The Impact of a Rigorous Multiple Work Shift Schedule and Day Versus Night Shift Work on Reaction Time and Balance Performance in Female Nurses: A Repeated Measures Study

Brennan J. Thompson, PhD, Matt S. Stock, PhD, Victoria K. Banuelas, BS, and Chibuzo C. Akalonu, BS

Objective: The aim of this study was to determine the impact of a demanding work schedule involving long, cumulative work shifts on response time and balance-related performance outcomes and to evaluate the prevalence of musculoskeletal disorders between day and night shift working nurses. **Methods:** A questionnaire was used to identify the prevalence of past (12-month) and current (7-day) musculoskeletal disorders. Nurses worked three 12-hour work shifts in a 4-day period. Reaction time and balance tests were conducted before and after the work period. **Results:** The work period induced impairments for reaction time, errors on reaction time tasks, and balance performance, independent of shift type. Musculoskeletal symptom prevalence was high in workers of both work shifts. **Conclusions:** Compressed work shifts caused performance-based fatigue in nurses. Reaction time and balance tests may be sensitive fatigue identification markers in nurses.

Nurses consistently exhibit among the highest nonfatal workplace injury rates of any job group, with a musculoskeletal disorder incidence rate ranking the second highest for all private sector industries, behind only the transportation and warehousing sector.[1] This alarming statistic is particularly impactful when considering that the health care industry comprises one of the largest portions of the labor force (~12%, 17 million workers),[2] and is projected to experience the highest growth of any other industry in the upcoming years—adding 5 million jobs through 2022.[2] Musculoskeletal injuries are the most commonly reported, and the leading causes have been proven to be (1) overexertion, and (2) slips, trips, and falls.[1,3] Notably, these predominant causes of injury may be largely preventable, particularly because they are factors that are influenced by the individual-environment dynamic. For example, improvements in individual health and performance abilities [ie, reduced fatigue, improved body mass index (BMI), enhanced response time, muscular strength, etc.] and/or the work environment/structure (ie, work organization such as work scheduling patterns, availability of mechanical lifting aids, etc.) would likely diminish risks to incur these leading causes of injury.[4]

It is understood that workplace practices and policies can influence worker outcomes such as health, performance, work-related injury risks, and patient safety and quality of care.[5–8] Previous researchers have highlighted evidence suggesting that demanding schedules—which includes 12-hour shifts and compressed (ie, 36 to 40 hours worked in less than a 5-day period) schedules typical to health care settings—are likely a major contributor toward the alarming injury statistics.[6,7,9] However, a bulk of the research investigating work-related influences on health care worker health-related outcomes has focused on the effects of a single work shift, with the primary interest being on the length of the shift.[9] Unfortunately, this has left a large research gap pertaining to the effects of successive shifts on the health, performance, and injury responses in this working population. For example, Hopcia et al[9] have suggested that recent trends of consecutive work shifts leading to cumulative hours may impact injury risks, and that research has previously focused on examining overtime work patterns, but has inadequately evaluated the influence of increasing shifts and hours worked in a given time period on worker outcomes. Support for enhanced injury risks among workers working successive shifts may be found in the data presented by Folkard and Tucker,[10] who showed reduced safety with the increasing number of successive shifts.

Manifestation of a high prevalence of fatigue in the working population[11] has spawned growing concern, particularly because of the apparent link to reduced performance, sickness absence, and disability.[12,13] Fatigue would be especially detrimental for direct patient care workers (nurses) who require uncompromised levels of accuracy throughout the duration of the work period.[7] With consequences of error in the nursing profession being at a maximum, even minimal alterations in error events have lethally profound implications. The demographic and job-specific predisposition of this profession only exacerbates the problem as female sex (>90% of nurses), low decision authority, and shift work—all proportionally high in the nurse profession—are risk factors for fatigue and predictors of long-term sickness absence.[13] However, despite its prevalence and lofty consequences, surprisingly, the use of objective measures to document a physical manifestation of fatigue has been overwhelmingly deficient in occupational research of nurses. Current methods of fatigue assessment deal largely with self-reported, or perceived fatigue status by the worker; however, this approach fails to objectively measure functional fatigue, which may be defined as "a transient decrease in the capacity to perform physical actions"[14] (pg. 11). Thus, because the worker is little aware of their fatigue and associated performance deficits, relying on nurses to self-regulate work schedule characteristics based on perceived incapacities is likely a major part of the problem.[7] Due to a lack of research studies that have used experimental designs to assess performance changes from real world, on-the-job work schedules, experimental research is clearly needed to establish the cause and effect of accumulating work shifts on objective indicators of fatigue, so that a foundation may be established from which to direct future research endeavors aimed at managing worker fatigue.

