CHAPTER 16

Shift Work and Long Work Hours*

Claire C. Caruso

CONTENTS

* The findings and conclusions in this chapter are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

16.1 INTRODUCTION

In today's society, services around the clock are needed from many types of workers and at times long work hours are not avoidable. As a result, shift work and long work hours are common in many workplaces. Research evidence is building that these types of work schedules are associated with several health and safety risks for workers. The risks also extend to their families, employers, and society when they make fatigue-related errors or show declines in performance. This chapter will discuss the wide range of risks that are linked to these schedules, theories about why these risks occur, and strategies to reduce risks.

16.1.1 Characteristics of Shift Work and Long Work Hour Schedules

Shift work involves work outside the daytime hours of approximately 7:00 AM to 6:00 PM. According to the U.S. Bureau of Labor Statistics, almost 15% of full-time workers (or 15 million Americans) work on evening, night, rotating, split or employer-arranged irregular shifts [1]. Both societal needs and economic factors drive the use of shift work. Society needs critical services around-the-clock for police and fire protection, health care, transportation, communications, public utilities, and military service. Other industries require workers around-the-clock because their production processes and operations need to be continuous to optimize capital investment in machinery, or the manufacturing process cannot be interrupted for production reasons. As a result, certain types of work are likely to always require shift workers.

Shift work schedules can be characterized by whether they are fixed or rotating schedules, the time of the shift, and if rotating shifts, the direction and speed of rotation. Fixed shifts have consistent work times. Rotating shifts change schedule, for example, from day shift to evening shift. Evening shifts are shifts with most of the work hours between 2:00 PM and midnight, and night shifts have most of the hours worked between 9:00 PM and 8:00 AM [1]. Some industries use split shifts, with two work periods separated by a longer break of a few hours to accommodate predicted peaks in activity. For example, a restaurant worker may work for the lunchtime hours, have a few hours off, and then return to work the dinnertime hours. Rotating shifts can change every few days (a fast rotation), weekly, or every 2 weeks or more (a slow rotation). The direction of the rotation can be forward or backward. Forward rotations change from day shift to evening shift to night shift. This pattern is recommended over a backward rotation because the shift change allows longer time off between shifts and has progressively later start times which allow the workers to get up later [2]. Backward rotations move from night shift to evening shift to day shift. This is a more difficult schedule because at the shift change the time off between shifts is short and

the work times progressively become earlier which require the workers to waken earlier. A short number of hours off between shifts (e.g., rotating from evening shift to day shift) is called a "quick change" and is difficult because of the reduced time available to commute, prepare for sleep, sleep, prepare for work, and commute back to work. Quick changes do not allow for 7 or more hours of sleep that are recommended for adults [3].

Long work hours include extended work shifts and schedules with more than 40 h per week. Extended work shifts may involve compressed work weeks, with fewer days of work and more days off and the weekly work hours remaining about 40 per week (e.g., 12 h day shifts with 3–4 work days per week). The point at which the number of hours becomes too long may not be a fixed number, but rather may be influenced by the demands of the job, the work environment, characteristics of the worker, and other work schedule characteristics such as the time of the shift and within-shift rest breaks [4,5].

16.1.2 Theory for Health and Safety Risks

Researchers theorize that shift work and long work hours increase health and safety risks by disturbing sleep and circadian rhythms and increasing strains on family and social relationships [4,6]. In addition, long work hours increase exposures to hazards at work and reduce recovery times. The immediate effects of demanding work hours can include stress, fatigue, negative mood, discomfort, and physiological dysfunction. Fatigue and stress may increase poor health behaviors such as smoking, low physical activity, and obesity. These in turn could lead to illnesses and injuries for the worker. The risks can also extend to families, for example, through conflicting work—family demands. Risks can extend to employers through reduced productivity and increases in worker errors which negatively impact goods and services. Mistakes by fatigued workers can have broad-reaching negative impacts to the community such as medical errors, motor vehicle crashes, and industrial disasters. Research indicates that the influence of shift work and long work hours on health and safety may involve a complex interaction of work schedule characteristics, as well as work demands, worker characteristics, compensation, commute time, occupational exposures, and the nature of worker control over their work schedule and work tasks.

16.2 METHODOLOGICAL CONSIDERATIONS FOR STUDIES OF WORK HOURS

Field studies examining the influence of work schedules on health and safety have several challenges in controlling for many factors that may influence outcomes. Knutsson [7] points out the methodological issues for studies of shift work, which are also applicable to long work hours: adequate comparison groups; need for complete descriptions of the workers, the job, and the work schedule; outcomes measures; and accounting for other influential factors.

The first challenge in studying work schedules is reliably measuring their various features to determine which patterns most impact health. Caruso et al. [4] list several characteristics of work schedules to consider when assessing studies. The time of the shift is a critical factor: for example, risks for accidents and incidents tend to be the lowest for day shift, intermediate for evening shift, and highest for night shift [5]. Start times of 6:00 AM,

or earlier, truncate sleep and are associated with more fatigue and sleepiness [8]. Backward rotations show higher risk than forward rotations [9–11]. Another important feature is the number of consecutive work days to rest days. Long series of work days without a day off increase risk. Work shifts having rest breaks only every 4 or 6 h are also associated with higher risks than those with breaks every 2 h [5]. Other factors to consider are the length of the shifts, total hours per week (or total hours over longer periods), distribution of days off, schedule predictability, and degree of worker control over their schedule. Research shows that schedules which combine difficult work scheduling factors (e.g., 12 h night shifts) tend to show increased risks [5,12]. All of these details are critical to account for when studying work schedules to better identify the key work schedule characteristics influencing risk and requiring modification.

Another research challenge is the control group. A desirable control group would consist of day-shift workers in jobs with similar occupational exposures and demands as the shift work or long work hour group. This is often difficult to achieve because the work that needs to be done sometimes differs at different times of the day. Also, the best comparison group would have no previous history of shift work or long work hours, because this history may be associated with continued adverse effects on health even after moving to a regular daytime schedule [13,14]. In addition, other work-related factors can vary as a function of time of day such as supervisor-to-employee ratio, pressures to perform, number of coworkers and other people at the worksite, activities at the worksite, types of food available, and work environment (lighting, noise, environmental temperature and humidity, and chemical exposure). These other factors may influence health and safety outcomes.

