

The Effect of Shift Rotation on Employee Cortisol Profile, Sleep Quality, Fatigue, and Attention Level: A Systematic Review

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ABSTRACT

Background: Disrupted circadian rhythm, especially working night duty together with irregular sleep patterns, sleep deprivation, and fatigue, creates an occupational health risk associated with diminished vigilance and work performance.

Purpose: This study reviewed the effect of shift rotations on employee cortisol profile, sleep quality, fatigue, and attention level.

Methods: Researchers conducted a systematic review of relevant articles published between 1996 and 2008 that were listed on the following databases: SCOPUS, OVID, Blackwell Science, EBSCO Host, PsycINFO, Cochrane Controlled Trials Register, and CEPS. A total of 28 articles were included in the review.

Results: Previous research into the effects of shift work on cortisol profiles, sleep quality, fatigue, and attention used data assessed at evidence Levels II to IV. Our systematic review confirmed a conflict between sleep-wake cycle and light-dark cycle in night work. Consequences of circadian rhythm disturbance include disruption of sleep, decreased vigilance, general feeling of malaise, and decreased mental efficiency. Shift workers who sleep during the day (day sleepers) experience cortisol secretion increases, which diminish the healing power of sleep and enjoy 1 to 4 hours less sleep on average than night sleepers. Sleep debt accumulation results in chronic fatigue. Prolonged fatigue and inadequate recovery result in decreased work performance and more incidents. Rotation from day shift to night shift and its effect on shift workers was a special focus of the articles retained for review.

Conclusions: Disturbed circadian rhythm in humans has been associated with a variety of mental and physical disorders and may negatively impact on work safety, performance, and productivity.

KEY WORDS:

sleep quality, fatigue, rotating shift work, systematic review, nursing.

normal secretion conditions, are high during the day and low at night. Cortisol is an essential hormone produced by the adrenal glands that affects many bodily functions, including metabolism and regulation of the immune system. Imbalances of cortisol are associated with fatigue, depression, obesity, and immune dysfunction (Kudielka, Buchtal, Uhde, & Wust, 2007). Compared with that of permanent day workers, cortisol secretion in night shift workers is lower in the morning and higher at night (Kudielka et al., 2007; Lac & Chamoux, 2004; Perkins, 2001). Night shift workers mostly sleep during the day. However, high cortisol secretion and high body temperature during the day can affect the quality of sleep and decrease the number of hours slept. Indeed, approximately 60% of shift workers complain about insufficient sleep and insomnia (Edell-Gustafsson, Kritz, & Bogren, 2002; Lamond et al., 2003; Muecke, 2005; Natale, Martoni, & Cicogna, 2003; Purnell, Feyer, & Herbison, 2002). Night shift workers generally feel more fatigued than daytime workers because the amount of sleep they get is usually insufficient, and their circadian rhythm is in a state of lethargy.

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Introduction

In developed countries, at least 15%–20% of the working population is engaged in shift work (Hossain et al., 2004). Disturbances in circadian rhythms may cause various physiological and psychological problems in shift workers, especially where night shift is involved. For example, shift work can affect body cortisol secretions, which, under

In addition, nonpermanent shift workers (i.e., those who work rotating shifts) experience chronic fatigue more often than permanent shift workers (Brooks & Swailes, 2002; Seki & Yamazaki, 2006; Winwood, Winefield, & Lushington, 2006). Fatigue and long-term poor sleep quality have been found to affect work performance, and although subjective cognitive ability is not considerably affected, objective cognitive performance for shift workers decreases significantly. Reaction time and the rate of critical incidents also increase during night work (Dingley, 1996; Lee, Chan, & Kwok, 2003; Smith, Folkard, & Poole, 1994).

Nursing staff are the largest group of professionals in the healthcare team that provide 24-hour patient care across a 7-day work week. There is an increased awareness that circadian rhythms in physiological and psychological processes are at a low ebb during the night. Work at the low point of circadian cycle increases the risk of night nurses being less alert than ideal. This may impair the efficiency with which they carry out their duties and endanger the lives of patients. The objective of this literature review was to investigate the influence of shift work on nursing staff cortisol profiles, sleep quality, fatigue, and attention levels. We propose that the results can be used as a reference point for nursing administrators to construct work schedules more suitable for maintaining shift worker health and safety.

Objectives

The objective of this review was to examine the broad evidence regarding cortisol profiles, sleep quality; fatigue, and attention levels as they relate to shift work in general and to nursing shift work in particular.

Methods

Search Strategy

The review included articles published from 1996 to 2008. The following electronic databases were searched: SCOPUS, OVID, Blackwell Science, EBSCO Host, PsycINFO,

Cochrane Controlled Trials Register, CEPS, and thesis system. Key words used included shift worker or shift work or night duty or rosters, circadian rhythm disturbance or circadian rhythm, cortisol profile or cortisol, sleep deprivation or sleep quality, attention concentration or concentration or attention, and fatigue. The combined terms followed both MeSH terms and text words. Researchers also performed an extensive manual search and cross-referencing from reviews and original articles.

Inclusion Criteria

Inclusion criteria for the study were as follows: (a) full-time shift workers (including day, evening, night shift, and irregular rotation shifts), (b) shift work focus on cortisol profile change or sleep quality or fatigue or attention concentration, (c) English language, and (d) quantitative research articles.