Given the demanding physical and mental nature of the nurses' job, which may occur across a several decade career, the development and implementation of performance tests that are sensitive to relevant physiological functioning impairments are warranted. These tests may be implemented to identify, quantify,

From the Neuromuscular Research Laboratory, Kinesiology and Health Sciences Department, Utah State University, Logan (Dr Thompson); Applied Physiology Laboratory, Department of Health Professions, University of Central Florida, Orlando (Dr Stock); and Human Performance Laboratory, Department of Kinesiology & Sport Management, Texas Tech University, Lubbock (Banuelas, Akalonu).

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Address correspondence to: Brennan J. Thompson, PhD, Assistant Professor, Kinesiology and Health Sciences Department, Utah State University, 7000 Old Main Hill, Logan, UT 84322 (brennan.thompson@usu.edu).

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and ultimately provide decision-making data toward effective management of such impairments, and could thereby be a useful tool in mitigating health hazards and injuries. Appealing tests for this purpose may include reaction time (RT), with a vigilance component, and measures of balance performance. RT capabilities may provide insight into the general fatigue level, which may be affected by the sleepiness or arousal status of the nurse. This may be assessed by using simple, choice, or vigilance-related RT tasks. The attributes of these tests also conveniently provide information regarding error responses during the course of the test. In particular, the psychomotor vigilance task (PVT) is a several minute long test that assesses the subject's response times with a durability component. Because the essence of nursing is focused around vigilance (the art of watching out),[15,16] this test may highlight their capacity to respond rapidly, and correctly, to urgent events. Also particularly relevant to the nursing population—due to the high prevalence of falls-related events and associated injuries—would be indicators of balance performance. Often assessed in the form of postural sway, using a force plate which measures center of mass movements, this mode of balance testing is portable, relatively simple to administer and analyze, cost-effective, and requires low effort on the subject's part. It may also be performed at varying levels of difficulty, such as moving from a two-foot stance (bipedal) to single foot (unipedal), and may even extend further into tests involving an unstable surface (foam pad) or with the eyes closed. Because this test may be inherently linked to RT performance, but shows a more functional outcome, it could supplement RT data, with the two providing complementary information on overall fatigue status, injury risk, and arousal state.

Nurses working night shifts may have more difficulty remaining awake and may be prone to making more errors.[16,17] Some research also suggests that "other than day" shift nurse workers may be at a greater risk for musculoskeletal disorders.[17–19] However, a majority of studies examining this issue have only examined limited body regions (generally neglecting lower extremities)[20] and have not segregated the "other than day" shift status into constituent components (evening, rotating, and night shift included together as a nonday shift factor).[17,19] As the various nonday shifts may exhibit unique characteristics regarding musculoskeletal disorders, more research is needed that controls for the type of nonday shift (eg, day vs night shift only). Therefore, the purpose of this investigation was to determine the impact of a demanding work schedule involving long (12-hour), cumulative (multiple and semi-successive shifts) work shifts on RT and balance outcome measures in day versus night shift full-time female nurses. A secondary aim was to evaluate the prevalence of musculoskeletal symptoms in eight body regions between day and night shift working nurses. On the basis of the literature, we hypothesized that significant decreases in the RT and balance performance variables would be incurred, and that night shift nurses would exhibit greater musculoskeletal disorders for a majority of the body regions than the day shift.