The "survivor effect" is another challenge for studies of work schedules: workers tend to self-select their work schedule and job, which influences findings. People who feel they could not tolerate a nonstandard work schedule would tend to avoid jobs requiring shift work or long work hours, leaving workers who are more likely to tolerate these scheduling demands. As a result, any significant finding is particularly noteworthy.

A wide range of health outcomes have been examined in studies. Outcomes have included simple symptom surveys, laboratory tests for evidence of beginning pathological processes, whether or not the individual had sought medical care, diagnoses, absenteeism, workers' compensation claims, disability, and death. Outcomes can have limitations: for example, absenteeism may be influenced by not taking time off from work when sick for a variety of reasons, as well as taking sick time for reasons other than sickness. Some studies have used standardized health indicators, which improves the ability to examine the complex interactions between work scheduling patterns and risk factors across studies.

Clear and complete description of the job demands helps enlighten the influence of work scheduling patterns on outcomes. Jobs vary in physical, cognitive, emotional, and social demands as well as the ability of the worker to control the timing, speed, and type of work performed. For example, physical factors such as heavy lifting, pushing and pulling, awkward postures, or repeated forceful exertions play a major role in development of work-related musculoskeletal disorders and are critical to account for in studies of work hours and these outcomes. Similarly, other types of job demands may be critical factors for developing other types of health and safety problems.

Seniority and age impact shift and job assignment. With seniority, workers tend to move to day shift, so day shift is associated with increased years of employment and increased age [15]. As a result, effect estimates will be reduced when comparing health in younger shift workers (who tend to be healthier), with older day workers (who tend to have more health problems). This will lessen the likelihood of finding differences in health across shifts. Other factors that appear to influence the relationship between work schedules and health outcomes include gender, compensation (as pay increased, negative outcome decreased), macro-economic conditions (recession or depression), commute time, and occupational exposures (chemicals, temperature extremes, noise, and job demands) [4,12].

In summary, field studies examining the influence of shift work and long work hours on health and safety have many challenges regarding controlling for a variety of other factors that influence risk. However, other related research topics contribute evidence, such as laboratory and field studies examining sleep deprivation, circadian rhythms, jet lag, and sleep disorders. The evidence from all these areas suggests shift work and long work hours are associated with several health and safety risks.

16.3 HEALTH AND SAFETY RISKS ASSOCIATED WITH SHIFT WORK AND LONG WORK HOURS

16.3.1 Sleep Findings

Shift work and long work hours can lead to difficulties with sleep because of the need to sleep at irregular times and at times out of phase with normal circadian rhythms. In addition, the time available for sleep may be reduced because of short periods between work shifts or demands from work and family.

To examine sleep in shift workers, Drake et al. [16] surveyed a representative sample drawn from the working population in the Midwest. They found 32% of night-shift workers and 26% of rotating-shift workers reported long-term insomnia and excessive sleepiness. Ingre and Åkerstedt [17] studied 169 monozygotic twin pairs who were discordant on exposure to night shift work. History of night shift significantly increased risk for sleep disturbances into retirement years. A meta-analysis by Pilcher et al. [18] of 36 studies found that permanent day-shift workers slept an average of 7.0 h per day, permanent and rotating evening-shift workers slept 7.6–8.1 h, permanent night-shift workers slept 6.6 h, and rotating night-shift workers slept the least, 5.85 h. As mentioned earlier, Healthy People 2020 recommends adults sleep 7 h or more each day [3].

In a review of studies examining extended work shifts, Knauth [19] reported 13 studies showed shifts longer than 8 h had negative effects on sleep, 8 studies showed mixed results, and 4 studies showed positive effects. Long weekly work hours and overtime have been associated with shorter sleep duration or sleep disturbances in several studies [20–24]. Basner et al. [25] conducted a study of a national representative sample of Americans and reported 1 additional hour of work a day was associated with 1.5 h less sleep.

16.3.2 Declines in Performance

Sleep is a biological need for life and health, similar to the need for food and water [26]. Most adults need 7–9 h of good-quality sleep each day [27]. Good-quality sleep means the

major sleep episode does not have frequent arousals and is long enough for the individual. Laboratory studies provide evidence for a wide range of cognitive declines associated with sleep deprivation, which are discussed as follows [28].

Without adequate sleep, people feel sleepy, are less alert, and can experience microsleeps (short episodes of sleep lasting a few seconds). During microsleeps, the person may appear to be awake (eyes open), but his or her brain will not process information and lapses in attention occur. A sleep-deprived person cannot control the onset of microsleeps and is often not aware that they are occurring. Microsleeps can be identified on electroencephalograms and can be dangerous if they occur at critical times [29].

Sleep deprivation impairs performance on tasks that require intense or prolonged attention [30]. Performance is unstable with increased errors of omission (failing to respond to a stimulus) and commission (responding when a stimulus is not present). These errors occur more frequently over time. When the sleep-deprived person can pace activities without time pressure, cognitive slowing will be evident and response time slows, but accuracy can be preserved. Under time pressure, however, cognitive slowing will produce errors. Also, performance may begin well, but deteriorates as time-on-task increases and the effort to remain behaviorally effective increases.

Sleep deprivation negatively affects information processing and learning [28]. Both short-term recall and working memory performance decline. Tasks that require information to be accurately held in memory for brief periods will be impaired.

Communication skills decrease as sleep deprivation increases [30,31]. A worker may fumble trying to find the right word, say the wrong word when meaning to use another, or may misinterpret what another person said or wrote.

Sleep deprivation leads to impaired cognitive flexibility, negatively affects innovation, and decreases insight [28]. In situations during which "thinking outside of the box" is needed, sleep-deprived workers will tend to use routine solutions. They may fixate on an ineffective solution and may not be able to recognize better alternatives, even if these are clearly available.

Sleep deprivation reduces a person's ability to assess risks, and risk-taking behaviors increase [32]. A sleep-deprived person is less able to learn from the negative consequences of risky decisions. Activities judged to be nonessential are increasingly neglected because situational awareness is lost. For example, a worker may misjudge how much time has passed.

Sleep deprivation can result in impaired mood including irritability, anxiety, and depression. The sleep-deprived worker may behave in a rude or hostile manner because he or she views the situation in a more negative light. Sleep deprivation may lead to inappropriate behavior such as giggling or laughing in serious situations.

