result of following our intervention.

**Compliance**

Given that we designed our intervention with feasibility concerns in mind, we expected that nurses would comply with the majority of the components of the intervention. As expected, most participants wore the sleep mask and the sunglasses at the majority of the recommended times, and nearly all of the nurses used the light box when instructed. On average, nurses also received bright light exposure for the recommended duration and at the appropriate distance. Thus, we can conclude that nurses were willing to implement the intervention as recommended and that they did so accurately (relative to our instructions).

**Feasibility**

As mentioned, we attempted to emphasise feasibility during the elaboration of the intervention plan. This is one of the main reasons why, for instance, all our recommendations took place outside of work hours. As expected, nurses generally found the intervention feasible, minimally effortful, easy to implement, and effective. Nurses especially liked wearing the sunglasses after their night shifts. On the other hand, nurses rated the light box as the least feasible component; this is not entirely surprising as using the light box required more time than the other components (e.g., sleep mask, sunglasses). Some of the challenges that nurses reported included having to find the appropriate location to plug it in their home and having to plan their schedule accordingly. Nonetheless, nurses reported that they would likely implement the full intervention on a long-term basis if they had access to the necessary materials. This is particularly important as its long-term implementation would be necessary to potentially reduce the long-term effects of circadian misalignment.

**Daily Fatigue and Work-related Errors**

In addition to the previously discussed findings, our exploratory analyses yielded a number of interesting findings. Indeed, our first exploratory analysis showed that nurses were more fatigued when they reported errors at work relative to when they did not. This finding is consistent with the reports of previous studies: for example, nurse fatigue was found to be one of the three main causes of medication errors and has also been linked with increased errors of omission and errors in clinical judgement (International Council of Nurses, 2003; Kenyon et al., 2007; Leape et al., 1995; Mayo & Duncan, 2004). Researchers have additionally found that fatigued nurses are less likely to intercept other people's errors (Dorrian et al., 2006). In a hospital setting, where physicians, interns, and other nurses perform complex procedures and are often also fatigued, this can result in the occurrence of preventable adverse medical events and errors (Landrigan et al., 2004). This finding thus further supports the importance of developing strategies to reduce fatigue in nurses in order to promote patient safety.

**Daily Sleepiness and Work-related Errors**

We also assessed whether daily sleepiness levels would similarly be higher when nurses reported errors compared to when they did not. We did not find any association in this case. This is unexpected since studies typically find strong associations between work-related errors and sleepiness. For example, a study conducted by Dorrian and colleagues (2008) found that sleepiness was the most powerful predictor of errors. In another study of over 500 critical care nurses, the researchers also found a relationship between long work hours, increased sleepiness and work-related errors (Scott et al., 2006). However, the lack of association observed in this study may be due to the fact that errors occurred during the night shifts whereas state sleepiness was assessed before and after the night shifts. This time difference between the occurrence of errors and the sleepiness measurements could explain this inconsistent finding. The inconsistency could also result from differences in the sleepiness measure; we assessed sleepiness using the Karolinska Sleepiness Scale (i.e., single-item questionnaire, 9-point Likert scale) while the authors mentioned above assessed sleepiness during the previous day using a different single-item questionnaire (5-point Likert scale).

**Daily Fatigue and Sleepiness**

We were additionally interested in assessing whether daily fatigue levels would correlate with daily sleepiness ones. Consistent with some of the literature, our analysis revealed a positive association between the two variables; specifically, higher fatigue levels were associated with higher sleepiness levels. Although fatigue and sleepiness are distinct phenomena that are associated with different symptoms, they often co-occur in shift workers and are typically associated to some degree (Hossain, Reinish, Kayumov, Bhuiya, & Shapiro, 2003; Shahid et al., 2010). For example, Shen and colleagues (2006) assessed over 400 workers and found a positive correlation ($r = .33$) between subjective fatigue (Fatigue Severity Scale) and sleepiness (Epworth Sleepiness Scale). The researchers concluded that the strength of the association indicated that fatigue and sleepiness were largely independent phenomena. In our study, we observed a similar but stronger correlation ($r = .39$), suggesting that even though fatigue and sleepiness may be distinct constructs, they seem to overlap to some extent.