METHODS

Subjects

Nurses were solicited from local hospitals via flyers, on-site visits, and word of mouth. Thirty-eight female health care workers completed the experimental work trial; however, a total of 41 had completed the pretest trial, which included the musculoskeletal injury questionnaire. Thus, the musculoskeletal injury analysis includes these 41 subjects, whereas the performance test outcomes include only the 38 workers who completed the experimental work period. Subjects completing the experimental trial included 20 day (mean $\pm$ SD: age $= 31.0 \pm 7.5$ years, height $= 161.6 \pm 8.9$ cm, body mass $= 74.6 \pm 19.3$ kg, BMI $= 28.7 \pm 7.8$ kg/m^2) and 18 night (age $= 33.5 \pm 12.5$ years, height $= 166.0 \pm 6.7$ cm, body mass $= 72.6 \pm 18.0$ kg, BMI $= 26.3 \pm 5.9$ kg/m^2) shift workers. Inclusion criteria required subjects to be full-time female registered nurses (RNs), nurses' aides (CNAs), or licensed vocational nurses (LVNs) currently working 12-hour day or night shifts (mid-shift excluded) in hospitals, and had been working their current shift for a minimum of 3 months. Subjects were required to be free of any neuromuscular diseases (eg, Parkinson, multiple sclerosis), medically diagnosed sleep disorders, had no previous musculoskeletal injuries or surgery on their dominant leg within the previous 1 year, and could not be pregnant. Following screening and debriefing procedures, participants signed an informed consent document that was approved by the University's Institutional Review Board.

Procedures

Subjects visited the laboratory on three separate occasions at the same time of day ($\pm$2 hours), with the first visit being used to familiarize subjects on all the performance tests. The second visit was the pretest and was scheduled within 24 hours of the first work shift and a minimum of 48 hours following any previous work shift in order to enable a similar recuperated state among nurses and to avoid the effects of previous work-induced fatigue on the testing measures. The third visit was required to be within 3 to 24 hours of the final 12-hour work shift. This postshift time period was set in order to reflect the presence of residual, chronic fatigue rather than the effects of acute fatigue (immediately after the shift), as to provide insight into the fatigue effects presented on the "day after" the heavy work period. This approach would be the first to our knowledge to capture the potential effects of a particular type of long-lasting fatigue, known as low-frequency fatigue, which onsets within the first hour of activity task termination and may persist for over 24 hours.[21] Notably, this type of fatigue has not been assessed in occupational populations, and yet may be of particular importance because of its almost imperceptible presence, and direct impact on delayed recovery. The 4-day period between the pretest and posttest involved an experimental work period that involved the nurse working three, 12-hour work shifts (ie, 36 hours) in a 4-day period of which the first and fourth day were required to be a working day. This work schedule was designed to elicit a demanding semi-cumulative work period with 36 hours of work being performed in the context of long work shifts (12 hours) in a relatively condensed time period (96 hours)—which is routinely performed in nursing professions. To assess the effects of work-induced fatigue, subjects were instructed to refrain from any structured exercise or vigorous physical activity during the course of the study (eg, no exercise sessions, competitive sports participation, or physically rigorous leisure activities that may induce muscle soreness or excessive fatigue).

Musculoskeletal Symptom Assessment

Past and current musculoskeletal symptoms were assessed using the Nordic Musculoskeletal Questionnaire, which is widely used in occupational settings to answer the question: "do musculoskeletal troubles occur, and in what parts of the body are they localized?" Subjects were presented a visual of the body divided into the following regions: neck, shoulders, elbow, upper back, lower back, hips/thigh/buttocks, knees, and ankles/feet. Items are used to determine the symptoms experienced in specific regions in the past 12 months and 7 days. This questionnaire and procedures have been previously used to identify musculoskeletal symptoms in female nursing personnel.[22,23]

Performance Tests

Reaction Time

The PVT test was used to assess vigilance-based RT. The PVT was selected, as it is considered to be the "gold standard"[24] vigilance and visual RT test, and has been successfully used in nursing populations. Notably, Surani et al[16] have suggested that it may be relevant to nurses because ''professional vigilance, the art of 'watching out' is the essence of nursing'' (pg. 1). Conveniently, this test has been recently developed and validated using a freely downloadable personal computer-based (PC) software program.[24] The PVT was conducted similar to the procedures of Khitrov et al,[24] using the downloadable software, a PC laptop (Dell Precision M6500; Dell Inc., Round Rock, TX) and optical gaming mouse (Razer Abyssus; Razer, Carlsbad, CA). The PVT was 5 minutes in duration, and subjects were asked to turn off all personal electronic devices and were not allowed to have any other persons present in the room during the test administration. In addition, the Deary-Liewald RT (DLRT) test was performed that involves both simple (SRT) and four-choice (CRT) RT tasks to assess both simple reactive response times and the subject's ability to rapidly select an accurate response from a choice-based stimuli.[25] This PC task has also been reported to be a reliable and valid RT test,[25] and is freely downloadable. For the PVT test, measurement variables included mean, standard deviation, fastest and slowest 10%, and minor lapses (500 to 1000 ms response times). The DLRT tasks included mean, standard deviation, and premature responses for both the SRT and CRT tests as well as the number of wrong responses for the CRT.

