Physiological and behavioural response patterns at work among hospital nurses

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Aim The aim was to determine whether hospital nurses are experiencing physiological strain at work by examining their physiological and behavioural response patterns over 12-hour shifts.

Background Excessive workload for nurses may lead to poor quality of care and high nursing turnover rates. Energy expenditure (EE), heart rate (HR) and work pace (WP) can be used to examine the physiological impact from the workload.

Methods A total of 145 nurses wore monitors for one 12-hour day shift to record HR and WP, which were used to calculate EE. Individual and work-related factors were assessed through questionnaires and work logs.

Results Energy expenditure accumulated over the 12 hours reached the EE level of 8-hour shifts in which individuals work at a moderate physical intensity level. The HR data indicated a moderate cardiac stress level throughout the shifts, despite which WP decreased after 15.00 hours. Inadequate work break and sleep, family care-giving responsibility and aging may challenge work recovery.

Conclusions Nursing workload of 12-hour shifts has a negative physiological impact on hospital nurses.

Implications for nursing management Nurse managers need to be aware of the physiological strain experienced by staff nurses, and focus on ensuring sufficient breaks and proper work accommodations for older nurses.

Keywords: energy expenditure, heart rate, nursing workload, shift work, work pace

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Introduction

Hospitals in the USA are experiencing a severe nurse shortage (US Department of Health and Human Services [HHS] 2002, Goodin 2003), which in turn can lead to poor quality of patient care and high nurse turnover rates (Buerhaus & Needleman 2000, Aiken *et al.* 2002). While the necessity of legislating staffing levels is still debated (Vessey *et al.* 2002, Donaldson *et al.* 2005), it has received overwhelming support from

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bedside nurses (California Nurses Association & National Nurses Organizing Committee 2008). Such a reaction indicates a significant need to protect nurses from excessive workload (Keepnews 2005).

The reality in today's hospitals is that too few nurses take care of too many critically ill patients; nurses often describe their work as 'heavy,' 'overwhelming,' 'busy' and 'exhausting' (Gaudine 2000, Joint Commission on Accreditation of Healthcare Organizations 2002, Geiger-Brown *et al.* 2004). Although the American Nurses Association (2005) did point out that nurses' work health should be evaluated periodically for the consideration of staffing adequacy, little empirical data are available on the physiological impact of current workload on hospital staff nurses during daily shifts.

An acceptable level of workload is defined as a level that an individual is able to sustain for a given work shift in a physiologically steady state without fatigue or discomfort (Wu & Wang 2001). When the workload moves beyond the acceptable level, physiological strain (e.g. elevated heart rate) and adaptive behaviours (e.g. slower pace) may occur, adversely impacting individuals' well-being and work performance (Goldstein *et al.* 1999, Caruso *et al.* 2004). Identifying whether workloads exceed the physiological limits is imperative to the determination of workload allocation and shift scheduling (Mathiassen & Winkel 1996, Saha *et al.* 2008). The purpose of this study, therefore, was twofold: (1) to describe the physiological and behavioural response patterns at work among hospital nurses, and (2) to determine whether hospital nurses are experiencing physiological strain at work.

Background

The physiological responses at work refers to the internal responses within the body that regulate physiological processes in an optimal way to adapt to the demands of the work environment (Gaillard & Kramer 2000). While the capacity for performing a job is determined primarily by cardiovascular, pulmonary, nervous, musculoskeletal, endocrinal and other regulating body systems, both individual intrinsic characteristics (e.g. age, sex, body fitness, health conditions) and work-related factors (e.g. workload intensity, shift duration, nature of the work) can modify physiological functions and work performance (Astrand *et al.* 2003). Monitoring of physiological and behavioural responses over a period of time at work, therefore, allows for the observation of a dynamic adjustment process occurring in the human body in response to the changing workload (Fahrenberg & Wientjes 2000).

Energy Expenditure (EE) has been a well-accepted parameter for evaluating the physiological impact of the workload. Previous studies of nursing activities (Irimagawa *et al.* 1991, 1993, Garcia 1993, Irimagawa & Imamiya 1993a, Wakui 2000, Wakui *et al.* 2002) measured EE spent at work by tracking heart rates (HRs) via the HR–oxygen uptake relationship. Sample sizes for these studies, however, ranged only from 1 to 20, being highly restricted by the complex techniques required for assessing individual HR–oxygen uptake linear relationships (Rennie *et al.* 2001). In recent years, a newly developed technique combining accelerometer with HR telemetry has made it possible to measure EE in population-based studies (Strath *et al.* 2005). Furthermore, this method yields a more precise estimate of EE than when tracking HR alone, as an accelerometer can help to differentiate between physical activity and other factors (e.g. emotion and caffeine) that interfere with HR readings (Strath *et al.* 2001, 2002). The present study applied this technique to assess the EE for nurses in hospital settings.