**Multidimensional Fatigue and Fatigue Reduction**

We further wanted to determine whether some individual differences were associated with greater reductions in fatigue. In other words, we were interested in assessing whether individuals with particular characteristics experienced greater benefits than others. We found no significant association between participants' multidimensional fatigue scores (i.e., general, motivation, physical, mental, and activity) and the difference in their daily fatigue levels during the intervention phase relative to the baseline phase. This suggests that participants' scores on the multidimensional fatigue questionnaire at the beginning of the study were not strongly associated with improvements in daily fatigue as a result of following our intervention. With that in mind, the strength of the observed associations was potentially limited by the small variability of the multidimensional fatigue scores. Indeed, the average score for each subscale was around 14 and the standard deviations were relatively small (2 to 4 points). This is not necessarily surprising as we had to exclude nurses who were likely more fatigued (e.g., suffered from sleep disorders). However, as a result of this restricted range, the correlation coefficients may have been reduced (Bland & Altman, 2011). It would therefore be interesting to see if this finding replicates with a larger range of scores.

**Age and Fatigue Reduction**

In addition to multidimensional fatigue, we wanted to assess whether participants' age would be associated with the degree of improvement in fatigue they experienced as a result of using our intervention. We found that age was not associated with changes in fatigue from one phase to the other. That is, younger nurses seemed to experience similar benefits as older ones. Although few studies have evaluated the effect of circadian-based interventions in relation with shift workers' age, many studies have found associations between age and tolerance to shift work (Saksvik, Bjorvat, Hetland, Sandal, & Pallesen, 2011). A recent review of the literature reported that over a dozen studies found that younger individuals were more tolerant to working night shifts (Eastman et al., 1994; McLaughlin, Bowman, Bradley, & Mistlberger, 2008; Ognianova, Dalbokova, & Stanchev, 1998; Reid & Dawson, 2001; Saksvik et al., 2011; Takahashi et al., 2005), whereas different studies found that older workers had a higher tolerance to shift work (Burch et al., 2009; Karlsson, Knutsson, & Lindahl, 2001; Nagaya, Yoshida, Takahashi, & Kawai, 2002; Reinberg & Ashkenazi, 2008). On the other hand, a total of 6 additional studies did not find any association (Korompeli, Sourtzi, Tzavara, & Velonakis, 2009; Marquie & Foret, 1999; Saksvik et al., 2011; Smith et al., 1999), while one study reported that middle age workers were more tolerant than both younger and older workers (Blanch, Torrelles, Aluja, & Salinas, 2009). Thus, the current literature is quite mixed. One might hypothesize that individuals who are more tolerant to shift work would benefit less from fatigue-reduction interventions than others given that they naturally experience fewer side effects of shift work. Instead, our study suggests that there is no association between the two variables. As in the case of multidimensional fatigue, this may be partly due to a relatively restricted age range; our sample in fact did not include many older nurses.

**Chronotype and Fatigue Reduction**

Finally, we wanted to assess whether participants' chronotype would be related to the degree of improvement in fatigue that nurses experienced. Our results suggest that individuals who have an evening preference (evening types) experienced larger benefits than those with a morning preference (morning types). Since morning types typically have more difficulties adjusting to night shifts (Gamble et al., 2011), we expected that those individuals would benefit more from our intervention; however, the opposite seems to be the case. Although this finding is surprising, there are a few potential explanations. First, relative to morning types, evening types typically have an easier time adjusting to night shifts as their circadian phase is naturally more delayed (Gamble et al., 2011; Ritonja et al., 2019; Saksvik et al., 2011). As a result, it is possible that these individuals only need to additionally phase delay by a small amount in order to experience the benefits associated with partial circadian alignment. On the other hand, morning types would typically require large delays in their circadian phase in order to experience even partial circadian alignment (Ritonja et al., 2019; Saksvik et al., 2011). It is thus possible that our intervention delayed the circadian rhythms of evening types enough for them to experience benefits but not enough to translate into meaningful improvements for morning types.