Exclusion Criteria

Exclusion criteria included studies that identified a metabolic or neurological disease and a study focus on the exploration of hormones or hypnotic medication effect.

Critical Appraisal

Quality assessment of randomized controlled trials and non-randomized controlled trials was performed independently by two reviewers. The methodological quality of eligible randomized controlled trials was assessed using the 6-point Quality Scale Assessment (QSA) tool developed by the Cochrane Collaboration. The methodological quality of non-randomized controlled trials was evaluated using a modified version of the Jadad Scale (Fernandez & Griffiths, 2004). All studies were ranked according to National Health and Medical Research Council levels of evidence (Table 1; National Health and Medical Research Council, 1999). Synthesis of data were presented in text and tabular format. Meta-analysis was not possible because of the heterogenic nature of reviewed studies.

TABLE 1.
Levels of Evidence Ranked According to the Australian National Health and Medical Research Council

Level	Definition
I	Evidence obtained from a systematic review of all relevant randomized controlled trials
II	Evidence obtained from at least one properly designed randomized controlled trial
III.1	Evidence obtained from well-designed pseudo-randomized controlled trials
III.2	Evidence obtained from comparative studies with concurrent controls, cohort studies, case-control studies, or interrupted time series with a control group
III.3	Evidence obtained from comparative studies with historical control, two or more single arm studies, or interrupted time series without a parallel group
IV	Evidence obtained from case series, either posttest or pretest/posttest

Data Extraction

A total of 28 key journal articles were included in the review. All articles selected for review were entered into a bibliographic software package (Endnote Version 11). A data extraction sheet was used to extract data from eligible studies (Table 2–5).

Results

A total of 28 relevant journal articles were included in the review. Previous research on the effects of shift work on cortisol profiles, sleep quality, fatigue, and attention used data assessed at evidence Levels II to IV. One article involved a randomized controlled trial and 27 addressed non-randomized controlled trials. Study subjects included nursing staffs, physicians, healthy adults, factory workers, ambulance and train drivers, firefighters, locomotive engineers, policemen, and college students.

Effect of Shift Work on Cortisol

Cortisol secretion is controlled by the hypothalamic–pituitary–adrenal axis. Factors influencing cortisol secretion include diurnal rhythm, consciousness, and the sleep–wake cycle together with neural pressure signals. Normal cortisol secretion follows a negative slope. Cortisol secretion is lowest during Stage 1 sleep and increases gradually during Stage 2 sleep (Kudielka et al., 2007). The highest concentration of cortisol is reached the moment we wake up in the morning (Hennig, Kieferdorf, Moritz, Huwe, & Netter, 1998). Normal serum cortisol concentrations (approximately 250–850 nmol/L between 8:00 and 10:00 a.m.) maintain daytime consciousness then decrease continuously throughout the day (Putignano et al., 2001). The cortisol concentration at night is about half the daytime concentration, with a normal range of 110–390 nmol/L (Putignano et al., 2001). The range of cortisol concentration fluctuation is stable around the clock. However, increased cortisol secretion can be observed when an individual is under pressure or stress (Kudielka et al., 2007; Putignano et al., 2001).

Table 2 presents a summary of previous research on the effect of shift work on cortisol levels. According to the QSA tool developed by the Cochrane Collaboration, the levels of evidence in studies collected were Level III-2 to Level IV. Study subjects included nursing staff, healthy men, factory workers, and ambulance drivers. In these studies, saliva, blood, and urine samples were used to measure cortisol.

The time at which peak cortisol level occurs (cortisol acrophase) was observed at 6:00 a.m. in day shift workers, 7:00 a.m. in evening shift workers, and 11:00 a.m. in night shift workers. From studies conducted investigating cortisol levels, a typical cortisol-awakening rise (CAR) was observed in night shift workers. However, the average salivary cortisol acrophase of the night shift worker in the morning was 11 nmol/L. This level was lower than that of day shift workers (16 nmol/L). The CAR profile of night shift workers

decreased at night. Abnormal CAR was observed in subjects who changed from day shift to rotating shifts. When night shift workers sleep during the day, their sleep cycles are reduced, and sleep quality is poor because of high cortisol concentration and low melatonin levels (Holmback et al., 2003; Kudielka et al., 2007; Lac & Chamoux, 2004; Mitani, Fujita, & Shirakawa, 2006). Circadian rhythm studies of shift workers also report that circadian rhythm is completely adjusted in shift workers after about 7 days, especially among shift workers transferring from day shift to night shift. Similar to circadian rhythm, the increase of cortisol concentration in day shift workers starts at 6 a.m. From Day 1 to Day 4 of the night shift, cortisol levels decreased between 9 p.m. and 12:00 a.m. and increased between 12:00 and 6:00 a.m. On Day 5 of the night shift, the cortisol levels start to increase at 9 p.m. In consecutive night shifts, cortisol concentration is higher in the afternoon than that in the morning, and reverse rhythm and night shift adjustments have been observed (Hennig et al., 1998; Lac & Chamoux, 2004).