Balance

Balance and neuromuscular control was assessed using a commercial balance testing system (BioSway Balance System, Shirley, NY). The platform consists of an interface with computer software that enables an objective assessment of static balance. Subjects performed bipedal, and unipedal static balance testing of the dominant foot.[26–28] Testing consisted of the subjects standing on the platform without footwear, and knees unlocked at no more than 10°, with arms at their sides and eyes fixed straight ahead at the computer monitor that was set at eye level.[26,28] Foot position coordinates were recorded and remained constant throughout all testing trials. Each test consisted of a 30-second evaluation[26,28] and subjects performed two trials of each condition with 1 minute of rest between trials.[28] Order of testing was performed in the order of increasing difficulty[29] such that subjects first performed bilateral testing, followed by unilateral testing of the dominant foot. The measure of postural stability was the overall score provided by the software program, as this index has been commonly reported and used as an effective postural stability metric.[26–28]

Statistical Analyses

Independent samples *t* tests and Chi-square (χ^2) were used to analyze demographics between day and night-shift workers. Chi-square (χ^2) was used to determine differences between day and night-shift workers on the prevalence of musculoskeletal symptoms for all body regions. Two-way mixed factorial [group (day vs night shift) × trial (pretest vs posttest)] analyses of variance (ANOVAs) were used to examine the performance variables. When appropriate, *t* tests were used for posthoc pairwise comparisons. IBM SPSS Statistics (Version 21.0; SPSS Inc., Chicago, IL) was used for the statistical analyses, and an alpha level of P of 0.05 or less was considered statistically significant.

RESULTS

There were no differences between the day and night-shift workers for age ($P = 0.46$), height ($P = 0.10$), body mass ($P = 0.75$), BMI ($P = 0.29$), or self-reported hours of aerobic exercise per week ($P = 0.80$). In addition, there were no differences ($P = 0.73$) for job type between the day (RN, CNA, LVN: 13, 6, 1) and night (10, 6, 2) shift workers. The musculoskeletal symptom results are presented in Table 1. All but five of the nurses reported having worked the present job (current shift, unit, and full-time status) for at least 12 months before the study, and all nurses had been working the present job for a minimum of 3 months. Twelve-month and 7-day musculoskeletal symptom prevalence ranged from 4.8% to 52.4% and from 4.8% to 28.6%, respectively, in the day shift, and from 0.0% to 25.0% and from 0.0% to 15.0% in the night-shift nurses. Day-shift nurses exhibited higher prevalence for lower back ($P = 0.05$), and hip/thigh ($P = 0.02$) body regions than night shift nurses; however, no other differences were found between shift types for any of the other body regions ($P = 0.07$ to 0.93). In addition, 75.6% of the combined day and night-shift nurses had experienced at least one musculoskeletal symptom in the past 12 months.

For the PVT RT measures, there were no group × trial interactions for mean ($P = 0.90$), fastest and slowest 10% ($P = 0.44$, 0.68), standard deviation ($P = 0.54$), or minor lapses ($P = 0.32$). However, there were main effects for trial for mean ($P < 0.01$), slowest 10% ($P < 0.01$), standard deviation ($P = 0.02$), and minor lapses ($P = 0.02$) but no main effects for fastest 10% ($P = 0.054$). For all PVT main effects, the scores for the posttest were greater than the pretest (Figs. 1 and 2). For the DLRT RT measures, there were no group × trial interactions for SRT and CRT mean ($P = 0.50$, 0.54), standard deviation ($P = 0.07$, 0.30), premature responses ($P = 0.89$, 0.29), and CRT wrong responses ($P = 0.61$). However, there were main effects for trial for SRT standard deviation ($P = 0.03$) and SRT premature responses ($P < 0.01$), but no main effects for SRT and CRT mean ($P = 0.12$, 0. 39), and CRT standard deviation ($P = 0.79$), premature responses ($P = 0.57$), and wrong responses ($P = 0.93$). Posttest scores were greater for SRT standard deviation and premature responses than pretest (Figs. 2 and 3). For the balance measures,