Heart rate is a common physiological parameter used to evaluate workload in field studies. Hui *et al.* (2001) and Nuikka *et al.* (2001) paired working HRs with different nursing activities among hospital nurses, and reported HRs ranging from 79 to 129 beats per minute (bpm). Importantly, HR also can be calculated to $\%HR_{max}$, the percentage of maximal HR. This method is used to evaluate cardiac stress level by taking into account the effects of individual cardiorespiratory fitness (Panter-Brick 2003). Nuikka *et al.* (2001) reported a reverse correlation between $\%HR_{max}$ and cardiorespiratory fitness among hospital nurses. Regardless of cardiorespiratory fitness status, positive correlations between HR and the strenuousness of patient handling activities were seen in a number of studies (Wakui 2000, Nuikka *et al.* 2001, Wakui *et al.* 2002). Based on these findings, HR was chosen as an important indicator of physiological responses to nurses' work in the present study.

Work pace (WP) was measured using pedometers to count the number of walking steps per shift in a number of studies of nursing activities (Garcia 1993, Irimagawa & Imamiya 1993b, Takahashi *et al.* 1999, Wakui 2000, Wakui *et al.* 2002). Some studies suggested that nurses can self-pace themselves to cope with long working hours. For example, based on the counts of steps measured, Takahashi *et al.* (1999) reported slower pace throughout 16-hour night shifts than throughout 8-hour evening and night shifts. Szczurak *et al.* (2007) found that nurses working 12-hour shifts reported increased fatigue during the end of the shifts when compared with those who worked 8-hour shifts. They suspected that nurses decreased their work activities at the end of the 12-hour shifts to cope with fatigue. Reid *et al.* (1993) conducted an observational study, and confirmed that during the last quarter of the shifts, while direct patient care increased and unofficial breaks decreased for 8-hour shifts, direct patient care decreased and unofficial breaks increased for 12-hour shifts. As both Szczurak *et al.* (2007) and Reid *et al.* (1993) did not control for the workload levels during the first 8 hours and last 4 hours of the 12-hour shift, it is undetermined whether it was fatigue rather than decreased workload slowing down nurses' WP during the last hours of the shift. Rogers *et al.* (2004) suggested that when workloads are heavy, nurses who work extended hours do not always have control over the pacing. They found that the nurses who worked longer shifts were more likely to have shorter breaks or no breaks than were those working shorter shifts.

In the present study, WP was considered as nurses' behavioural response to their workload, as measured by accelerometers. Unlike the pedometer, the accelerometer records not only the total number of body movements, but also the frequency, intensity, and duration of the activities (Westerterp 2009).

Methods

Research questions

The research questions for the study were:

- What are the levels of EE, HR and WP among hospital nurses who work 12-hour day shifts?
- How do EE intensity, HR, and WP during the first 8 hours of the 12-hour shift compare with the last 4 hours of the shift for hospital nurses?

Design

The study was a non-experimental, descriptive study. Physiological and behavioural responses to work were measured by continuously tracking nurses' EE, HR, and WP over their 12-hour shifts (07:00–19:30 hours). Questionnaires and work logs were used to collect data on the individual and work-related characteristics of the sample. Participant recruitment and data collection were conducted from May to August in 2007.

Sample

The study was conducted in three acute care community hospitals located in a Midwestern area. The hospitals ranged in size from 550 to 700 beds, and each of them employed a total of 600–700 full-time-equivalent registered nurses (RNs). Convenience sampling was used in the recruitment of participants. While convenience sampling always involves a risk of bias, efforts were made by recruiting participants from a variety of units to appropriately represent the population of hospital nurses. The study units included three types: medical–surgical (i.e. orthopaedic, rehabilitation, oncology and gerontology units), telemetry and step-down units (i.e. post-intervention recovery, neurology and progressive care units). The inclusion criteria for participation were: (1) female RNs; (2) without a second job; (3) in healthy condition without work restriction and not regularly taking medications for treatment of arthritis, cardiovascular disease, insomnia, depression, or anxiety.