Effect of Shift Work on Sleep Quality

There are five stages in each cycle, with four to five cycles in a typical night's sleep. Sleep Stages 1 to 4 are non-rapid eye movement (NREM) stages, whereas Stage 5 is a rapid eye movement (REM) stage. Sleep starts from being awake to a light sleep stage (Stages 1 and 2), then progresses to the deep sleep stage (Stages 3 and 4), and finally the REM stage (Stage 5). Each sleep cycle takes an average 90 to 100 minutes to complete. NREM Stages 1 and 2 were found to be shorter among long-term night shift nursing staff. In a normal physiological situation, melatonin induces sleepiness in a dark environment, and cortisol secretions maintain daytime consciousness during the morning. In general, peak sleepiness occurs between 3:00 and 6:00 a.m. However, because night shift workers sleep in the daytime, inconsistent with normal circadian rhythm, their sleep is easily interrupted by environmental factors such as light, noise, temperature, and telephone noise (Frey et al., 2002; Kudielka et al., 2007).

Because of these and other sleep disturbing factors, night shift workers are quite often sleep deprived. A study on sleep deprivation reported that when subjects were awakened during the REM stage of sleep, 60% to 90% said they were dreaming at the moment of awakening. Selective deprivation of the REM sleep stage was found to result in emotional instability and restlessness in such research subjects (Kudielka et al., 2007).

Table 3 presents data from previous research on the effect of shift work on sleep quality. According to the QSA, levels of evidence in these studies ranged from Level III-2 to Level IV. Study subjects included healthy women from the community, nursing staff, train drivers, railway traffic control staff, air traffic control staff, policemen, locomotive engineers, and pharmaceutical factory workers. Tools applied to measure quality of sleep included polysomnography,

TABLE 2.
A Summary of Previous Research on the Effect of Shift Work on Cortisol Levels

Author (Year)	Participants (Sample Size <i>n</i>)	Measuring Instruments	Results	Study Design
				Level of Evidence
				Methodological Quality Score
Hennig et al. (1998)	Nurses (<i>n</i> = 24)	1. Freiburg Personality Inventory 2. Salivary cortisol	1. After night work, participants exhibited lower duration and less consistency in recovery sleep 2. Cortisol changes after the fifth consecutive night shift 3. Cortisol concentration lower in the early morning than evening 4. Reversal could be seen after the fifth night of shift work, indicating that the circadian function changes and adapts to the altered demands on the subject	Time series with a control group III.2 5
Holmback et al. (2003)	Males (26–43 years; body mass index = 19.9–26.6 kg/m ² ; <i>n</i> = 7)	Blood samples: glucagon, insulin, pancreatic polypeptide, leptin, C-peptide, thyroid-stimulating hormone, fT4, tT3, chromogranin, cortisol	The decreased evening/nocturnal responses of cortisol indicate that night work might have health implications	Interrupted time series without a parallel control group III.3 7
Kudielka et al. (2007)	Electronic manufacturing sector, West Germany (<i>n</i> = 118)	1. Salivary cortisol 2. Questionnaire package assessment of demographics and health status, sleep, vital exhaustion, perceived chronic stress, effort–reward imbalance, and overcommitment	1. Endocrine results show that the CAR is observed in day and night shift work 2. Circadian cortisol profiles are not disturbed in former night workers who recently switched to a fast rotating shift 3. Implementation of night work in former day workers seems to cause initially blunted cortisol profiles that normalize after a short adjustment period 4. In permanent night workers, cortisol profiles are blunted during night shift and days off 5. Overall cortisol secretion is generally lower during night shifts compared with day shifts	Comparative with concurrent control III.2 6
Lac and Chamoux (2004)	Males (23–56 years; <i>n</i> = 32), control group (<i>n</i> = 16), experimental group (<i>n</i> = 16)	1. Salivary cortisol 2. Karasek Questionnaires 3. Bortner test	1. Cortisol circadian profiles, the greatest changes observed in night shift workers, more particularly for the 7/5 group (7 days work, 5 days rest) 2. Shift workers expressed a higher stress level and frequency of health problems and a lower satisfaction at work than the control	Pseudo–randomized controlled trials III.1 6
Mitani et al. (2006)	Ambulance men (<i>n</i> = 9)	1. 24-hour urine cortisol 2. 24-hour electrocardiogram Holter	Cortisol in urine was 47.3 ± 19.9 μg/day on off days, 51.0 ± 23.3 μg/day on duty days	Case series IV 5

Note. CAR = cortisol-awakening rise.

TABLE 3.
A Summary of Previous Research on the Effect of Shift Work on Sleep Quality