Several studies show evidence of similarities between fatigue-related impairment in mental and physiological functioning and impairments because of alcohol intoxication [33–35]. In these studies, participants' performances were tested and compared after staying awake for extended periods of time and after drinking alcohol to a certain blood alcohol concentration (BAC). Participants staying awake for 17 h showed performance deficits similar to a BAC of 0.05%, and after 24 h awake, the deficits were similar to having a BAC

of 0.10%. The United States defines legal intoxication for purposes of driving as having a BAC of 0.08% or greater. However, driving impairments are seen at lower levels, and some countries use a 0.05% or lower cutoff [36].

A common misconception is that a person can overcome the effects of sleep deprivation through motivation, professionalism, training, or experience. Recent research provides evidence to the contrary [33,37]. A study of medical residents did not provide evidence that they adapted to sleep deprivation better as their training years progressed. In fact, researchers found that sleep-deprived participants did not reliably recognize the extent of their declines in performance.

Performance declines vary for individuals when they are sleep deprived [28]. Testing the same person over time showed consistent patterns in his or her response to sleep loss. However, some people showed a greater decline in performance than others, which may reflect an individual trait or sensitivity.

16.3.3 Increased Risk for Worker Injury and Errors

Declines in neurocognitive performance could lead to higher rates of fatigue-related injury and worker errors. There is evidence that certain work scheduling patterns are associated with higher risks. When compared with the day shift, risks for accidents and errors were 15% higher for evening shifts, and 28% higher for night shifts [5]. When compared with 8 h shifts, 10 h shifts increased the risk by 13%, and 12 h shifts increased this risk by 28% [5]. As the number of successive night shifts worked increased, risk increased (by 17% for the third night shift, and 36% for the fourth). Dembe et al. [38] reported a possible "dose response"—as weekly work hours increased, injury rates to workers increased. Only a few studies have examined mandatory overtime but the evidence available raises concern. Studies of nurses linked mandatory overtime with higher risk for needlestick and other work-related injury, work-related illness, and missing more than 2 days of work because of these [39,40].

16.3.4 Poor Health Behaviors and Metabolic Syndrome Linked to Shift Work and Long Work Hours

Research links shift work and long work hours to poor health behaviors. Bushnell et al. [41] found that of nine work schedule patterns, the patterns predicted to be the most difficult were associated with the highest rates of smoking, obesity, and low physical activity. A systematic review by Frost et al. [42] concluded that smoking was generally more frequent in shift workers. Workers may be drawn to smoking as a countermeasure for the fatigue, sleepiness, and stress linked to demanding work schedules. A review of obesity and shift work by Antunes et al. [43] concludes there is considerable epidemiological evidence for a link between shift work and obesity. A few studies have examined long work hours and obesity, and some report a significant positive relationship [44,45]. The mechanism could be through poor-quality sleep and short sleep duration promoting an imbalance in appetite hormones that increase feelings of hunger and metabolic changes leading to obesity, insulin resistance, and reduced lipid tolerance [46]. Bushnell et al. [41] found there are few studies to date that have examined exercise and shift work or long work hours, and these have reported mixed findings.

16.3.5 Diseases Associated with Shift Work

Along with sleepiness, mood disturbances and gastrointestinal complaints are common initial symptoms that occur after disturbances to sleep. This set of complaints is frequently reported by people experiencing quick changes to their sleep/activity cycle due to traveling across several time zones [47]. Shift workers commonly complain of gastrointestinal symptoms including abdominal pain, gas, diarrhea, constipation, nausea, vomiting, change in appetite (either eating more or less than usual), indigestion, and heartburn [48,49]. A variety of stomach and digestive disorders have been reported in shift workers. Schernhammer et al. [50] reported an increased risk of colon cancer in nurses working 3 or more nights per month for 15 or more years. Possible mechanisms for gastrointestinal disturbances include disturbances to circadian rhythms involved in eating and digesting food, sleep deprivation leading to stress response, changes in immune function, or the types of foods that are available during these shifts [48,49]. Shift workers commonly report psychological complaints including bad mood, depression, irritability, anxiety, personality changes, and difficulty with personal relationships [51].

Shift workers are at somewhat higher risk for cardiovascular disorders. A review by Puttonen et al. [52] reported the epidemiologic data support a possible link with cardiovascular disease, including myocardial infarction, chest pain, and high blood pressure. Brown et al. [53] recently reported an increased risk for ischemic strokes. The mechanism could be through metabolic changes and smoking. Frost et al. [42] concluded there is some evidence that workers are at higher risk for metabolic disturbances and increases in smoking after starting shift work.

In 2007, the International Agency for Research on Cancer of the World Health Organization announced sufficient evidence supports that shift work with circadian rhythm disruption is a probable carcinogen [54]. The data from human studies suggest the link is possible, while the evidence from animal studies is sufficient. The most studied cancer in shift workers is breast cancer. A meta-analysis by Megdal et al. [55] of 13 studies reported night work increased cancer risk by 48%. Two of three studies found an increase in prostate cancer [56–58]. Costa et al. [59] discuss mechanisms that could possibly lead to cancer: exposure to light at night reduces melatonin levels, repeated shifting of the times of sleep and activity, and depression of immune surveillance.

Shift work is associated with adverse reproductive outcomes for women. A review by Frazier and Grainger [60] reported that shift work was associated with a modest increase in spontaneous abortion, preterm birth, and reduced ability for women to become pregnant. Shechter et al. [61] reported increased medical office visits for menstrual cycle symptoms and cycles that were shorter, longer, or irregular.

Persons with chronic diseases may have more difficulty managing their symptoms and disease progression when working shift work. Some medications have changes in effectiveness across the circadian cycle which can lead to more difficulty in determining the appropriate dosage and time for administration when working shift schedules. Shift work can also interfere with treatment regimens that involve maintaining regular sleep times, avoiding sleep deprivation, and controlling amounts and times of meals

and exercise. Sood [62] warned that the following conditions could get worse: heart disease, high blood pressure, stomach and intestinal disorders, sleep disorders, insulin-dependent diabetes, seizure disorders, asthma requiring medication, psychiatric diseases, and alcohol/drug abuse.

Some people have many symptoms, do not get relief from medical therapies, and appear unable to adjust to shift work. Harrington [63] estimated 20% of workers who tried shift work were unable to adjust. The reason is not fully understood, but it may be due to an inherited tendency to be more sensitive to sleep loss and disruption of circadian rhythms.