A preliminary check showed that the percentages of the differences in EE, HR and WP between 08.00–15.00 hours and 15.00–19.00 hours time-periods from EE, HR and WP during 08.00–15.00 hours were 0.9, 0.7 and 6.6%, respectively (n = 16 shifts, $P > 0.1$). Based on a formula provided by Eng (2003), a sample size of 125 is needed to detect 5–10% differences in HR, EE and WP between the two time-periods with a power of 0.80 ($P = 0.05$). To ensure that the target sample sizes were achieved, 150 participants were recruited for the study. The physiological and behavioural responses were measured over one 12-hour shift for each of the participants. To eliminate accumulating effects from previous working days, participant's first day back to work from off-days was chosen as the shift to be monitored, and it may have fallen on any day during a week.

Ethical considerations

Study approvals were granted by the Institutional Review Boards of the University of Cincinnati and participating hospitals. The researcher attended unit staff meetings to explain the study and recruit participants. Recruitment flyers were posted in staff lounges. Before the data collection, participants read and signed the consent forms. They were informed that all information collected in the study would be treated confidentially.

Measurements

Physiological and behavioural responses – HR, EE and WP

Actiheart™ (Cambridge Neurotechnology Ltd, Cambridge, UK) is a lightweight (12 g), non-intrusive, single device combining the functions of heart monitor and accelerometer (Brage *et al.* 2005). The device can be attached onto participants' chests through two electrodes to pick up the electrocardiogram and body movement signals.

The participants' HRs were sampled by the device once every 15 seconds, within a sensing range of 35 to around 225 bpm. Every four readings were averaged and then registered as HR per minute. Vertical body (including extremities) movements of the participants were sampled 32 times in an epoch of 15 seconds and summed as movement counts per minute, which represents WP. The corresponding data regarding the intensity and duration of the body movements were also recorded (Cambridge Neurotechnology Ltd 2006).

The data stored in the Actiheart™ were downloaded into a database in a computer. The HRs and activity data, along with age, gender, height, weight and resting HR, were used to calculate EE in a branched equation model through the Actiheart™ Application Program software. Because resting HR is most stable during sleep, the participants were asked to wear the Actiheart™ during sleep one time when off duty to obtain their sleeping HRs. The 10th lowest observation of HRs during the night was chosen as resting HR baseline (Brage *et al.* 2005).

Actiheart™ is a technically reliable and valid instrument in measuring EEs of a wide range of free-living activities (Brage *et al.* 2005, Thompson *et al.* 2006, Crouter *et al.* 2008). Actiheart™ was validated against a doubly labelled water calorimetric technique, the gold standard for measuring EE in field settings, showing no difference between the two methods for EE estimates (Assah *et al.* 2010).

Individual factors

In a questionnaire, information regarding age and family care-giving responsibility were collected. The question, 'Do you have children under 13 years old or elders with limited level of daily living activity to be taken care of at home?' (response choices = yes/no) measured family care-giving responsibility. All the participants were weighed by the same calibrated, digital weight floor scale. Body mass index (BMI) was calculated to represent physical fitness status. Information regarding ethnicity, type of the unit and employment status (full time or part time) were collected when the researcher met with the participants.

Work-related factors

During the monitored shifts, the participants completed work logs to report their hours of sleep at the night before the shift, body discomfort bothersome to their work during the shift, time and length of breaks, and perceived heaviness of workload for the current shift compared with their past shift experiences. These items were chosen based on the literature of work health in nurses (Barak *et al.* 1996, Trinkoff *et al.* 2001, Rogers *et al.* 2004, Scott *et al.* 2006). The researcher met with participants to explain the terminology used in the work log, such as 'body discomfort' and 'workload.' The question for body discomfort at work was 'Do you currently have body discomfort that is bothering your work?', and the response choices were 'yes' and 'no'. The question for perceived workload was 'Please rate your workload today compared with your past shifts by choosing a number from 0 to 10 (10 is the heaviest).' The participants marked their ratings on a visual analogue scale (DeVellis 2003) at the end of their shifts. The participants also recorded the time and durations of their breaks during the shifts. 'Breaks' refer to official intervals approved for withdrawal from nursing duties, such as meal breaks and taking time off from the floor.