Author (Year)	Participants (Sample Size <i>n</i>)	Measuring Instruments	Results	Study Design
				Level of Evidence
				Methodological Quality Score
Cheek et al. (2004)	Community-based women (<i>n</i> = 121)	1. Electroencephalogram, electromyogram, electro-oculogram 2. Sleep hygiene practice index	Caffeine intake, moderate alcohol intake, physical diseases were significant predictors of sleep quality.	Case series IV 7
Dorrian et al. (2006)	Full-time nurses in a metropolitan hospital (<i>n</i> = 23)	Logbook daily recordings (work hours, sleep length and quality, sleepiness, and fatigue levels, frequency and type of nursing errors, near errors, and observed errors)	1. Nurses had trouble falling asleep on 26.8% of days 2. The most commonly reported sleep aids were prescription medications (62.7%), followed by alcohol (26.9%) 3. Sleep was significantly shorter on days when an error or a near error was recorded 4. Sleep duration was a significant predictor of error occurrence	Case series IV 5
Edell-Gustafsson et al. (2002)	Female nurses in casualty departments (<i>n</i> = 156)	Sleep Likert scale	Sleep initiation difficulties, troubled sleep, and exhaustion significantly predicted reduced sleep quality and decreased resilience to stress and vulnerability to psychophysiological disorders	Case series IV 5
Harma et al. (2002)	Male train drivers (<i>n</i> = 126) and railway traffic controllers (<i>n</i> = 104)	1. Sleep-wake diaries 2. Karolinska Sleepiness Scale	1. The odds ratios showed that the risk for severe sleepiness was 6–14 times higher during night shift and about twice as high during morning shift compared with the day shift 2. Shift length increased the risk for severe sleepiness by 15% for each hour of the shift. Duration of sleep during the main sleep period decreased the risk by 15% for each hour of the main sleep	Case series IV 6
Lamond et al. (2003)	Nurses (<i>n</i> = 15)	1. Psychomotor vigilance task 2. Polysomnography	1. Total sleep time for each of the daytime sleeps was reduced 2. Average cumulative sleep debt of 3.53 hours before the final night shift 3. Day sleep was shorter than the nocturnal baseline sleep	Case series IV 5
Natale et al. (2003)	Air traffic controllers (<i>n</i> = 18)	Wrist ActiGraph	1. Evening types presented more flexible sleep habits and slept significantly less than morning types 2. The morning shift reduced the amount of sleep whereas night shift produced a decrease in daily activity	Case series IV 5

(continues)

TABLE 3.
A Summary of Previous Research on the Effect of Shift Work on Sleep Quality, continued

Author (Year)	Participants (Sample Size <i>n</i>)	Measuring Instruments	Results	Study Design
				Level of Evidence
				Methodological Quality Score
Neylan et al. (2002)	Police officers and peer-nominated comparison subjects (<i>n</i> = 1063)	<ol style="list-style-type: none"> 1. Pittsburgh Sleep Quality Index 2. Mississippi Scale for Civilian Posttraumatic Stress Disorder 3. Critical Incident History Question 4. Work Environment Inventory 5. Revised 90-item Symptom Checklist 	<ol style="list-style-type: none"> 1. Police officers demonstrated significantly worse sleep quality and less average sleep time than the two corresponding control groups 2. Stress was strongly associated with poor sleep quality 3. The variable-shift officers had higher Critical Incident History Question exposure scores than stable day shift officers 	Comparative with concurrent control III.2 6
Roach et al. (2006)	Locomotive engineers (<i>n</i> = 253)	<ol style="list-style-type: none"> 1. Sleep diary 2. Melatonin urine samples 	<ol style="list-style-type: none"> 1. The rate of MT6s excretion was lower, sleep duration was shorter, and sleep quality was lower for sleep initiated during the daytime compared with sleep initiated at night 2. Sleep onset between 12:00 and 2:00 a.m. have the best sleep quality 3. Sleep onset between 12:00 and 1:00 p.m. showed a decrease in sleep duration and MT6s excretion rate 	Case series IV 4
Rotenberg et al. (1998)	Female workers engaged at an assembly (<i>n</i> = 29)	Daily sleep logs	<ol style="list-style-type: none"> 1. The length of the first sleep episode on a day, which usually began in the morning, was correlated to the total amount of sleep per day and the total number of fatigue complaints 2. Night workers whose sleep onsets were allocated to the morning and were able to sleep for many consecutive hours, tended to show less complaints 	Case series IV 6

actigraphy, a subjective evaluation questionnaire, a sleep diary, the Sleep Hygiene Practice Index, the Epworth Sleepiness Scale and Pittsburgh Sleep Quality Index, and the Karolinska Sleepiness Scale.

Sleep deprivation can accumulate, and large sleep deficits may result in chronic fatigue (Edell-Gustafsson et al., 2002; Lamond et al., 2003; Natale et al., 2003; Purnell et al., 2002; Rotenberg, Moreno, Benedito-Silva, & Menna-Barreto, 1998). Reduced length of daytime sleep in night shift workers affects sleep quality and causes increased fatigue. Thus, increasing daytime sleep duration on the first day of night shift work can decrease fatigue and subsequently

improve shift workers' overall sleep quality. Encouraging shift workers to sleep longer on their first day of sleep after starting night duty is therefore recommended. Compared with regular shift workers, irregular shift workers exhibited abnormal sleep patterns and shorter sleep times (Kudielka et al., 2007; Neylan et al., 2002; Roach, Reid, Ferguson, & Dawson, 2006; Rotenberg et al., 1998). Compared with day shift, the severity of sleepiness in the night shift is 6 to 14 times higher. It was 0.7 times as high in evening shift workers and 2.3 times higher in the early morning shift workers (Harma et al., 2002). Work duration increases of 1 hour resulted in an increase in degree of sleepiness of 15%.