Second, our intervention included two main circadian components: (1) seeking bright light before night shifts and (2) avoiding light after night shifts. However, one component may have been more influential than the other. For the purpose of this argument, we will assume that participants' Tmin were not dramatically different from usual prior to starting the intervention; this was likely the case as studies suggest that the circadian rhythms of rapidly rotating shift workers are typically similar to those of day workers given their limited potential for circadian alignment (Eastman, 1990). Under this assumption, we hypothesize that our intervention advanced the circadian phase of morning types and delayed the one of evening types. Indeed, because the evening bright light usually occurred many hours before nurses' Tmin, it likely only elicited a small phase delay regardless of chronotype (Eastman et al., 1995). On the other hand, morning light avoidance (around 7:30AM) took place much closer to participants' T min; this was especially the case for evening types. Assuming that the Tmin of morning types was around 4:00AM (Baehr, Revelle, & Eastman, 2000), they were likely exposed to morning sunlight (via hospital windows) closely after their Tmin, thus advancing their circadian phase. Conversely, assuming that the Tmin of evening types was later in the morning (around 6:00AM or 7:00AM; Baehr et al., 2000), the majority of their morning exposure to sunlight likely took place before their Tmin, thus further delaying their circadian phase. This could potentially explain the observed association between chronotype and improvements in fatigue and suggest that morning sunlight may be driving the effect. In a future study, it would be interesting to see if this finding can be replicated and attempt to isolate the underlying mechanism(s). It could also be useful to test whether morning types experience larger improvements in fatigue if they avoid light as soon as the sun rises.

**Limitations**

This study has several limitations. First, the most important methodological limitation of this study is the lack of a distinct control condition. Although using a within-subject design enabled us to maximise our statistical power, the absence of a comparison group does not permit us to rule out expectation effects; in other words, it is not possible to determine whether the observed effects were due to our fatigue-reduction intervention or to participants' expectations alone. Second, we did not collect any objective measures. Given that this is an exploratory study, we relied on self-reported measures. We attempted to minimise recall bias by having participants complete the questionnaires frequently. Further, we selected subjective measures that have been validated against objective ones (e.g., individual error reports correlate highly with incident reports; O'Neil et al., 1993) and that are frequently used in field studies (e.g., KSS). Third, we were not able to objectively track compliance. Although participants reported whether or not they implemented our intervention, it was not possible for us to track exactly how much light exposure each participant received nor how effective their sunglasses were at blocking sunlight. Finally, we had to exclude the most fatigued nurses—those with fatigue-related medical conditions and who had been involved in fatigue-related driving accidents—to minimise the potential risks associated with our intervention. Although this was necessary, it likely artificially limits the strength of our effects since the nurses who perhaps could have most benefited from a fatigue-reduction intervention were not included in the study. In other words, our intervention may be more powerful than our results suggest.

**Future Studies**

Given these limitations and the questions that remain, this study opens avenues for future research. Follow-up studies should, for instance, assess the long-term effectiveness of our intervention in a more controlled manner. Specifically, studies should compare our intervention against a control group (e.g., sleep hygiene); this would enable us to assess the added benefit of bright light exposure and evaluate the contribution of expectations or demand characteristics. Future studies should also include objective measures of sleep and activity (e.g., actigraphy), sleepiness (e.g., psychomotor vigilance task), and circadian phase (e.g., continuous body temperature). This would help isolate potential mechanism(s) of action. Future studies should additionally determine whether similar interventions place nurses at a higher risk of road accidents due to possible increases in fatigue when returning home from work. The goal of many circadian alignment strategies is to delay the peak drowsiness time (from around 4:00 AM) until after the work shift and ideally into the subsequent sleep episode (Smith & Eastman, 2012). Because circadian rhythms can only be delayed gradually, this potentially involves the peak drowsiness time occurring during the commute home. Future research should compare these risks against the benefits of fatigue reduction during the night shift, especially in professions that require driving. In any case, we saw no evidence that our intervention increased fatigue in our sample even after night shifts. Future studies could also try to objectively assess participants' Tmin at the beginning of the study and tailor the recommendations to their chronotype (e.g., light avoidance earlier in the morning), to test our feasible intervention with other types of shift workers (e.g, police officers), and to assess the influence of our intervention on other meaningful outcomes such as job satisfaction and turnover rates.