Data analysis

Statistical analyses were undertaken using Statistical Package for Social Sciences 15.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to summarize the characteristics of individual and work-related factors, EE, HR and WP. Resting metabolic rate (RMR) was estimated for the individual based on weight, height and age (Mifflin *et al.* 1990), in order to calculate metabolic equivalent (MET) (multiples of RMR), which is one measure for EE intensity. The $\%HR_{max}$ was calculated by the percentages of working HR to maximal HRs (maximal HR = 220 − age) for each of the participants to examine the cardiac stress level.

Because it was necessary to adjust the placements of the Actiheart™ device between 07.00 and 08.00 hours of the monitored shifts, only 7 hours were used to make up the first time-period (08.00–15.00 hours) of the 12-hour shift. Paired samples *t*-tests compared three parameters – EE intensity, HR, and WP, between 08.00–15.00 hours and 15.00–19.00 hours time-periods. If differences by time-period were detected for EE, HR and/or WP, one-way ANOVA, independent sample *t*-test, and Pearson correlational analyses were planned to be conducted with EE, HR and/or WP and ethnicity, unit, hospital, employment status, family burden, body discomforts, age, BMI, sleep hours before shift, break duration and perceived workload, respectively. Then repeated-measures ANCOVA were performed using the variables related to EE, HR and/or WP as covariates, to examine how these variables along with the within-subject factor, time period, contributed to the identified changes in the parameter(s). The significant level was set at $P < 0.05$ for all the statistical tests.

Results

Characteristics of the sample

Of 150 participants, 145 provided complete data useable for data analysis (non-Magnet hospital 1 = 56, non-Magnet hospital 2 = 46, and Magnet hospital 3 = 43). Data for five participants were excluded because of a significant number of missing signals for HR and WP. The characteristics of the sample are summarized in Table 1.

Compared with the results for hospital RNs in 2004 National Sample Survey, the mean age of the sample was younger (37.8 *vs.* 43.3 years) and the percentage of African-Americans was higher (12.4 *vs.* 4.2%) (HHS 2006). The prevalence of obesity among the sample was higher than that in US female population (33.8 *vs.* 24.8%) (The Centers for Disease Control and Prevention 2008).

The typical RN-to-patient ratios for the monitored shifts were 1:4–5 for medical-surgical units, 1:3–4 for telemetry units and 1:2–3 for step-down units. Compared with past shift experiences, participants rated the perceived workload of their monitored shift as an average of 5.6, which well represented the workload level in a typical shift. While the participants slept 6.1 hours, on average, during the preshift night, a majority (69.7%) of them took breaks for <1 hour during the shift. Of the participants, 46% took only one break, and 5% took no breaks. The sleep hours before the shift ($r = -0.18$; $P = 0.029$) and duration of break ($r = -0.17$; $P = 0.044$) were negatively correlated with perceived workload. Interestingly, participants working in the Magnet hospital took significantly longer breaks than those working in the other two hospitals ($F_{(2,142)}$ 9.89; $P < 0.001$). In addition, age was positively correlated with BMI ($r = 0.26$; $P = 0.002$), and negatively correlated with sleep hours before the shift ($r = -0.25$; $P = 0.003$) and duration of break ($r = -0.22$; $P = 0.009$). The mean age of the nurses who experienced body discomfort during the shift ($t_{(143)}$ 3.125; $P = 0.002$) was higher than that among those without discomfort at work.

Table 1
Individual and work-related characteristics ($N = 145$)

Variable	*Mean*	*SD*	*n* (%)
Ethnicity			
Caucasian			121 (83.4)
African American			18 (12.4)
Asian and Pacific Islander			4 (2.8)
Hispanic			2 (1.4)
Age (years)			
22–30	37.8	10.4	61 (42.1)
31–40			29 (20.0)
41–50			38 (26.2)
51–63			17 (11.7)
Employment status			
Full time (≥36 hours per week)			126 (86.9)
Part time (<36 hours per week)			19 (13.1)
Unit			
Medical–surgical			72 (49.7)
Telemetry			60 (41.4)
Step-down			13 (8.9)
Body mass index			
<18.5	27.9	6.7	3 (2.1)
18.5–24.9			53 (36.5)
25.0–30.0			40 (27.6)
>30.0			49 (33.8)
Family care-giving responsibility			
Yes			67 (46.2)
No			78 (53.8)
Body discomfort at work			
Yes			59 (40.7)
No			86 (59.3)
Preshift sleep hours			
3–4	6.1	1	11 (7.6)
5–7			122 (84.1)
8–10			12 (8.3)
Break duration (minutes)			
0–29	44.0	20.4	27 (18.6)
30–59			74 (51.1)
60–95			44 (30.3)
Perceived workload (10-point scale*)			
1–3	5.6	1.8	19 (13.1)
4–6			78 (53.8)
7–10			48 (33.1)

*Scale: 0 = lightest, 10 = heaviest.