16.3.6 Diseases Associated with Long Work Hours

The number of studies examining the influence of long work hours on health has been growing recently but is substantially less than the number of studies examining shift work. Several studies report long work hours are associated with increased fatigue, poor mood, poor recovery from work, and reduced perceived health [20,24,64–68]. Higher risk for depression is reported [69]. Suwazono et al. [70] reported better scores for depression and fatigue when work hours were less than 12 per day and 58 per week. Long work hours are associated with increased risk for heart disease, high blood pressure, and diabetes although not all studies consistently report a significant increase [20,22,65,71–73]. A systematic review identified eight studies with controls for physical demands that link long work hours to adverse musculoskeletal disorders [74]. This may be due to longer exposure to physical demands and less recovery time between work periods. Possible adverse reproductive outcomes include increased time to pregnancy [75]. A meta-analysis of six studies suggested a possible weak relationship with preterm birth [76].

16.4 IMPACTS TO FAMILY, EMPLOYER, AND COMMUNITY

Fatigue-related impairments can lead to reduced performance on the job. Rogers et al. [77] reported that the odds for a nurse making an error at work increased by three times when work shifts lasted 12.5 h or longer, compared with 8.5 h shifts. Interns working long hours made more serious medical errors in intensive care units [78]. Circadian, a shift work consulting firm, estimates fatigue-related accidents, lost productivity, and health care expenses costs employers $116.5 billion per year [79]. Similarly, Rosekind et al. [80] estimated annual fatigue-related productivity losses for four employers were $1967 for each of their employees, a total of $54 million.

Worker fatigue is a problem not only in the workplace, but also in the community. Experts who examined drowsy driving crashes listed shift work and long work hours in the top five factors that increase risk for a motor vehicle crash [81]. As a consequence, drowsy workers could also endanger others on the road. Worker fatigue has also been linked to several well known industrial disasters including the 2005 BP Texas City explosion, the Buffalo jet crash, and the Exxon Valdez oil spill [5,82,83]. In addition, society may be negatively impacted by a shortage of workers in critical jobs because too few people are willing to work demanding hours, as has been reported in the nursing workforce [84].

16.5 OVERVIEW OF SLEEP, CIRCADIAN RHYTHMS, AND FATIGUE PHYSIOLOGY

Sleep and circadian rhythm physiology provides insights into why workers make errors and develop chronic illnesses when they work demanding hours and do not get adequate sleep. Although science does not have the full answer for the function of sleep, evidence is mounting that critical processes occur during sleep that are connected with maintaining health and life. For example, a laboratory study reported rodents who were kept awake for a few weeks died as a result of sleep deprivation [26]. Sleep deprivation took just a little longer than time until death due to starvation.

Insufficient sleep is associated with reduced immune functioning and impaired mental functioning [85]. Spiegel et al. [86] linked sleep loss with insulin resistance, changes in appetite hormones that increase hunger and appetite, increases in sympathetic activity, and increases in evening cortisol. In the study, young healthy men restricted their sleep to 4 h a night for 6 nights. At the end of this time, their test results showed clinically diagnosable impaired glucose tolerance. These findings suggest that not only do sleep deprived people feel sleepy, but other changes occur in their bodies that could speed the development of a broad range of chronic health problems such as obesity, diabetes, and cardiovascular disease. Sleep researchers warn that sleep appears to be as important for living as food and water, and recommend that people get the amount of sleep they need.

16.5.1 Regulation of Sleep: Simple Two-Process Model

Basic scientific information about sleep regulation provides insights into why workers have difficulty with shift work and long work hours and also guides coping strategies. Human physiology promotes sleep at consistent times at night and wakefulness and activity during the daylight hours. As a consequence, working during the night and sleeping during the daylight hours or sleeping at irregular times goes against human physiology and is difficult.

The sleep/wake cycle is driven by two processes: (1) homeostatic sleep drive and (2) circadian rhythms [87]. These two processes interact to determine the time of sleep and time of wakefulness, as well as the stability of waking neurocognitive functions (e.g., how well the person feels when awake).

The homeostatic sleep drive refers to a buildup of pressure to sleep in the brain the longer a person is awake, which gets stronger the longer a person is awake. Pressure to sleep decreases during sleep and reach a low after a full night of good-quality sleep. On awakening, the homeostatic process begins to build again the longer the person is awake. If a person remains awake for long periods, sleep pressure builds even further, putting higher pressure on the person to fall asleep.

The second process driving the sleep/wake cycle is circadian rhythms, which are internally-driven cyclic rises and falls of biochemical, physiological, and behavioral processes of living beings that occur across the 24 h day. There are numerous circadian rhythms in the human body; in fact, it is unusual to find a physiological phenomenon that does not display a circadian rise and fall across the 24 h day. A pair of circadian pacemakers in the hypothalamus of the brain orchestrates the timing of the circadian rhythms so they work together. Circadian rhythms cause a predictable rise and fall in wakefulness across the 24 h day. A peak

in wakefulness occurs in the evening a few hours before usual bedtime for a person on a normal, daytime activity schedule. This can be experienced as enhanced alertness in the early evening, even after being awake for long periods. The evening peak in alertness, called the "forbidden zone" or "wake maintenance zone," makes it difficult to go to bed earlier [88].

Circadian rhythms promote sleepiness before usual bedtime, initiate sleep, and begin promoting wakefulness before usual waking time in the morning. Circadian rhythms also promote a shorter period of sleepiness in the middle of the afternoon, a time when people tend to want to take a nap. The pacemakers have an internally-driven 24 h rhythm which tends to run longer than 24 h, but is entrained (reset) every day by external timing cues to keep the cycle at 24 h. Researcher theorize this is why when changing sleep times, it is easier to get up later than it is to get up earlier—because the circadian pacemakers naturally run longer than 24 h. The strongest external cue is the light/dark cycle of the sun [89]. Exercise and melatonin also appear to exert an influence on the timing of the pacemakers, but they have less influence than light. Normally, light from the sun enters the eye (through closed eyelids while asleep) and signals to the pacemakers the time for awakening and activity and time for sleep. In addition to sleep and wakefulness, pacemakers orchestrate the timing for numerous circadian rhythms that regulate physiological and behavioral processes in our bodies such as: hormones, body temperature rhythm, and times of physiological processes connected with eating and digesting food.

Circadian rhythms have an important purpose: they prepare the body for expected changes in the environment (e.g., the time for activity, time for sleep, and times to eat). External cues have a strong influence on the timing of the circadian pacemakers. The strongest cue is the sun's light/dark cycle; however, artificial light also influences the pacemakers [90,91].