TABLE 4.
A Summary of Previous Research on the Effect of Shift Work on Fatigue

Author (Year)	Participants (Sample Size <i>n</i>)	Measuring Instruments	Results	Study Design
				Level of Evidence
				Methodological Quality Score
Brooks and Swailes (2002)	Nurses (<i>n</i> = 2987)	Postal questionnaire (professional commitment, perceived workload, job security, career progression)	<ol style="list-style-type: none"> 1. Permanent night shift nurses reported lower levels of commitment 2. Most nurses preferred early work days with flexi time 	Case series IV 6
Hossain et al. (2004)	Underground miners/first survey (<i>n</i> = 241), second survey (<i>n</i> = 225), third survey (<i>n</i> = 182)	<ol style="list-style-type: none"> 1. Epworth Sleepiness Scale 2. Stanford Sleepiness Scale 3. Fatigue Severity Scale 4. Performance Testing (Mackworth Clock test) 5. Polysomnography 6. Shift work questionnaire: sleep, fatigue, performance (alertness, memory, and attention), job satisfaction, driving difficulties, physical health, nutrition, and domestic and social interaction 	<ol style="list-style-type: none"> 1. Forward-rotating 10-hour shift schedule reported more refreshing sleep, fewer performance impairments, and driving difficulties than backward-rotating 8-hour shift 2. Significantly improved performance, less lapses in attention, fewer incidences of falling asleep behind the wheel, fewer near misses and accidents while driving on the forward-rotating night shift compared with the backward-rotating night shift 	Interrupted time series without a parallel control group III.3 6
Lamond et al. (2004)	Young individuals (18–27 years; <i>n</i> = 15)	10-minute psychomotor vigilance task	<ol style="list-style-type: none"> 1. Response times significantly increased during the first six simulated night shifts 2. The first simulated night shift was associated with the greatest degree of performance impairment 3. In general, the impairment at the end of this shift was greater than that observed at a blood alcohol concentration of 0.10% 4. During the second and third simulated night shifts, the performance impairment was less than on the first night but greater than that observed at a blood alcohol concentration of 0.05% 	Interrupted time series without a parallel control group III.3 4
Samaha et al. (2007)	Elder care shift-worker nurses (<i>n</i> = 111)	Checklist Individual Scale State-Trait Anxiety Inventory The Profile of Mood Status Locus of Control and Behavior Scale Lifestyle Appraisal Questionnaire Pittsburg sleep quality	Mood disturbances, locus of control, and trait anxiety are statistically significant predictors of chronic fatigue Poor sleep quality was the lifestyle factor which most strongly contributed to fatigue	Case series IV 4

(continues)

TABLE 4.
A Summary of Previous Research on the Effect of Shift Work on Fatigue, continued

Author (Year)	Participants (Sample Size <i>n</i>)	Measuring Instruments	Results	Study Design
				Level of Evidence
				Methodological Quality Score
Seki and Yamazaki (2006)	Nurses (<i>n</i> = 88)	Self-reporting questionnaire (shifts, fatigue, sleep duration, workload, busyness, and occurrence of near-miss errors)	<ol style="list-style-type: none"> 1. Nurses whose perceived level of fatigue before work was lower during the day shift 2. Nurses who had longer sleep duration during the evening shift. 3. Night shift workers' sleep duration before work was shorter compared with other shifts 	Case series IV 5
Takeyama et al. (2005)	Firefighters (<i>n</i> = 11)	<ol style="list-style-type: none"> 1. Fatigue questionnaire 2. Critical flicker fusion frequencies 3. Three-choice reaction times 4. Oral temperature 	Irregular sleeping patterns caused many complaints of subjective fatigue and adversely affected physiological functions	Comparative with concurrent control III.2 5
Winwood et al. (2006)	Nurses at two South Australian hospitals (<i>n</i> = 1280)	Occupational Fatigue Exhaustion Recovery Scale	<ol style="list-style-type: none"> 1. Multiple shifts rather than single shifts have higher maladaptive chronic fatigue levels 2. Among participants working permanent night duty, the mean scores for chronic fatigue and recovery were consistently poorer than for those working a single shift during the day 3. Lower maladaptive fatigue was associated with better recovery among partnered nurses with dependents 	Case series IV 5

Sleep duration increases of 1 hour resulted in a decrease in degree of sleepiness of 15% (Harma et al., 2002). Evidence suggests that adjusting working hours and rest times for shift workers can decrease degree of sleepiness. In addition, a short sleep before starting duty can decrease the nighttime electroencephalogram delta wave and increase alertness (Frey et al., 2002). In the studies reviewed, sleep quality was significantly related to change in sleep patterns. Shift workers were more likely to drink excessively, smoke, drink coffee, and take hypnotics and sedatives than non-shift workers. A total of 60% of nursing staff used sleep aids, whereas 62.7% reported taking prescription medications and 26.9% drank alcohol to sleep (Dorrian et al., 2006). Studies indicated caffeine and alcohol intake as significant predictors of sleep quality. Subjects who drank more than two cups of coffee or more than one glass of alcohol per day and subjects who were ill felt less vigorous after sleep and had poorer sleep quality. Sleep quality and physical condition after sleeping

were closely related to incidences of work-related error (Cheek, Shaver, & Lentz, 2004; Dorrian et al., 2006; Neylan et al., 2002).

Shift Work Fatigue

Irregular sleep patterns and interruption of night sleep can cause sleep deprivation, fatigue and physical collapse and affect physiological functions. When fatigue increases, shift worker reaction times increase and attention and judgment decrease (Samaha, Lal, Samaha, & Wyndham, 2007; Takeyama et al., 2005; Winwood et al., 2006).