**Implications**

Our current study has a number of implications. To begin, it is one of the first studies to demonstrate the potential benefits of using short durations of evening bright light exposure for rapidly rotating shift nurses; this suggests that testing these kinds of interventions with rapidly rotating shift workers is worthwhile. It is also one of the first studies to develop a feasible intervention plan, which can be implemented without the need for any institutional changes, and that combines circadian and sleep hygiene principles. Although this does not negate the need for more permanent institutional policies that address fatigue, circadian misalignment, and their associated consequences, this provides workers with an alternative method to better cope with rapidly rotating shift work. Our positive results also carry implications for workplace health and safety. As discussed, the observed reductions in fatigue were associated with a reduction in work-related errors which can directly influence the quality of care that patients receive as well as the safety of both patients and nurses. This should be of interest for institutions as fatigue and errors at work are tied to significant financial costs: fatigue, for example, has been linked with higher nurse turnover rates, which cost an average of $25,000 per leaving nurse in Canadian hospitals (O’Brien-Pallas, Tomblin Murphy, & Shamian, 2008), while fatigue-related productivity loss has been estimated to cost just under $2,000 per worker each year (Rosekind et al., 2010). Moreover, medical errors have been associated with billions of dollars in annual costs to hospitals (Thomas et al., 1999). Reducing fatigue and work-related errors can thus also be beneficial for institutions. Finally, our intervention has the potential to scale. Throughout the process of developing the fatigue-reduction plans, our team also developed an algorithm to automate the process, enabling us to easily tailor to recommendations to each nurse’s work schedule. This kind of algorithm could eventually be incorporated into a website or app which would allow nurses and other shift workers around the world to easily access feasible and personalized fatigue-reduction recommendations.

**Conclusion**

The present study tested a light-based intervention to reduce fatigue, sleepiness, and work-related errors in rapidly rotating shift nurses working in hospital settings. We found that our intervention reduced subjective daily fatigue as well as the frequency of work-related errors, though it did not seem to influence subjective daily sleepiness. Further, nurses rated the intervention and its different components as feasible and complied with the large majority of our recommendations. Despite its limitations, this study suggests that our intervention is feasible to implement and may be effective at reducing fatigue and errors in the workplace. Our positive results warrant a more controlled follow-up study to assess the long-term effects of our intervention, evaluate potential underlying mechanisms of action, and control for placebo effects.

Nonetheless, these promising findings suggest that this is a feasible and cost-effective intervention that may significantly improve outcomes that are meaningful to patients, nurses, and institutions. More generally, it allows rapidly rotating shift workers to take control of their fatigue and overall health.

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Appendix 1: Recruitment Poster

McGill

Centre universitaire de santé McGill
Institut de recherche

McGill University Health Centre
Research Institute

# Reducing Shift Work Fatigue in Nurses

## Participants wanted for a research study


We are seeking participants for a study testing the impact of fatigue reduction knowledge on the fatigue level, sleep quality, and work quality of nurses.

**Eligible participants must:**

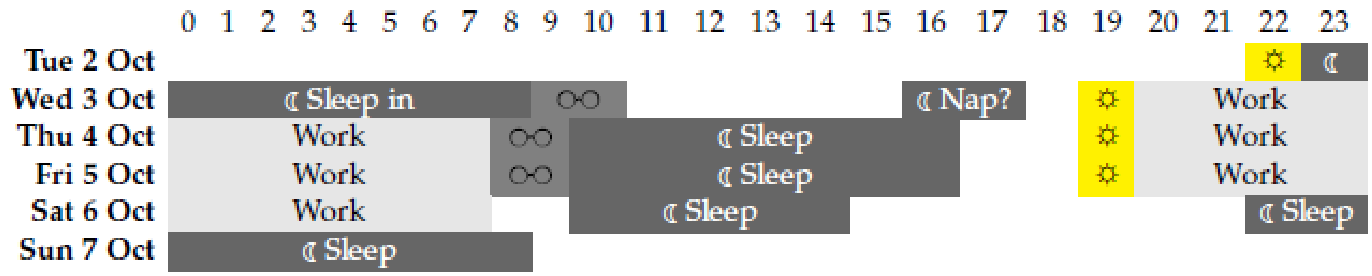
- ✓ **be MUHC registered nurses for at least one year**
- ✓ **work in the ICU, Internal Medicine Unit, or Emergency Room**
- ✓ **work rotating schedules that include 2 or more consecutive night shifts**
- ✓ **own a smart phone and sunglasses**
- ✓ **be between 18 and 65 years old**

Participants will be compensated after each set of night shifts completed in the study.
For more information, please email Mariève Cyr at marieve.cyr@mail.mcgill.ca with "Shift Work Study" in the subject line.