TABLE 1. Prevalence (%) of Musculoskeletal Symptoms for Day and Night-Shift Workers and Combined (Total)

	Day Shift ($n = 21$)		Night Shift ($n = 20$)		Total ($n = 41$)		
Body Region	12-Month Symptoms	7-Day Symptoms	12-Month Symptoms	7-Day Symptoms	12-Month Symptoms	7-Day Symptoms	P (12 month, 7 day)
Neck	23.8	9.5	15.0	5.0	19.5	7.3	0.48, 0.58
Shoulder	28.6	14.3	15.0	10.0	22.0	12.2	0.29, 0.68
Elbow	4.8	4.8	0.0	0.0	2.4	2.4	0.32, 0.32
Upper back	14.3	4.8	10.0	0.0	12.2	2.4	0.68, 0.32
Lower back	52.4	28.6*	25.0	5.0	39.0	17.1	0.07, 0.05
Hips-thigh-buttock	23.8*	9.5	0.0	0.0	12.2	4.9	0.02, 0.16
Knees	19.0	4.8	25.0	15.0	22.0	9.8	0.65, 0.27
Ankle-feet	23.8	9.5	25.0	15.0	24.4	12.2	0.93, 0.59
One symptom	81.0	57.1	70.0	44.4	75.6	51.3	0.41, 0.43

*Statistically significant difference between day and night-shift workers. $P \leq 0.05$.

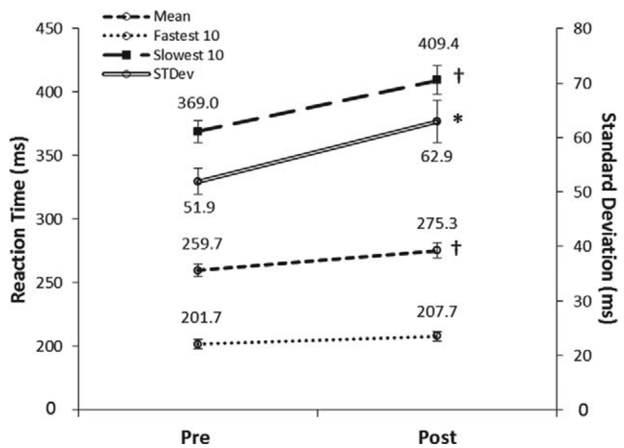

FIGURE 1. Work-induced changes from pretest to posttest for the psychomotor vigilance task (PVT) measurements for nurses (collapsed across work shift). Variables include mean, fastest 10% and slowest 10% of reaction time (primary axis, dashed lines), and standard deviation (STDev) of response times (secondary axis, double solid line). Values are mean $\pm$ SEM. *Significantly different from pretest at $P \leq 0.05$; †significantly different from pretest at $P < 0.01$.

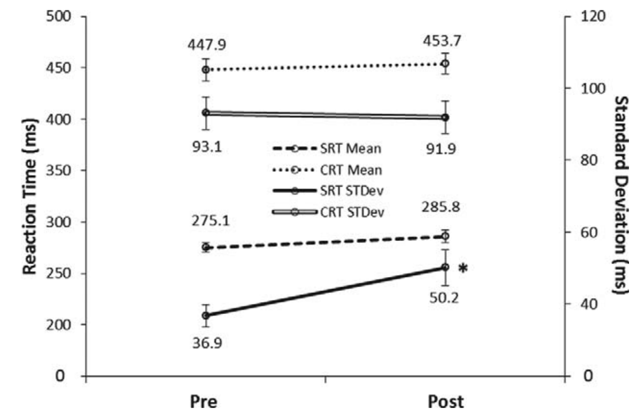

FIGURE 3. Work-induced changes from pretest to posttest for the simple reaction time (SRT) and choice reaction time (CRT) measurements for nurses (collapsed across work shift). Variables include mean (primary axis, dashed lines) and standard deviation (STDev) of response times (secondary axis, solid lines). Values are mean $\pm$ SEM. *Significantly different from pretest at $P \leq 0.05$.

there were no group $\times$ trial interactions for bipedal ($P = 0.69$) or unipedal ($P = 0.20$) balance; however, for unipedal balance, there was a main effect ($P = 0.04$) for trial such that the posttest scores (0.58 ± 0.28) were greater than the pretest (0.50 ± 0.17). There was no main effect ($P = 0.53$) for bipedal balance (0.24 ± 0.13 and 0.25 ± 0.12 for pretest and posttest, respectively).