Table 4 summarizes previous research on fatigue produced by shift work. According to the QSA, the levels of evidence were at III-2 to IV. Research subjects in these studies included young healthy individuals, nursing staff, and firefighters. The Fatigue Severity Scale, the Occupational Fatigue Exhaustion Recovery Scale, the Locus of

TABLE 5.
A Summary of Previous Research on the Effect of Shift Work on Attention

Author (Year)	Participants (Sample Size <i>n</i>)	Measuring Instruments	Results	Level of Evidence Methodological Quality Score
Dingley (1996)	Hospital night staff (<i>n</i> = 20)	Visual analogue scale (100-mm scale) Computerized unprepared simple reaction time task	1. Performance was generally worse at the beginning of a shift compared with the end 2. Performance improved to a peak at around Day 4. In the case of permanent nights, performance remained similar or deteriorated slightly toward the end of the shift	Comparative with concurrent control III.2 4
Frey et al. (2002)	Physician residents (<i>n</i> = 11), A group (<i>n</i> = 7), B group (<i>n</i> = 4)	Electroencephalogram, psychometric test, adjective checklist, reaction time, Pauli test, numerical memory test	1. Electroencephalogram analyses showed a significant decrease in alpha power and a significant increase in beta power in the evening compared with the morning 2. The nocturnal increase observed in delta activity was significantly less pronounced in duties with rest than that in duties without rest	Randomized crossover design II 3
Lee et al. (2003)	Basic surgical trainee specialists (<i>n</i> = 16)	Addition test, choice reaction time, memory scanning, picture recognition	Neuropsychological tests (memory scanning and addition tests) showed a significant decline in performance during the overnight call period	Comparative with concurrent control III.2 5
Purnell et al. (2002)	Male aircraft maintenance engineers working in a forward-rotating 12-hour shift pattern (<i>n</i> = 24)	1. Reaction time 2. Mackworth clock vigilance task 3. Actigraphy	Taking a nap during the first night shift significantly improved the response speed	Interrupted time series without a parallel control group III.3 6
Rouch et al. (2005)	Various occupational shift workers (<i>n</i> = 3237)	Cognitive test (memory test, digit-symbol substitution subtest of the Wechsler Adult Intelligence Scale, a selective attention test derived from the Sternberg test)	1. Shift workers showed lower cognitive performance than never-exposed workers 2. Memory performance decreased as shift work duration increased	Cohort studies III.2 6
Scott et al. (2006)	Critical care nurses (<i>n</i> = 502)	Logbooks (including the hours worked, the time of day worked, overtime hours, days off, and sleep-wake patterns)	1. Longer work duration increased the risk of errors and near errors and decreased nurses' vigilance 2. After working 12.5 or more consecutive hours, the risk for making an error almost doubled (odds ratio = 1.94)	Case series IV 6
Valdez et al. (2005)	Female undergraduate students (<i>n</i> = 8)	1. Rectal temperature 2. General information questionnaire (health condition, alcohol, tobacco, drug consumption), sleep disorder questionnaire	Circadian variations in attention components are relevant to the decrease in productivity and higher risk of accidents during night shift work	Case series IV 5

Control and Behavior Scale, the Visual Analogue Scale for fatigue, and the Profile of Mood Status were used to evaluate the severity of fatigue in the articles reviewed.

The level of chronic fatigue is related to different patterns of shifts. It is lowest among permanent day shift workers, followed by permanent night shift workers and those working multiple shifts except for the night shift. Severe chronic fatigue was reported in multiple shifts that included night shift (Samaha et al., 2007; Seki & Yamazaki, 2006; Winwood et al., 2006). Night shift nurses reported more severe fatigue than day or evening shift nurses. There are various possible explanations. In addition to needing to take care of more patients and usually going off duty later, many night shift nurses have sleep pattern disorders and shorter prework sleep time. Self-reported health conditions were worse among night shift staff than day shift staff.

Some studies have found that fixed shift workers adapt better and experience less fatigue than multiple shift staff (Edell-Gustafsson et al., 2002; Seki & Yamazaki, 2006; Takeyama et al., 2005) and that untreated acute fatigue may develop into chronic fatigue. Day shift and single shifts cause less chronic fatigue, and workers recover more easily from fatigue in comparison with night shift and multiple shift workers. The forward-rotating shift (i.e., day shift → evening shift → night shift → rest) produces more refreshing sleep and less fatigue than the backward-rotating shift (Brooks & Swailes, 2002; Hossain et al., 2004; Winwood et al., 2006).

Chronic fatigue affects work performance, and studies reviewed show that fatigue affects the worker similar to alcohol intoxication. Night shift workers getting up at 7 a.m. on the first day and working to the next night shift (about 24 hours of sleeplessness) have a state of consciousness similar to that of a person with a 0.1% blood alcohol concentration (Lamond et al., 2004). Workers experienced 30-second episodes spontaneous episodes of uncontrolled sleep, and the body was subject to "microsleeps" without any response to external stimuli (Lamond et al., 2004). Persistent fatigue and inefficient recovery are the main causes of critical incidents at work. Investigations of the frequency of critical incidents have shown that incidence was higher during the night shift as compared with day shift because of the behavioral compromise of shift workers at night (Smith et al., 1994).