Protocol number : 2018-2858

Appendix 2: Fatigue-Reduction Plan

**Fatigue Reduction Plan**




**Legend**

☼ Use the lightbox for **40 minutes**. Try to get the light as late as possible (e.g., the last 40 minutes before leaving for work). The lightbox should be in front of you within arm's reach, but you need not look directly at it. On your way to work, get as much light as possible (e.g. without sunglasses if walking).

**Wear sunglasses** as soon as you finish work until you go to sleep. Close curtains and blinds at home and wear your **sleep mask** when sleeping and napping. Avoid light as much as possible.

☾ **Sleep** Sleep as soon as you feel tired for as long as you can.

☾ **Nap?** Nap if needed, ideally late in the day.

**Summary**

- Before your night shift, get bright light.
- After your night shift, avoid light.
- Before the set of shifts, sleep in, avoid light in the morning, and nap late.

Appendix 3: Measures of Individual Differences

## Demographic Questionnaire

Age___________
Gender___________
Ethnicity___________
Marital Status___________
Height ___________
Weight___________
Number of children in the household___________
Highest degree of education obtained___________
Years employed as a nurse___________
Years employed as a nurse working night shifts___________
Years employed at the present hospital___________
Average number of shifts worked per week___________
Usual number of hours per shift___________
Number of shifts, by type, worked in the past 7 days:

- Day shifts____
- Evening shifts____
- Night shifts____

Amount of overtime worked in the past 14 days___________
Number of sick days in the past month___________

Taking everything into consideration, how do you feel about your job as a whole?

1.extremely dissatisfied
2.very dissatisfied
3.moderately dissatisfied
4.not sure
5.moderately satisfied
6.very satisfied
7.extremely satisfied

On average, how long does it take you to travel to and from work?

| | TO WORK | | FROM WORK | |
|---|---|---|---|---|
| Morning Shift | ___________ | mins | ___________ | mins |
| Afternoon Shift | __________ | mins | ___________ | mins |
| Night Shift | _____________ | mins | ___________ | mins |

What is your usual means of transportation? __________
Do you have a second job? __________
If YES, how many hours per week do you work at your second job on average? __________
Are you a smoker? __________
If YES, how many cigarettes per day do you smoke on average? __________
In a typical week, how many times do you exercise? __________

## Multidimensional Fatigue Inventory (MFI)

**Instructions:**
We would like to get an idea of how you have been feeling lately. For example, consider the statement:

"I FEEL RELAXED"

If you think that this is entirely true, that indeed you have been feeling relaxed lately, please place an X in the extreme left box; like this:

| Yes, that is true | X | | | | | No, that is not true |
|---|---|---|---|---|---|---|

The more you disagree with the statement, the more you can place an X in the direction of "No, that is not true". Please, do not miss out a statement and place one X next to each statement.

| Statement | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. I feel fit. | Yes, that is true | | | | | | No, that is not true |
| 2. Physically, I feel only able to do a little. | Yes, that is true | | | | | | No, that is not true |
| 3. I feel very active. | Yes, that is true | | | | | | No, that is not true |
| 4. I feel like doing all sorts of nice things. | Yes, that is true | | | | | | No, that is not true |
| 5. I feel tired. | Yes, that is true | | | | | | No, that is not true |
| 6. I think I do a lot in a day. | Yes, that is true | | | | | | No, that is not true |
| 7. When I am doing something, I can keep my thought on it. | Yes, that is true | | | | | | No, that is not true |
| 8. Physically, I can take a lot. | Yes, that is | | | | | | No, that is |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | true | | | | | | not ture |
| 9. I dread having to do things. | Yes, that is true | | | | | | No, that is not true |
| 10. I think I do very little in a day. | Yes, that is true | | | | | | No, that is not true |
| 11. I can concentrate well. | Yes, that is true | | | | | | No, that is not true |
| 12. I am rested. | Yes, that is true | | | | | | No, that is not true |
| 13. It takes a lot of effort to concentrate on things. | Yes, that is true | | | | | | No, that is not true |
| 14. Physically, I feel I am in a bad condition. | Yes, that is true | | | | | | No, that is not true |
| 15. I have a lot of plans. | Yes, that is true | | | | | | No, that is not true |
| 16. I tire easily. | Yes, that is true | | | | | | No, that is not true |
| 17. I get little done. | Yes, that is true | | | | | | No, that is not true |
| 18. I don’t feel like doing anything. | Yes, that is true | | | | | | No, that is not true |
| 19. My thoughts easily wander. | Yes, that is true | | | | | | No, that is not true |
| 20. Physically, I feel I am in an excellent condition. | Yes, that is true | | | | | | No, that is not true |

## Perceived Stress Scale (PSS)

The questions in this scale ask you about your feelings and thoughts during the last month. In each case, please indicate with a check how often you felt or thought a certain way.