Physiological and behavioural responses at work – EE, HR and WP levels

For the 145 monitored 12-hour shifts, the average measurement time per shift was 11 hours and 29 minutes. Based on calculated RMRs for individual participants, the total energy cost (including energy spent on basal metabolism, physical activity and food consumption) spent on 12-hour shift was estimated as, on average, 1454.4 kcal (SD ± 410.5). The EE intensity was 0.028 kcal/kg per minute (or 2.11 kcal/minute), or 1.91 METs. According to a physical intensity classification method commonly used to evaluate occupational activities (light, <3 METs; moderate, 3–6 METs; heavy,

>6 METs) (Pate *et al.* 1995), while the physical intensity was low for nursing activities, the total EE over the monitored 12-hour shifts (1.91 METs × 12 hours = 22.9) almost reached that of 8-hour shifts in which individuals work at a moderate physical intensity level (3 METs × 8 hours = 24).

The average HR for 12-hour shifts was 96.9 bpm (SD ± 15.8). About 36% of nurses experienced average HRs of above 100 bpm during their shifts. The average $\%HR_{max}$ values ranged from 52.7 to 53.9% during 08.00–19.00 hour period, indicating a moderate cardiac stress level (low, <49%HR_{max}; moderate, 50–69%HR_{max}; high, >70%HR_{max}) (HHS, 1996).

The average amount of physical activity was 20 158 (SD ± 8222) counts per shift, which equals 29.3 counts per minute, as WP level. If 1/3–1/2 of the body movements represented walking steps, and 2000 steps/mile is assumed, these nurses walked approximately 3.4–5 miles per shift.

The correlational analysis indicated that the EE intensity were highly correlated with HR ($r = 0.77$; $P < 0.001$), and moderately correlated with WP ($r = 0.39$; $P < 0.001$). These results were expected, as HR and WP were the major contributing factors to the estimate of EE. The correlation between HR and WP, however, was found to be significant but weak ($r = 0.24$; $P = 0.003$). The patterns of HR and WP during an 08.00–19.00 hour period are shown in Figure 1. The two lines demonstrating the mean HR and WP paralleled each other during most of the shift. In contrast to a gradually decreasing trend in WP, HR constantly stayed at 97–98 bpm except for 12.00–13.00 hours and 16.00–17.00 hours. Although WP was climbing during 14.00–17.00 hours, it stayed at the level found during the lunch-break period (11.00–13.00 hours). HR decreased to the lowest point for the shift at 4–5 p.m., then increased to around 97 bpm again during 5–7 p.m.

Comparisons of EE intensity, HR and WP between 08.00–15.00 hours and 15.00–19.00 hours

Data from 142 participants with complete recordings of HR and WP from 08.00 to 19.00 hours were used to compare EE intensity, HR, and WP between 08.00–15.00 hours and 15.00–19.00 hours. Results of the comparisons of the two time-periods along with the paired sample *t*-tests are presented in Table 2. While WP for 08.00–15.00 hours was significantly higher than that for 15.00–19.00 hours, ($t_{(141)}$ 2.72; $P = 0.007$), EE intensity ($t_{(141)}$ 1.67; $P = 0.097$) and HR ($t_{(141)}$ 0.71; $P = 0.478$) did not differ significantly between the two time-periods. Therefore, the slowing down of the WP while EE intensity and HR remained constant for the second time-period indicates that the physiological impact from the workload was unchanged for the two time-periods.