Physical condition and the ability to adapt to circadian rhythm both decrease with increasing age. The ability to adapt to shift patterns relates negatively to age. People older than 40 years feel more fatigued and exhibit poorer adaptiveness. Night shifts and multiple shifts produce more severe fatigue and poor recovery. Therefore, people older than 50 years should avoid night shift work (Harma et al., 2002; Winwood et al., 2006).

Effect of Shift Work on Attention

Activity and sleep alternate between day and night. Night shift affects sleep quality and quantity. Poor sleep quality

causes sleep deficits. Workers with sleep deficits are tired, have poor concentration, and do not function at peak behavioral levels, which, in turn, may lead to increased workplace risks. Studies have indicated that multiple shift work rotations result in poor adjustment, attention, concentration, and short-term memory as well as higher fatigue (Valdez et al., 2005).

Table 5 summarizes previous reports on the effect of shift work on attention level. According to the QSA, levels of evidence in these studies ranged from II to IV. Study subjects included nursing staff, physician residents, surgical trainee specialists, aircraft maintenance engineers, shift workers in various occupations, and college students. Attention assessment tools used included the Visual Analogue Scale (100-mm scale), the computerized unprepared simple reaction time task, the adjective checklists, the Pauli test, the numerical memory test, addition test, choice reaction time, memory scanning, picture recognition, the Mackworth clock vigilance task, the digit-symbol substitution subtest of the Wechsler Adult Intelligence Scale, and the selective attention test derived from the Sternberg test.

Sleep deprivation can affect short-term memory and performance speed; studies of neuropsychiatric function in shift workers or night shift workers have shown that attention and cognitive speed decreases in these subjects. Worker reaction times were prolonged, and the duration without response lasted more than 10 seconds. Furthermore, the speed of mathematical calculation and judgment also decreased. Electroencephalogram analyses demonstrate that, compared with day shift workers, night shift workers exhibit decreased alpha waves and increased beta and delta waves. These results indicate decreased attention and psychomotor activity among night shift workers. A nap before a scheduled shift can decrease delta waves, whereas taking a nap during the first night shift significantly improves response speed (Frey et al., 2002; Purnell et al., 2002).

There was no significant difference in cognition between evening shift and day shift workers. However, in comparison with regular shift workers, night shift workers had poorer cognitive performance. Subjects engaged in shift work over a period of 1 to 4 years found decreased memory performance. Memory performance was even worse in employees engaged in shift work for 10 to 20 years (Dingley, 1996; Frey et al., 2002; Lee et al., 2003; Rouch, Wild, Ansiau, & Marquie, 2005; Seki & Yamazaki, 2006; Valdez et al., 2005). Attention is related to fatigue level, with employee vigilance higher at the beginning of a shift than at the end. For more than 3 to 8 days of continuous night shifts, staff reaction time decreased by 3.37%, 0.99%, and 0.75% per hour during the first, fourth, and seventh night shift, respectively (Dingley, 1996).

Arranging shift schedules that extend the 24-hour biological clock is suggested because it facilitates better adaptation. Forward rotating is better than backward rotating the shift because the former is better suited to adjusting circadian rhythm patterns. Longer periods of rest, usually 1 to 2 days,

are suggested between different shifts (Hossain et al., 2004; Scott, Rogers, Hwang, & Zhang, 2006). Evidence suggests that work duration should be less than 12 hours, and taking a short break during work to prevent work errors attributable to decreased vigilance is recommended. If shift rotation is inevitable, forward rotating is preferable.

Discussion

According to our systematic literature review, there are various inconsistent measures for the same variable and only a few studies used an RCT design. Because of the paucity of studies and significant heterogeneity in study population, outcome events, and results, we synthesized data in a qualitative manner. Thus, we did not conduct meta-analysis.

Reviewed topics were deliberately broad, and identified studies highlighted different influences relating shift work to nursing staff circadian rhythm. From the literature reviewed, it is evident that shift work remains a complex problem that simultaneously affects multiple aspects, for example, sleep–awake cycle disturbances, circadian misalignments, and predisposing individual and domestic factors. A majority of studies focused on single specific factors affected by shift work, including circadian rhythm, sleep quality, fatigue, or attention. In the future, a comprehensive, multilevel approach is needed to remedy the lack of research on the simultaneous comparison of the effects of shift work on nursing staff physiology and mentality.

This review of existing literature suggests that constant rotation of duty may make maintaining a good working symbiosis more difficult, in terms of biochemistry, behavior, and psychology. For example, plasma concentrations of cortisol, body temperature, sleep–wake cycles, and moods all exhibit cyclical circadian rhythms. Cortisol profiles in night shift workers who sleep during the day are relatively high and melatonin secretion is inhibited by light, leading to poor sleep quality. Adjustment of circadian rhythm is slowed by shift work. Cortisol increases at night during Day 5 of continuous night shifts, and the value is higher in the afternoon than that in the morning, presenting a reverse circadian rhythm during night shift adjustment. These findings suggest that working in a fixed shift can better maintain circadian rhythm. If rotating shift work is necessary, the easiest and most adaptable way is forward shifts, moving from days to evenings to nights.