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?

___0 ___1 ___2 ___3 ___4

2. In the last month, how often have you felt that you were unable to control the important things in your life?

___0 ___1 ___2 ___3 ___4

3. In the last month, how often have you felt nervous and "stressed"?

___0 ___1 ___2 ___3 ___4

4. In the last month, how often have you felt confident about your ability to handle your personal problems?

___0 ___1 ___2 ___3 ___4

5. In the last month, how often have you felt that things were going your way?

___0 ___1 ___2 ___3 ___4

6. In the last month, how often have you found that you could not cope with all the things that you had to do?

___0 ___1 ___2 ___3 ___4

7. In the last month, how often have you been able to control irritations in your life?

___0 ___1 ___2 ___3 ___4

8. In the last month, how often have you felt that you were on top of things?

___0 ___1 ___2 ___3 ___4

9. In the last month, how often have you been angered because of things that were outside of your control?

___0 ___1 ___2 ___3 ___4

10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

___0 ___1 ___2 ___3 ___4

## Perceived Workload (NASA-TLX)

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

## Reduced Morningness-Eveningness Questionnaire (MEQr)

Please circle the most appropriate answer.

**1. Approximately what time would you get up if you were entirely free to plan your day?**

- 5:00 AM–6:30 AM
- 6:30 AM–7:45 AM
- 7:45 AM–9:45 AM
- 9:45 AM–11:00 AM
- 11:00 AM–12 noon

**2. During the first half hour after you wake up in the morning, how do you feel?**

- Very tired
- Fairly tired
- Fairly refreshed
- Very refreshed

**3. At approximately what time in the evening do you feel tired and, as a result, in need of sleep?**

- 8:00 PM–9:00 PM
- 9:00 PM–10:15 PM
- 10:15 PM–12:45 AM
- 12:45 AM–2:00 AM
- 2:00 AM–3:00 AM

**4. At approximately what time of day do you usually feel your best?**

- 5 AM–8 AM
- 8 AM–10 AM
- 10 AM–5 PM
- 5 PM–10 PM
- 10 PM–5 AM

**5. One hears about "morning types" and "evening types." Which one of these types do you consider yourself to be?**

- Definitely a morning type
- Rather more a morning type than an evening type
- Rather more an evening type than a morning type
- Definitely an evening type

## Menstrual Cycle Questionnaire

Are your periods regular (that is, a cycle that lasts 24 to 35 days)? Yes No

If yes, what is the cycle length (days)? ______

Approximately how many days has it been since the first day of your most recent onset of menstruation (i.e., your last period)? ______

Appendix 4: Daily Measures

## Daily Fatigue Short Form (DFSF)

In the past 12 hours:

How often did you feel tired?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Never | Rarely | Sometimes | Often | Always |

How often did you experience extreme exhaustion?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Never | Rarely | Sometimes | Often | Always |

How often did you run out of energy?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Never | Rarely | Sometimes | Often | Always |

How often did your fatigue limit you at work (include work at home)?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Never | Rarely | Sometimes | Often | Always |

How often were you too tired to think clearly?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Never | Rarely | Sometimes | Often | Always |

How often did you feel tired even when you hadn't done anything?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Never | Rarely | Sometimes | Often | Always |

How often did you have to push yourself to get things done because of your fatigue?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

Never Rarely Sometimes Often Always

## Karolinska Sleepiness Scale (KSS)

During the previous 5 minutes:

Which statement best describes your sleepiness?

1) Extremely alert
2) Very alert
3) Alert
4) Rather alert
5) Neither alert nor sleepy
6) Some signs of sleepiness
7) Sleepy, but no effort to keep awake
8) Sleepy, some effort to keep awake
9) Very sleepy, great effort to keep awake, fighting sleep

## Work-related Errors

Enter any errors or near-errors made during your shift:

Approximate Time (e.g. 23:30):

Type:

1) Medication
2) Transcription
3) Charting
4) Procedural
5) Slip/fall
6) Other

Severity of consequences:

1. Minor
2. Moderate
3. Serious

Brief description (e.g. almost gave patient wrong medication):

NOTE: Participants could add as many additional errors and near-errors as they wanted.