When examining the differences in WP based on individual and work-related variables, independent sample *t*-test analysis revealed that WPs of full-time nurses (28.2 counts/minute) were significantly lower than that of part-time nurses (34.6 counts/minute) ($t_{(143)}$ −2.347; $P = 0.020$). No significant differences were identified for ethnicity, unit, hospital, family burden and body discomforts to the changes of WP. As the majority of the participants worked full time, Pearson correlation analysis was conducted only for full-time nurses ($n = 123$). As presented in Table 3, WP was not correlated with BMI, sleep hours before the shift and duration of break, but was negatively correlated with age ($r = -0.24$; $P = 0.009$), and positively correlated with perceived workload ($r = 0.20$; $P = 0.027$). Tables 4 and 5 show the full-time nurses' WPs in 08.00–15.00 hours and 15.00–19.00 hours based on perceived

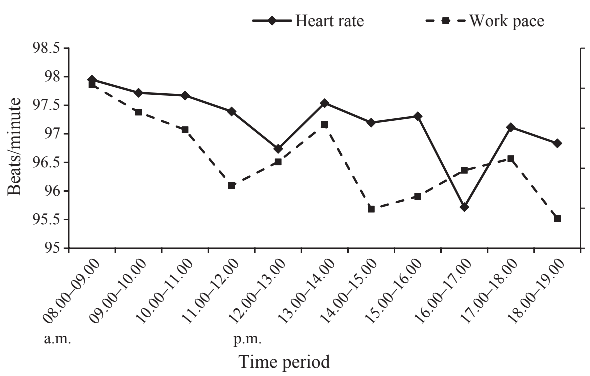

Figure 1
Heart rate and work pace during the 08.00–19.00 hours period.

Table 2
Comparisons of energy expenditure (EE), heart rate (HR) and work pace (WP) between 08.00–15.00 hours and 15.00–19.00 hours periods

Shift period	*EE intensity (kcal/kg per minute)* Mean (SD)	*HR (bpm)* Mean (SD)	*WP (counts/minute)* Mean (SD)
08.00–15.00 hours	0.0278 (0.006)	97.5 (15.4)	29.9 (12.6)
15.00–19.00 hours	0.0273 (0.006)	96.8 (18.2)	28.0 (11.7)
t-Statistics	1.67	0.71	2.72**

**$P < 0.01$.

Table 3
Pearson correlations between work pace (WP) and sample characteristics among full-time RNs (N = 123)

	WP	
Variables	*r*	*P*
Age	–0.24	0.009**
Body mass index (BMI)	–0.09	0.335
Preshift sleep hours	0.08	0.380
Break duration	–0.03	0.741
Perceived workload	0.20	0.027*

*$P < 0.05$, **$P < 0.01$.

Table 4
Comparisons of work pace (WP) between 08.00–15.00 hours and 15.00–19.00 hours periods by perceived workload among full-time RNs (N = 123)

	WP (count/minute)		
Perceived workload	*08.00–15.00 Hours, mean (SD)*	*15.00–19.00 Hours, mean (SD)*	*n*
1	20.4 (0.5)	21.5 (3.0)	2
2	21.6 (13.4)	24.9 (15.2)	4
3	19.8 (5.8)	19.8 (7.6)	7
4	33.9 (8.0)	29.0 (8.0)	15
5	30.3 (12.5)	26.8 (9.6)	36
6	29.7 (12.7)	29.0 (10.8)	17
7	34.8 (13.6)	33.2 (13.9)	18
8	28.6 (13.1)	28.2 (15.8)	17
9	28.6 (14.3)	29.2 (14.0)	6
10	42.4	53.2	1

Table 5
Comparisons of work pace between 08.00–15.00 hours and 15.00–19.00 hours periods by age among full-time RNs (N = 123)

	WP (count/minute)		
Age (years)	*08.00–15.00 Hours, mean (SD)*	*15.00–19.00 Hours, mean (SD)*	*n*
20–29	32.5 (14.5)	30.7 (13.4)	41
30–39	30.0 (9.6)	26.8 (8.7)	29
40–49	27.3 (12.6)	26.8 (11.8)	36
50–59	30.9 (8.2)	29.5 (11.9)	13
60–69	14.7 (7.1)	14.5 (6.1)	4

workload level and age, respectively. The WP during 15.00–19.00 hours decreased for perceived workloads ranging from 3 to 8, but increased for workloads rated as 1, 2, 9 and 10. While WP decreased during 15.00–19.00 hours for all the age-groups, nurses older 60 years were noted to have significantly lower WP than that of other age groups. However, the repeated-measures ANCOVA indicates that the difference in WP between 08.00–15.00 hours and 15.00–19.00 hours was not significantly associated with either time-period (Wilks' lambda 0.98; $F_{(1)}$ 2.725; $P = 0.101$) or its interactions with age (Wilks' lambda 0.995; $F_{(1)}$ 0.61; $P = 0.438$) or perceived workload (Wilks' lambda 1.00; $F_{(1)}$ 0.599; $P = 0.440$).