The circadian system needs time to adjust to new sleep times and cannot shift to a new schedule quickly, such as when switching shifts [90]. So, although workers can try to force themselves to be awake and work at night, they will be working against the sun's light/dark cycle and their circadian pacemakers that are strongly promoting sleep at night and wakefulness during daylight hours. Researchers are testing manipulating timing of light exposure to promote adjustment of the circadian rhythms to working at night [92].

Night work and shift work often result in de-synchronization or dissociation of the homeostatic and circadian processes so they no longer work together, negatively impacting sleep. As a result, sleep during the daytime tends to be lighter, shorter, more fragmented, and less recuperative than sleeping at night [93]. Workers on night shift commonly build up pressure to sleep during their work shift so they tend to fall asleep quickly upon their return home. However, because circadian rhythms promote wakefulness during daylight hours, they tend to awaken around noon and have difficulty going back to sleep. Because of this waking pressure, small environmental disturbances such as outside noise, or minor discomfort, can awaken them before they have slept sufficiently. During night shift, workers often have to fight the strong pressure to sleep due to circadian rhythms that promote sleepiness. This is especially true between 2:00 and 6:00 AM [94].

Individual factors influence a person's ability to sleep at different times, and how the person performs when he or she does not get enough sleep. Some people have more difficulty than others. One factor researchers are studying is the "morningness/eveningness"

trait. People with "morningness" or "lark" trait are naturally early-to-bed and early-to-rise and tend to have more difficulties working night and evening shifts. Persons with the "night owl" or "eveningness" trait are naturally late-to-bed and late-to-rise and tend to have fewer difficulties working night and evening shifts. Some people will show the "intermediate" trait, between "larks" and "owls."

The morningness/eveningness trait may be inherited, or part of the functioning of the person's circadian pacemakers [95]. Teenagers and young adults tend to be "evening" types, and researchers theorize this may be due to brain development at those ages [96]. Morningness increases with age, so older adults tend to be "morning" types [97]. This trait may have consequences for shift preferences and coping capabilities. However, according to Sack et al. [98], sufficient research evidence is not currently available to support the validity and reliability of a morningness/eveningness questionnaire score to predict a person's ability to adapt to night shift.

There is individual variability in the length of sleep each person needs [95]. Most adults need 7–9 h of good-quality sleep per night. Sleep researchers report the amount of sleep needed by each person may be an inherited trait like eye color and hair color and recommend that each person gets the amount they need each day.

Research links some factors to more vulnerability to sleep loss. People with an inherited trait show more neurocognitive performance declines with sleep loss [28]. Another factor is age. Younger people (children, teens, and young adults) tend to be able to sleep during the daytime and have more flexibility in the times they can sleep. They also tend to have a longer sleep length need. Aging is associated with less tolerance of shift work, which may be due to age-related changes in sleep that may make it more difficult for older people to initiate and maintain sleep at different times of the day [99]. As a consequence, some workers may experience more difficulties as they grow older, even those who adjusted adequately to shift work at younger ages.

16.5.2 Drowsiness and Fatigue

Long periods awake and poor-quality sleep build up "sleep debt"; extra sleep is needed to "pay down" this debt. For example, a person needing 8 h of sleep, but only getting 6 h, would accumulate a "sleep debt" of 2 h that day. If the person has a habit of restricting their sleep, they could experience ongoing fatigue, sleepiness, and other negative effects during their wake time hours. To keep the sleep debt down, a person should use good sleep behaviors to prepare for sleep and sleep long enough to feel rested shortly after awakening.

Research suggests building up a sleep debt and paying if off later is risky. Although the level of sleepiness may return to normal after a day or two of recovery sleep, neurocognitive performance will still be reduced compared to baseline [100,101]. Thus, getting adequate sleep on a regular basis, rather than episodically, is important. This is especially important for workers working 12 h shifts, who do not sleep much between the 12 h shifts [19], then try to catch-up on sleep after the block of shifts ends.

Sleep deprivation increases pressure for the brain to fall asleep. The transition from wakefulness to sleep is abrupt and rapid and occurs in an on-off-type switch in the brain stem [102]. The nature of this on-off-type switch transition to sleep can lead to dangerous situations if sleep occurs during critical times such as when driving or operating equipment.

The warning signs that the brain is close to falling asleep include: difficulty focusing; frequent blinking or heavy eyelids; daydreaming or wandering and disconnected thoughts; yawning repeatedly or rubbing eyes; difficulty keeping head up; and feeling restless and irritable [103]. When driving, the following symptoms indicate sleep may be imminent: trouble remembering the last few miles driven, missing exits or traffic signs, drifting from a lane, tailgating, or hitting a shoulder rumble strip. If these symptoms occur, the person should stop as soon as possible and take action quickly to protect self and others from the dangers of drowsiness while driving or during work.

Wesensten et al. [94] discussed three key factors that promote fatigue-related errors: time of day, time awake, and time-on-task. The time of day or circadian factor predicts that the strongest decrease in wakefulness occurs during the early morning hours (2:00–6:00 AM). Other vulnerable times are in the middle of the afternoon (2:00–5:00 PM) and from midnight to 2:00 AM. The time-awake factor predicts the longer a person has been awake (or the poorer the quality and shorter the amount of sleep the person had recently), the greater their risk for fatigue. Lastly, the time-on-task factor predicts the longer the time spent on a task, particularly one that is monotonous, the more likely a person will feel fatigue. If two or three factors occur at the same time, risk for fatigue increases.

16.6 STRATEGIES TO REDUCE RISKS

Strategies to reduce risks from shift work and long work hours focus on correcting disruptions to sleep and circadian rhythms and strains on family and social life. Workers, managers, and employers share the responsibility of implementing strategies to reduce risks. Strategies for managers include instituting policies and systems in the workplace to reduce fatigue. Strategies for workers include adopting good sleep practices and behaviors and allowing sufficient time to get enough sleep.