DISCUSSION

The primary finding of this study was that the combination of long and cumulative work shifts yielded declines in performance abilities for nurses, particularly for vigilance-related (PVT) RT and unipedal balance measures. These results also demonstrated that no differences were observed in performance-based fatigue responses between day and night-shift work schedules. In addition, musculoskeletal symptom prevalence was prominent in both shift types; however, work shift specific disparities were observed for the low back and hip regions, with a higher prevalence reported in the day-shift workers.

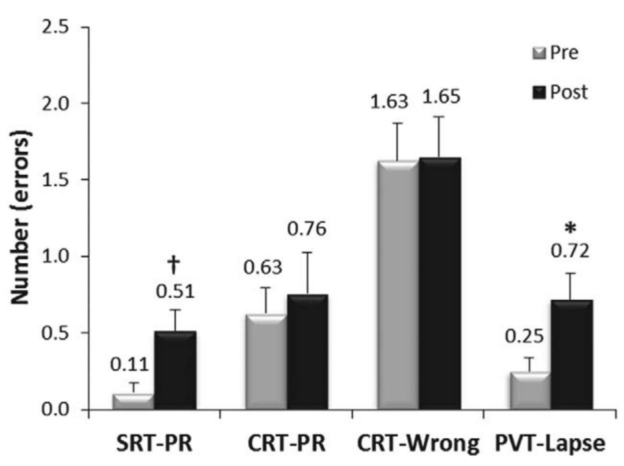

FIGURE 2. Work-induced changes from pretest to posttest for number of errors for the simple reaction time (SRT), choice reaction time (CRT), and psychomotor vigilance task (PVT) tests. CRT-Wrong, number of wrong responses for the CRT test; PR, Premature responses for the SRT (SRT-PR) and CRT (CRT-PR) tests; PVT-Lapse, number of minor lapses (500 to 1000 ms) for the PVT test. Values are mean $\pm$ SEM. *Significantly different from pretest at $P \leq 0.05$; †Significantly Significantly different from pretest at $P < 0.01$.

A novel finding of the present investigation was the observed changes in functional performance, for both shift types, following a demanding nursing work period specifically consisting of three 12-hour work shifts confined to a 4-day time period. The nursing work period induced an increase in response times for the mean (6.0%) and slowest 10% (10.9%) RT measures as well as an increase in the standard deviation (21.2%) for the mean RT variable for the PVT test. In addition, there was an increase in the amount of errors committed as a result of an increase in the number of premature responses (simple RT) and lapses of the PVT test; however, no differences were shown for the choice RT task for premature responses nor wrong response count. These findings highlight that RT performance, especially applicable to vigilance, is most predominantly affected in terms of both an elongated response time and a higher likelihood of making a response-related error, as a result of work-induced fatigue. These findings differ from Surani et al[16] who concluded that a 12-hour nursing work shift did not impair PVT RT outcomes and that total error changes were inconsistent; however, their study only examined a single work shift, as opposed to the present study that investigated the impact of accumulating work shifts (ie, three 12-hour shifts) on these RT measures. The combined findings of the present study and Surani et al[16] provide insight into the effects of work shift quantity/volume on these measures. Specifically, it appears that a single work shift may not induce fatigue-related impairments in response times, and that such impairments may only be observable following multiple shifts.