Discussion

Hospitals are required to provide a 24-hour service system to ensure the continuity of health-care delivery. While the 12-hour shift system has evolved into a widely accepted standard of hospital staffing, it is important to balance nursing preferences with protecting safe practice from fatigue (Lorenz 2008, Geiger-Brown & Trinkoff 2010). There are increasing concerns regarding the negative effects of 12-hour shifts upon nurses' well-being and work performance (Fitzpatrick *et al.* 1999, Wilson 2002, Trinkoff *et al.* 2006, Keller 2009, Geiger-Brown & Trinkoff 2010). The EE and HR data presented in our study reveal a moderate physiological strain experienced by 12-hour shift nurses, regardless of their slowed paces during the last 4 hours. Moreover, inadequate work break and sleep, family care-giving responsibility and aging presented challenges that may have prohibited nurses from full recovery and potentially exacerbated the negative impacts of 12-hour shifts.

The physical intensity estimated in our study appears to correspond to the characteristics of physical activities in hospital nurses. Although lifting and transferring patients are the most strenuous work (Garg *et al.* 1992, Engels *et al.* 1994a,b, Marras *et al.* 1999), they are relatively short and infrequent when compared with other activities over a shift period (Ilmarinen *et al.* 1991, Nuikka *et al.* 2001). Bending, standing, and walking have been recognized as the typical physical activities among hospital nurses. For example, performing nursing care at bedside involves frequent bending and standing, and locating equipment, supplies, charts and personnel require considerable amount of walking in the units (Welton *et al.* 2006, Freitag *et al.* 2007, Upenieks *et al.* 2007). According to a number of time studies (Garcia 1993, Engels *et al.* 1994a,b, Jansen *et al.* 2001, Frings-Dresen & Sluiter 2003, Freitag *et al.* 2007), the percentages of working time spent in weight-handling, bending and standing/walking among hospital nurses were 0.6–1.6, 20–25 and 62–91%, respectively. As bending, standing and walking in habitual work style are low in EE intensity (Ainsworth *et al.* 1993, 2000), the physical intensity level could be low for the majority of the nursing activities.

Studies showed that the cumulative energetic impact of low-intensity physical activities over long period is greater than that of high-intensity activities in short period (Panter-Brick 2003, Levine 2004). Light-intensity activities may become heavy when workers are exposed to prolonged working hours and insufficient recovery (Panter-Brick 2003). Frequent resting over prolonged working hours has been recognized as an effective strategy to alleviate fatigue, as a small cycle of work–rest allows an efficient compensation for oxygen requirement by work activities (Panter-Brick 2003, McArdle *et al.* 2007). Many state laws mandate that workers receive a break every 4 hours in addition to the meal period (US Department of Labor 2010a,b). While nurses' EE spent in 12-hour shift estimated in our study was at moderate level, about half of the nurses only took one break or even no breaks over a shift. The inadequate break reported in our study is consistent with the study of US hospital RNs by Rogers *et al.* (2004), who reported the total duration of the breaks for 12-hour shifts ($n = 2437$ shifts) were 40 minutes with/without duties. In addition, we found that nurses who took shorter breaks and/or slept less reported higher perceived workload. We suspect that the heavy workload kept nurses from taking breaks, and fatigue unrelieved by insufficient sleep and breaks exacerbated the perceived workload. The average hours of sleep before the shift reported in our study is similar to the average of 6.7 hours reported in a study using a national random sample ($n = 895$) of hospital RNs (Scott *et al.* 2007). Family care-giving responsibility may keep nurses from getting sufficient rest before their shifts. Scott *et al.* (2006) and Watanabe *et al.* (2004) found that nurses caring for children and elders at home were more likely to be sleep-deprived than single nurses. Furthermore, if nurses need to take care of family members at home right after the shifts, they will spend additional energy by the end of the working day.