16.6.1 Improving the Workplace

There is no single best work schedule pattern: hundreds of shift scheduling patterns exist. However, researchers offer several recommendations for improving work schedules [2,104,105]. A common recommendation is to give workers input on the design of their schedule since this promotes schedules that better meet the worker's needs. Work scheduling patterns that are associated with higher risks for fatigue-related accidents and errors can be avoided. Very early morning start times (6:00 AM or earlier) are not recommended because these tend to truncate sleep. Examine work start and end times and consider whether the evening and nighttime hours are required for the products and services produced. Avoid quick changes with less than 10–11 h off between shifts because this does not give enough time for a worker to commute to work, get ready for work, and get the 7–9 h of sleep most people need every day. Night shifts are associated with higher risks, so researchers commonly recommend using fixed nights with caution and limiting the consecutive number of night shifts to three for shift rotations [2,5,105]. Since longer shifts are also associated with higher risks, Folkard and Lombardi [5] recommend using shorter more frequent work shifts rather than longer, less frequent shifts. Avoid a long series of work days followed by a long series of days off (a mini-vacation without use of vacation days) because long series of work days tend to build

up fatigue. Researchers recommend using a forward rotation for rotating shifts (day shift to evening shift to night shift) over a backward rotation (evening shift to day shift to night shift) [2,106]. They recommended avoiding a weekly rotation, and suggested using rotations that change shifts several times per week, or every 2 weeks or more [2,106,107]. Researchers recommend maintaining a regular and predictable schedule because it helps the worker prepare for work, sleep, and other responsibilities. The inability to plan makes unscheduled mandatory work periods more difficult. Keep overtime to a minimum. Schedule 1 or 2 full weekends off each month to help workers maintain contact with family and friends [105].

Extended shifts require special consideration for the worker's needs due to the long number of consecutive hours worked. Knauth [19] recommended the following conditions be met for using extended shifts:

- The nature of the work and workload are suitable and do not include heavy physical demands, dangerous work, fast-paced demands, or high stress.
- Work periods include adequate rest breaks.
- The shift system, work tasks, and other features of the job are designed to minimize fatigue.
- There are adequate arrangements for covering absentees so that overtime will not be added.
- Toxic exposure is limited.
- Complete recovery after work is possible.
- Assessments are systematically carried out to identify adverse effects early.
- Demographic factors that are linked to more difficulties with long shifts are not present, such as an aging workforce.

The combination of difficult scheduling patterns or long shifts with heavy work demands is associated with higher risks. For example, a review by Caruso et al. [12] reports a pattern of adverse findings when 12 h shifts combine with more than 40 h a week, when 12 h shifts combine with very early start times, and when high workloads or hot work environments combine with 12 h shifts. Managers and workers can carefully consider the combined scheduling and job demands and modify schedules and workload to reduce risks.

Managers can work toward moving their organizations to make use of naps during work shifts. This includes policies to allow naps during the work shift, good nap environments, systems to schedule naps and awaken napping workers, and adequate staffing to cover the work.

Frequent rest breaks during the work shift help reduce risks. By pooling findings from several studies, Folkard and Lombardi [5] estimated that rest breaks every 2 h reduced risks more than 4 or 6 h rest breaks. Managers can improve their workplace approach for taking rest breaks.

Managers can schedule employees to work with others rather than working alone. They can also consider the timing of demanding tasks and try to schedule these at times when there is less chance for fatigue [105]. Long periods working on monotonous tasks increase

risk for fatigue [94], so it is useful to break up time on these tasks with other activities. In addition, managers can assess if staffing levels are appropriate for workload needs.

Managers can also consider the timing of services, environmental conditions, and social programs [105]. Since workers on shift work and long work hours may be at higher risk for certain diseases, managers can encourage regular health examinations to identify and treat any problem early. It would be helpful to schedule occupational health and counseling services so they are convenient for workers on evening and night shifts. The environmental conditions during nonstandard shifts should be considered and maintained so they are comfortable during the evening and night-shift hours. Workplaces often organize social programs during the holidays and at other times. These events should be planned to include shift workers and scheduled at times that are convenient for them.

There is widespread lack of appreciation and knowledge about the risks connected with insufficient sleep and demanding work hours, and as a consequence, workers and workplaces often lack systems to protect against these risks [108]. Training programs for workers and managers are recommended by the National Occupational Research Agenda (NORA) Long Work Hours Team, the American Petroleum Institute, and other organizations [4,109]. Content for training programs can include these nine topics:

1. Basic information about sleep, circadian rhythm, and fatigue physiology
2. Good sleep practices and behaviors to get adequate sleep
3. Sleep disorders and other sources of sleepiness and the importance of identifying and treating them
4. Safety risks linked to insufficient sleep
5. Risks for development and exacerbation of acute and chronic diseases from insufficient sleep and shift work and long work hours
6. Strategies to reduce fatigue-related injuries and errors
7. Signs of fatigue and workplace policies and strategies when workers are fatigued at work
8. Workplace interventions to reduce safety and health risks associated with shift work and long work hours
9. Training for family members about the special needs of workers on shift work and long work hours so they can provide better understanding and support

Workplaces can conduct systematic assessments to examine the influence of work schedules on factors on- and off-the-job including: performance, alertness, sleep, unintentional injury, worker errors, near misses, illnesses, and off-the-job responsibilities. An anonymous, no-blame reporting system can collect incident and near miss reports. Include information about the time of the incident, shift details, number of consecutive shifts worked, number of hours the person has been awake, number of hours of sleep in the previous 24 h, and normal or unusual circumstances such as overtime because of a weather

emergency [109]. Analyses of several incident reports may reveal factors that can be modified to reduce risks. Workplace fatigue-related policies can guide workers and managers on things such as the appropriate actions when a worker appears to be too fatigued to work safely, and the level of work hours that may be too high for safety reasons.

16.6.2 Improving Sleep Habits and Routines

The key strategy for reducing risks is getting enough good-quality sleep every day. Good sleep habits and routines, such as making the sleep environment more conducive to sleep and preparing oneself for sleep, improve sleep quality. Information on sleep hygiene, sleep disorders, and strategies for shift workers is available from several sources [98,110–113]. Figure 16.1 summarizes frequently recommended suggestions for improving sleep.