Accordingly, the influence of multiple/successive shifts on performance decrements may be a root cause for injury risks. Support for this may be found in the findings of Folkard and Tucker[10] who demonstrated the presence of a progressive and significant increase in injury incidents from successive shifts. These performance impairments should be considered to be of paramount importance to the profession of nursing, as exemplified by a previous author's declaration that nursing vigilance is the essence of ''attention to and identification of significant observations, risk calculation, and readiness to act to minimize risk and respond to threats.''[15] Errors are thus directly related to the state of vigilance, and such impairments, which compromise nursing performance, may impact not only the safety and well-being of the nurse but may also have detrimental consequences to the safety of the patient. With previous reports attributing hospital-based medical errors to approximately 400,000 lethal events and two to four million serious nonlethal adverse events per year,[30] the manifestation of reduced nursing vigilance and associated impaired response times, coupled with an increase in the likelihood of committing errors from such effects, should receive the focus and utmost attention of health care professionals, hospital administrators, and occupational researchers. In practical terms, these results indicate that a relatively simple, freely available computer-based RT test requiring only 5 minutes of test time may provide sensitive markers of work-related fatigue, particularly when used in the context of a long demanding multiple shift work period. However, further research is warranted to (1) substantiate these findings in the context of different nurse populations, shift types (eg, rotating shifts), nurse settings (eg, long-term care facilities vs home health care setting, etc.), and work schedule patterns (overtime, time periods of more or less than three work shifts, recovery time between work shifts, etc.), and (2) identify and/or develop other potentially sensitive fatigue assessment tools capable of meeting the requirements of being implemented on a large scale, in real-world health care facility settings.

The nursing work period also induced decrements in unipedal balance performance, which resulted in an increase in postural sway by 13.8%, although no changes were observed for bipedal balance. This may indicate that tasks that require more challenging postural stability positions may be at a higher risk for balance impairments (ie, those tasks that involve positions other than standing upright with two feet placed firmly on the ground). It also suggests that tests used for the purpose of identifying fatigue-related impairments in balance may be more sensitive when using more challenging tasks such as a unipedal versus bipedal test protocol. Previous findings have shown that postural stability may be impaired as a result of simulated occupational tasks such as repetitive box handling,[31] or repetitive overhead work,[32] and may effectively discriminate drowsiness-related postural control impairments in drivers working night shift.[33] Such findings may demonstrate that (1) postural stability may not only be compromised by general fatigue, but that whole-body postural consequences may also result from localized neuromuscular stress/fatigue,[32] (2) fatigue may be implied as a contributor to an increased risk of falling,[32,34] and (3) that certain interventions may be effective in mitigating fatigue-related impairments in balance and falls risk.[31] Although Sobeih et al[35] examined firefighters, their findings support the present findings in which they found that postural stability decreased across a long work shift, which prompted the conclusion that this may contribute to the high falls prevalence observed in firefighters. This model may also be applicable to nurses, as they also have a very high prevalence of falls, work very long hours, and demonstrate poorer balance performance than either construction workers or firefighters.[36] Moreover, postural balance was shown to be associated with physical work ability and capable of effectively predicting declines in work ability in firefighters over a 3-year follow-up period.[37] In addition to the reported work-related validity of balance abilities, the use of balance testing (typically assessed from a force platform) offers the advantages of cost-effectiveness, portability, and simplicity of testing (short duration, low exertion, and ease of use for subject and tester). However, although its use has been performed in various occupational populations, objectively based balance testing has neither been validated in nor practically applied to the full-time nursing worker population. Thus, future research may consider exploring the use of this testing modality and its capability of being used as a fatigue and/or performance evaluation tool in nurses to help prevent the high incidence of slips, trips, and falls while on the job. Finally, acute sleep loss patterns may also impact postural stability,[38] which may be an undesirable effect of successive work shifts, although this theory needs to be validated with research in nurses working irregular types of shifts, as well as the influence that various levels of recovery may have on restoring balance function.

The present findings confirm the general consensus of a high prevalence of musculoskeletal symptoms for nurses. The most commonly reported symptom was the lower back region (39% and 17.1% for 12 months and 7 days, respectively), followed by the ankles/feet (24.4% and 12.2%) and the knees and shoulders (22% each for 12 month). These frequencies for specific body regions are similar to previous reports for several of the investigated body regions (ie, low back, knees, hips, ankles/feet),[39,40] but somewhat lower than the general trend previously reported (ranging from ~36% to 55% for annual prevalence of several of the same body regions, averaged across a multitude of studies for each region) in nursing populations.[20] Differences between the musculoskeletal symptom frequencies of the present study and other study findings may be due to rather large variations in nurse demographics, work organization characteristics, unit and health care facility types, geographical locations, as well as the wide range of definitions, intensity thresholds, and durations used to categorize musculoskeletal disorders among the many different studies.[20,41] It is also notable that a large majority of the nurses in this study had experienced at least one symptom within the past 12 months (75.6%) or 7 days (51.3%), which further substantiates the magnitude of musculoskeletal problems in these workers.