A comparison between 08.00–15.00 hours and 15.00 –19.00 hours reveals that WP significantly decreased after 15.00 hours, which is in line with the findings of Reid *et al.* (1993) study. The results indicated a drop in HR between 16.00 and 17.00 hours while WP stayed at a level similar to that during lunch break. Two reasons, separately or in combination, may account for these findings. First, workload decreased during period 16.00–17.00 hours. Second, nurses were trying to slow down during this period, in order to save energy to become busy again during the last 2 hours of the shift. Slowing down after 15.00 hours, however, was not observed from the nurses with heavy perceived workloads. Furthermore, despite potential pacing efforts, nurses' unchanged EE intensity and HR levels throughout the shift suggest a persistent physiological impact from the workloads. In addition, considering that over one-third of the nurses experienced average working HRs of above 100 bpm and moderate cardiac stress level shown in our study, hospital nurses may be at the risk for cardiovascular disorders, especially if they are overweight or obese (Wei *et al.* 1999, Singh 2003, Savonen *et al.* 2007).

A steady trend of aging has been indicated among the nursing work force in the US (HHS 2002). Over the next decade, the largest cohorts of RNs are projected to be between the ages of 50 and 69 years, if numbers of younger women choosing nursing as a career continue to decline (Buerhaus *et al.* 2000). Acknowledging the value of older RNs with respect to expertise, skills and knowledge, scholars collaborating with hospitals are making efforts to retain older RNs employed in acute care settings (The Lewin Group, Inc. 2009). Some studies stated that high work pace, demanding physical workload and personal health conditions were the major work challenges for older nurses (Keran *et al.* 1994, Andrews *et al.* 2005, Chiu *et al.* 2007, Cameron *et al.* 2009). There is evidence that older nurses favour working 8-hour rather than 12-hour shifts (Hoffman & Scott 2003, Trinkoff *et al.* 2006). In our study, older nurses working 12-hour shifts had less recovery time, had poorer body fitness and were more likely to experience body discomfort at work than their younger counterparts. Furthermore, we found that nurses aged above 60 years worked at a significantly slower pace than did nurses in other age groups. These findings indicate a need for health promotion interventions and work accommodation for older bedside nurses.

Implications for nursing management

Our results related to EE and HR suggest that nursing workload of 12-hour shifts has a negative physiological impact on nurses. This finding may have far-reaching effects with respect to legislations focusing on both length and workload intensity of the shifts for hospital nurses. First, mandated work–rest schedules may need to be instituted into health-care facilities, as self-regulation fails to provide sufficient breaks to guard against physiological strain throughout the shift. In our study, the nurses working in the Magnet hospital took longer breaks than those in non-Magnet hospitals, which may indicate organization-wide cultural impact on self-care behaviours in nurses. In addition, the nurses who have family care-giving responsibilities at home should be encouraged to avoid working consecutive 12-hour shifts, to ensure a full recovery between the shifts. Second, as the nursing workforce continues to age, special focus will need to concentrate on limiting the physical and psychological workloads that may significantly increase physiological strain on nurses. To promote well-being among older staff nurses, nurse managers may consider providing flexible shift hours, ergonomic modifications, wellness programs, and transferring older nurses from bedside nursing to mentoring younger RNs (The Lewin Group, Inc. 2009).

Limitations

First, although Actiheart™ is a valid and reliable instrument measuring EE in a range of free-living activities, there is a need to validate the sensitivity of the Aciheart™ technique in measuring nursing activities in various health-care settings. Second, we found weak correlations between HR and WP as well as between perceived workload and WP. Considering that HR and WP can be influenced by biological, behavioural and environmental factors at different levels of strength, we suggest that future studies evaluate a wide range of the sources in hospital environment for their potential effects on nurses' physiological status and behaviours. For example, Morrison *et al.* (2003) reported that noise, caffeine intake, work experience and shift schedule could influence the working HRs in hospital nurses. Third, this study only examined the physiological impacts of 12-hour shifts. Future studies may compare the physiological and behavioural response patterns between the 12- and 8-hour shift nurse groups, to understand the differences of the physiological impacts from the two shift systems.

Conclusion

The findings of this study suggest that hospital nurses are experiencing a moderate physiological strain when working 12-hour day shifts. Such evidence supports the findings about excessive workloads for hospital nurses, reported in numerous studies using subjective measures. Furthermore, nurses were faced with the issues of inadequate work breaks and sleep, family care-giving responsibilities and aging that may negatively interfere with nurses' recovery from the shifts.

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