As previously stated, night shift workers should work at night and sleep during the day. When sleeping during the day, cortisol secretion increases, which diminishes the healing power of sleep. Furthermore, because of the fact that duration of daytime sleep is also generally shorter in comparison to sleeping at night, studies have found that if subjects go to sleep between 8:00 and 10:00 p.m., sleep duration would be relatively long. However, if subjects go to sleep between 10:00 a.m. and 12:00 p.m., sleep quality was worse and sleep duration the shortest. On the second day of the night shift, NREM sleep cycles usually decrease, REM sleep increases, and then total sleep duration decreases. Night shift

workers sleep 1 to 4 hours less than daytime workers on average (average 2 hours). The shortening of daytime sleep in night shift workers affects sleep quality. Increasing daytime sleep duration on the first day of the night shift can decrease employee fatigue and, subsequently, increase sleep quality. An appropriate sleeping environment to avoid interference and maintain good sleep hygiene can improve night worker sleep quality.

Working multiple shifts (include night work) was associated with higher acute work-related fatigue, poorer recovery, and higher maladaptive chronic fatigue. Workers on night shift experienced more fatigue than on day and evening shifts. The present review indicated that with an increase in the number of workdays, level of fatigue also increases. Appropriate rest days between different shifts should be scheduled to allow workers time to recover from circadian rhythm disturbances. In addition, regular breaks and meal times during the work day can allow nurses to rest and recover from fatigue.

Night shift workers showed slower response speed and lower accuracy levels in comparison with day shift workers. When nurses work night shifts, lack of sleep and forced somnolence during the normal circadian rhythm sleeping phase may reduce alertness and compromise work safety and productivity. Sufficient rest can assist the individual to avoid errors in work. To avoid sleep debt accumulation, excessive workdays should not be arranged in succession. Overall, the fewest problems and the least amount of disruptions occur for staff who adhere to a regular work pattern. An evening shift lifestyle suits staff with average temperature rhythms who perform better in the afternoon and evening, whereas “night owls” may perform better when working nights. Studies show that the circadian rhythms of shift workers completely adjusted after approximately four to five consecutive duties, especially when transferring from day to night shift work. However, evidence also shows that injury risk for night shift staff rose at the end of the workweek. This finding seems inconsistent with any beneficial effect of circadian adjustment over successive night shifts. Rosters, therefore, must simultaneously consider that staff may suffer from fatigue because of long working hours (12 hours) as well as long consecutive stretches of night duty (weeks or months on end).

Nevertheless, managers who want to minimize adverse effects on shift workers should maintain fixed scheduling to decrease circadian rhythm disruptions. This review suggests several countermeasures for scheduling arrangements, such as forward-rotating shifts and scheduling a maximum of three consecutive night shifts, a minimum of two consecutive days off to rest sufficiently before returning to work, and taking regular short breaks during working hours when the scheduled shift is less than 12 hours long.

Conclusions

Undoubtedly, shift work interferes with worker circadian rhythms and, subsequently, affects sleep quality. Shift work

also causes fatigue and decreases attention levels, which can result in decreased work performance and more critical incidents. Physiology and work efficacy are especially important to maintaining a healthy workforce. To develop a proper shift rotation schedule, administrators who prepare and coordinate nursing rosters should consider work patterns, circadian rhythm disorders caused by night shift and rotating shift work, incentives for working night shifts, and workplace characteristics. As most employees cannot rapidly adjust their circadian rhythm to match changing working hours, we suggest that employees keep to regular shifts and working hours as much as possible to better maintain regular circadian rhythm. If shift work is necessary, shifting “forward” is the easiest way to allow the body to adapt. Extended working hours should be avoided because of negative impacts on attention and physical strength. Regular short breaks during working hours can improve work performance. A proper shift rotation system and staff education on sleep hygiene and knowledge of circadian rhythm functions can increase staff retention and improve workplace morale.

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輪班工作對cortisol變化、睡眠品質、疲倦、注意力之影響： 系統性文獻回顧

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- 背景** 輪班的工作人員，特別是夜間工作者，因晝夜節律受干擾及不正常的睡眠型態，會產生睡眠剝奪、疲倦並降低警覺性及負向影響工作安全。
- 目的** 回顧護理人員輪班對cortisol變化、睡眠品質、疲倦、注意力之影響。
- 方法** 此系統性文獻查詢自1996自2008年發表之文章，資料庫搜尋包括SCOPUS、OVID、Blackwell Science、EBSCO Host、PsychINFO、Cochrane Controlled Trials Register及中華民國期刊論文索引，總共有28篇文獻納入。
- 結果** 文獻中關於輪班工作對cortisol變化、睡眠品質、疲倦、注意力之影響的研究，所採用為實證等級II至IV的證據。經由系統回顧發現，夜班工作者於睡醒週期及光暗週期發生衝突，引起的晝夜節律紊亂，影響睡眠品質產生疲倦並降低注意力，會導致工作效率降低。夜間工作者於日間體內cortisol分泌高時睡覺，會影響睡眠品質及睡眠時數，睡眠時數較白班工作者於夜間睡眠時數少1-4小時。大量的睡眠債會產生慢性疲倦。長期的疲勞和不足夠的休息，導致工作警覺性降低與意外事故增多。
- 結論** 夜間工作者，因晝夜節律受干擾，會引起包括生理及心理上各種問題，並負向影響工作安全及效率。

關鍵詞：睡眠品質、疲倦、輪班工作、系統性文獻、護理。

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