An important finding was the higher musculoskeletal symptom prevalence for the day than the night-shift workers specifically for the lower back (28.6% vs 5%, respectively, for 7 days) and hip/thigh regions (23.8% vs 0% for 12 months). This finding was somewhat unexpected, in light of the previous studies that have reported that nonday shift schedules have been found to be a risk factor for injuries.[17,19,42] However, upon closer examination, none of these studies specifically examined disorders of the hip region, leaving a gap only filled by the present study regarding this particular body region. Moreover, Stimpfel et al[42] had only examined newly licensed RNs, which may be unaccustomed to the novelty of night-shift work patterns, and Lipscomb et al[19] revealed that shift work was only associated with musculoskeletal disorders when specifically combined with a weekend work schedule. On the contrary, Burdelak et al[43] found no differences for any diseases or conditions, including chronic back pain, between night and day-shift nurses. Thus, the present findings are apparently unique in the literature showing a potential higher risk for day shift workers for these two specific regions. Although the authors reported an increased injury risk for night versus day-shift workers, Stimpfel et al[42] presented some night shift-specific work characteristics that could provide certain aspects of night shift with a lighter workload, such as lowered interprofessional patient rounding, reduced testing and procedures, and less visits from physicians/therapists. To this point, we add anecdotal support to this rationale, arising from the nurses in the present study whom had experienced working both day and night shifts during their career, having noted that they had perceived day shifts to be ''more difficult'' than night shifts due to a generally heavier and faster paced workload. However, this claim has not been investigated, and is actually the opposite of the hypothesis proposed by de Castro et al[17] suggesting potentially more demanding job characteristics for the nonday shifts. We therefore can only speculate as to the reasons for the higher back and hip/thigh musculoskeletal symptoms for those working the day shift. Although higher workload factors for day shift schedules is an appealing explanation given that this may be a result of shift-specific job differences such as more patient transfers, a higher proportion of time spent on their feet walking or performing other miscellaneous tasks, we must consider the possibility of other factors influencing the present findings. For example, the healthy worker effect may be an influencing factor[43] due to the unique occupational features of shift work in health care. Specifically, the women who are generally healthier and more robust to injuries may better tolerate the unique demands of night shift work, whereas those who are less tolerant may switch to day shifts.[43] This theory, however, could work in the opposite direction as well, if nurses in some units/facilities perceive the day shift to be the more rigorous schedule, making a change to night shift would be an application of the healthy worker effect in reverse; however, the present study design was not able to control for the healthy worker effect, and this should be considered in future research. There is also a pressing need for more research capable of elucidating differences in physiological workload and hazardous exposure characteristics between day compared with night-work shift schedules.[17] It is noteworthy that the nurses in the present study all worked 12-hour shifts, and we propose the possibility of a shift length exposure threshold, which above such a point could theoretically increase injury risks regardless of work shift type. It may be that working a 12-hour shift is a dominant factor for injury risks, and the type of shift worked is only secondary to this predominant factor.

CONCLUSIONS

These findings collectively highlight that both day and night-shift workers are at risk for work-related musculoskeletal injuries and performance-based fatigue from demanding schedules. A key feature of this study was that these changes were demonstrated objectively using physical performance-based measurements, and not solely based off of self-reported or perceived functional status. The combination of both slowed response times and impairments in postural stability may be particularly detrimental to performances that require rapid responses to bodily perturbations (eg, recovery from a slip, reacting to a patient emergency, etc.). This may in turn be linked to the high prevalence of falls in the nursing field. Interventions and programs aimed at minimizing injury risks and managing fatigue should involve equal application and implementation to nursing workers regardless of the type of shift worked. These interventions may focus on preventing declines of performance traits (eg, RT and balance) through physical training, manipulating job-specific scheduling and/or physical workload features, nutritional/ergogenic considerations, or a combination of these in an attempt to improve nurses' health and well-being. More research is needed specifically in full-time nurses to determine the most effective fatigue identification and management strategies capable of being incorporated into health care work settings.

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