- Get the amount of sleep needed each day; most people need 7–8 h of sleep.
- Sleep at about the same times every day to help improve sleep.
- Use the bedroom only for sleeping and intimacy to foster associating it with relaxation and sleep. Do not use the television or work in the bedroom. Sleep in a very dark, quiet, well-ventilated space with a comfortable, cool temperature. Have a comfortable bed and pillows.
- For night and evening workers who need to sleep during daylight hours, create a completely dark bedroom by covering the windows with opaque coverings and block light from coming under the doorways. Light bulbs emitting dim red light or very dim night lights can be used by the path to the restroom. An alternative is to use an eye mask during the entire sleep episode. Prevent noise by using a white noise machine (like a fan) or ear plugs. Take measures to prevent awakening because of phone calls or the door bell.
- Relax before going to bed. Keep the light levels lower 2 h before bedtime and avoid household chores or stimulating activities for at least 2 h before bedtime. Avoid bright computer screens during this time period (or wear dark sunglasses to reduce this light exposure). Follow a relaxing bedtime routine within an hour or more of sleep to signal the brain it is time to sleep. Brushing the teeth and getting ready for bed facilitate relaxation and sleep. Some suggestions to help relax are a warm bath, listening to soothing music, meditating, breathing exercises, and other relaxation techniques.
- Avoid before bedtime.
  i. Heavy or spicy meals (2–3 h before bed).
  ii. Liquid intake (to avoid getting up to go to the bathroom).
  iii. Alcohol (causes early awakening and sleep disturbances).
  iv. Caffeine (avoid for several hours according to person's own sensitivity).
  v. Nicotine (avoid for several hours).
  vi. Going to bed on an empty stomach.
- Face the clock away from the bed to avoid focusing on the time if awaking before wake-up time.
- If unable to fall asleep within 30 min of going to bed or awaking early and being unable to get back to sleep, get out of bed and try a relaxing activity such as reading until becoming drowsy, but keep the light level low because bright light will promote wakefulness.
- Exercise regularly to improve sleep. However, end exercise at least 5 h before bedtime.

FIGURE 16.1 Suggestions for getting a good night's sleep. (From Patlak, M., *Your Guide to Healthy Sleep*, U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, NIH Publication No. 06-5271, 2005.)

Because sunlight and artificial light have an alerting effect and a strong influence on the timing of sleep, workers who need to sleep during daylight hours should take additional measures to prevent light exposure to their eyes during their sleep period and prevent disturbances from noise.

16.6.3 Correcting Other Causes of Sleepiness

Another strategy for reducing risks from fatigue is to identify and manage other factors that increase daytime sleepiness, including sleep disorders and a wide range of other chronic disorders that disturb sleep. Sleep-related problems are common, afflicting 50–70 million Americans, but are often undiagnosed and, therefore, not treated [108]. Insomnia increases with age. According to the National Sleep Foundation poll, "Sleep in America," only 33% of women ages 18–24 had a sleep problem a few nights a week, but 48% of women ages 55–64 did [114]. Sleepiness is a common side effect of several medications, such as antidepressants, cold tablets, and antihistamines. Sleep deprivation from shift work or long work hours can exacerbate underlying sleep disorders [115]. Because workers with fatigue who work these demanding schedules will be particularly vulnerable to fatigue-related risks, they should consider seeking an evaluation from a sleep disorders specialist if symptoms are present.

16.6.4 Using Naps

The Standards Practice Committee for sleep medicine recommends planned naps before or during night shifts, because research reflects a high degree of clinical certainty for their effectiveness [111]. Takahashi's [116] findings support the positive effects of naps during work shifts. Research indicates that a brief period of sleep (15–20 min), not just a quiet period, has an alerting effect [117]. If time is available, longer naps of 1.5 h or more can reduce sleep debt and provide further gains. However, after naps of greater than 45 min, there will be a period of grogginess, so it is important to allow time for this to pass before resuming dangerous or critical tasks [118]. When workers are sleepy after the work shift, a short nap may help restore alertness before the drive home.

16.6.5 Using Caffeine

Caffeine is a commonly used stimulant that takes approximately 30 min to reach peak plasma levels [119]. The equivalent of two cups of coffee can increase alertness for a few hours [120]. However, heavy daily use of caffeine may reduce its effectiveness. Instead, workers can use it strategically when the stimulant effect is needed.

16.6.6 Using a Combination of a Nap and Caffeine

If experiencing drowsiness while driving, experts suggest stopping driving, consuming caffeine, and then quickly taking a short nap [113]. On awakening, the person will gain the benefits from both. The combination of a 2.5 h nap before a night shift and caffeine at the beginning of the shift had positive effects on alertness [98,121].

16.6.7 Using Light

Researchers are testing the effectiveness of light treatments to improve adaptation to shift work. Light increases alertness and is a strong signal for circadian rhythms [91,110]. Many questions remain about the optimum color of light, intensities, and length of time for exposure to light to use to improve adjustment of the circadian rhythms [122]. Sunlight is most effective, but common levels of artificial room-level light (100 lux or more) also increase alertness [110]. For night workers, some researchers suggest intermittently going into well-lit areas during the first several hours of the shift and reducing light exposure a few hours before bedtime to help prepare the body for sleep when home [98,111].

16.6.8 Diet and Exercise

Many research questions remain about the effects of diet when working shift schedules and long work hours. A few studies suggest that simple sugars may increase sleepiness, so it is best to avoid sugar-rich beverages and foods when prone to sleepiness and there is a need to stay alert [123–125]. There is not yet enough evidence to clearly determine the best time to eat when working night shift and to give detailed information about what to eat to reduce metabolic disturbances and optimize alertness and performance [126]. Circadian rhythms involved in eating and digesting food are timed for eating during the day and fasting during the night. Researchers theorize that shift workers experience gastrointestinal symptoms, reduced glucose and lipid tolerance, and other gastrointestinal problems because of the mismatch in these circadian rhythms and the timing of food intake, sleep, and activity. Given the evidence currently available, Lowden et al. [126] offer the following dietary guidelines for shift workers:

- Avoid eating or reduce food intake between midnight and 6:00 AM. Use the normal daytime and nighttime pattern of meal timing as much as possible and divide intake into three meals per 24 h period.
- Eat more frequently when there are higher energy needs.
- During the shift, eat high-quality foods such as vegetables, salads, vegetable soups, fruits, wholegrain sandwiches, yogurt, cheese, eggs, nuts, and green tea. Avoid sugar-rich products, and low-fiber carbohydrate foods.
- Eat with colleagues in a pleasant environment away from the work site.
- For general dietary suggestions, avoid alcohol and foods with added sugar. Eat complete meals with animal products and starchy vegetables, or protein-rich plant foods (beans plus cereals, rice, pasta, plus roots) and non-starchy vegetables and fruits, or vegetarian meals consisting of protein-rich plant foods, fruits, and vegetables.
- For night workers, eat breakfast before day sleep to avoid waking due to hunger.
- Avoid large meals 1–2 h before the main sleep episode.