## Caffeine and Alcohol Consumption

Over the past 12 hours, how many cups/drinks have you consumed?

Coffee:

Caffeinated tea:

Cola drinks:

Energy drinks:

Alcoholic drinks:

## Level of Physical Activity

Pedometer steps (overall):

Did you wear your pedometer at work? Yes No

## Overtime

How much overtime did you work?

None

15 minutes

30 minutes

45 minutes

1 hour

1 hour and 15 minutes

1 hour and 30 minutes

1 hour and 45 minutes

2 hours

2 hours and 15 minutes

2 hours and 30 minutes

2 hours and 45 minutes

3 hours

3 hours and 15 minutes

3 hours and 30 minutes

3 hours and 45 minutes

4 hours

More than 4 hours

## Compliance

***Light***

Did you get light exposure from your light box last night? Yes No

From (e.g. 18:00):

Until (e.g. 19:00):

***Distance***

Distance from light box:

1) Under 30 cm/Within elbow's reach

2) 30–60 cm/Within arm's reach

3) 60–100 cm/Just outside of arm's reach

4) Over 100 cm/More than a metre away

***Sunglasses***

Did you wear your sunglasses this morning? Yes No

***Sleep Mask***

Did you wear your sleep mask? Yes No

## Anything else?

Optionally note anything else that may be helpful (e.g. forgot to bring pedometer to work):

Appendix 5: Post-intervention Questionnaire

## Post-intervention Questionnaire

Circle the number corresponding to your choice. Please answer as honestly as possible.

1. How **feasible** was the overall intervention, given your current lifestyle?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all feasible | | | | | | very feasible |

2. How **feasible** was each individual component, given your current lifestyle?

(a) Light box:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all feasible | | | | | | very feasible |

(b) Sunglasses:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all feasible | | | | | | very feasible |

(c) Sleep mask:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all feasible | | | | | | very feasible |

(d) Sleep/nap times:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all feasible | | | | | | very feasible |

3. How **effortful** was the overall intervention?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effortful | | | | | | very effortful |

4. How **effortful** was each component of the intervention?

(a) Light box:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effortful | | | | | | very effortful |

(b) Sunglasses:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effortful | | | | | | very effortful |

(c) Sleep mask:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effortful | | | | | | very effortful |

(d) Sleep/nap times:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effortful | | | | | | very effortful |

5. How **easy** was it to implement the overall intervention?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all easy | | | | | | very easy |

6. How **easy** was it to implement each of the following components?

(a) Light box:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all easy | | | | | | very easy |

(b) Sunglasses:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all easy | | | | | | very easy |

(c) Sleep mask:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all easy | | | | | | very easy |

(d) Sleep/nap times:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all easy | | | | | | very easy |

7. Overall, how **effective** did you find the intervention in producing the following effects?

(a) Reducing fatigue at work:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effective | | | | | | very effective |

(b) Increasing alertness at work:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effective | | | | | | very effective |

(c) Improving mood:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effective | | | | | | very effective |

(d) Improving sleep quality:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effective | | | | | | very effective |

(e) Reducing errors or near-errors at work:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all effective | | | | | | very effective |

8. If you had the available equipment, how likely would you be to incorporate the intervention into your personal routine in the long term?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all likely | | | | | | very likely |

9. If you had the available equipment, how likely would you be to incorporate each of the following components into your personal routine in the long term?

(a) Light box:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all likely | | | | | | very likely |

(b) Sunglasses:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all likely | | | | | | very likely |

(c) Sleep mask:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all likely | | | | | | very likely |

(d) Sleep/nap times:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all likely | | | | | | very likely |

10. Overall, how much did you **like** using the intervention?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all | | | | | | very much |

1. Which part of the intervention did you find easiest, and why?

2. Which part of the intervention did you find hardest, and why?

3. Did you encounter any challenges with the following components:

(a) Light box:

(b) Sunglasses:

(c) Sleep mask:

(d) Sleep/nap times:

(e) Anything else?:

4. What impacts, if any, did this intervention have on your personal life?

5. What impacts, if any, did this intervention have on your work life?

6. Do you have any suggestions that could help improve the intervention?

7. Did you have any issues adjusting to your day shifts after the intervention?