Although the evidence about the influence of exercise on shift work and long work hours leaves many questions, researchers offer some guidelines. A review by Caldwell et al. [110]

concluded that short periods of moderate exercise can increase alertness for brief periods (30 min), while longer periods of intense exercise may increase sleepiness. Sleep researchers commonly recommend regular exercise because it promotes better sleep. However, they recommend ending exercise at least 2–5 h before the main sleep episode [110,112].

16.6.9 Avoiding Ineffective Strategies

Researchers cautioned that several common strategies people use when feeling sleepy while driving actually do not help, such as putting down the window, turning the air conditioner on full blast, and playing the radio loudly [127]. Resorting to these strategies indicates that someone is struggling to stay awake and is too sleepy to continue driving safely [113].

16.6.10 Cautioning about Substances to Promote Sleep or Alertness

Many people can be helped by good sleep habits and routines, so it is best to use these behavioral strategies fully. Stimulants and sleep medications can help people who have difficulty with sleep or daytime sleepiness, but these substances can have side effects, can become addictive, and are generally just for short-term use [110,128]. In addition, they do not completely remedy the effects of inadequate sleep, and questions remain about their long-term use [111]. Given that caution, it is advisable for a worker to see a sleep disorders specialist if experiencing frequent sleep disturbances or excessive daytime sleepiness.

16.6.11 Gain Cooperation and Help from Family and Friends

Several studies link shift work and long work hours to strains on personal relationships and work/family conflict [51,129,130]. For families with children, Presser [131] reported divorce and separation are six times higher for men on night shift and three times higher for women on night shift. Mood disturbances from poor sleep and disturbances to circadian rhythms could be the source of some of these strains. Also, evening and night shifts and weekend work make it difficult to participate in normal social and family activities and give workers less quality time to spend with family and friends. Adopting good sleep practices and improving sleep would help reduce mood disturbances that strain relationships. Workers also can educate their family and friends about their special needs to gain their understanding and willingness to be flexible in juggling activities and demands [105]. Another strategy is to adopt systems to maintain communications such as writing notes and calling during the work shifts and scheduling time together.

16.7 FUTURE CONCERNS

There are many unanswered questions about risks linked to shift work and long work hours, the best work schedule patterns to use, and strategies to reduce risks. Because society requires many types of workers to provide vital services around the clock, it is not possible to eliminate shift work. At times, long work hours cannot be avoided. Future work settings and society would benefit from many types of research on this topic: (1) research to better explain the physiology underlying the health risks of circadian disturbances and sleep deprivation as well as strategies to reduce these risks; (2) studies to identify individual factors that account for the wide range of tolerances to sleep deprivation and circadian

rhythm disturbances; (3) epidemiology studies to assess the risks using better methods to handle underestimates from factors such as drop outs and the healthy worker effect; and (4) intervention studies using laboratory experiments as well as real world settings [4,93,132].

1. Research needs to provide a clear and complete description of the work schedules, the workers, and the work environment to better compare findings across studies, build evidence, and move the science forward.
2. Research needs to measure and control for factors that may influence the relationship between shift work and long work hours and outcomes.
3. Research should explore a wider range of possible outcomes: a variety of symptoms and functional deficits associated with having less time for sleep, work recovery, and other life necessities as well as longer exposures to occupational hazards and demands; the development of chronic diseases as well as acute injuries and illnesses; risks for the employer such as reduced productivity and quality of goods and services, increased absenteeism, higher health care and workers' compensation costs, and less successful recruitment and retention; short and long term impacts on marital partners, family life, and children; and impacts on the community.
4. Research should examine shift work and long work hours in occupations involving public safety (e.g., health care, law enforcement, transportation, utilities) since the consequences of errors due to fatigue can be especially great.
5. Research should examine workers in vulnerable groups: women who are pregnant and couples who wish to become pregnant; older workers; workers with chronic illnesses including symptom management and disease progression; workers exposed to occupational hazards; and socio-economically disadvantaged workers.
6. More regular, systematic tracking and assessment of work schedules in the United States is needed.
7. Research should develop and test interventions to reduce risks including but not limited to: various work scheduling patterns; manipulating light exposure, pharmacology agents, diet regimes, and other work organization strategies such as supervisor and coworker support; workplace or corporate interventions including fatigue-related policies, fatigue risk management systems, and education campaigns for workers and managers; models to predict risks; and studies of the impact of broader public policy measures (e.g., impact of the state laws limiting mandatory overtime for nurses).

REFERENCES

1. T. M. McMenamin, A time to work: Recent trends in shift work and flexible schedules, *Mon Labor Rev. 130*(12): 3–15 (2007).
2. P. Knauth and S. Hornberger, Preventive and compensatory measures for shift workers, *Occup Med (Lond). 53*: 109–116 (2003).
3. Healthy People 2020. Sleep health. www.healthypeople.gov/2020/topicsobjectives2020/objectiveslist.aspx?topicid=38 (accessed December 3, 2010).

4. C. C. Caruso, T. Bushnell, D. Eggerth et al., Long working hours, safety, and health: Toward a national research agenda, *Am J Ind Med. 49*: 930–942 (2006).
5. S. Folkard and D. A. Lombardi, Modeling the impact of the components of long work hours on injuries and 'accidents,' *Am J Ind Med. 49*: 953–963 (2006).
6. J. Barton, E. Spelten, P. Totterdell et al., The standard shiftwork index: A battery of questionnaires for assessing shiftwork-related problems, *Work Stress. 9*: 4–30 (1995).
7. A. Knutsson, Methodological aspects of shiftwork research, *Chronobiol Int. 21*: 1037–1047 (2004).
8. R. R. Rosa, M. Harma, K. Pulli et al., Rescheduling a three shift system at a steel rolling mill: Effects of a onc hour delay of shift starting times on sleep and alertness in younger and older workers, *Occup Environ Med. 53*: 677–685 (1996).
9. C. A. Czeisler, M. C. Moore-Ede, and R. H. Coleman, Rotating shift work schedules that disrupt sleep are improved by applying circadian principles, *Science. 217*: 460–463 (1982).
10. K. Orth-Gomer, Intervention on coronary risk factors by adapting a shift work schedule to biologic rhythmicity, *Psychosom Med. 45*: 407–415 (1983).
11. C. J. Poole, G. R. Evans, A. Spurgeon, and K. W. Bridges, Effects of a change in shift work on health, *Occup Med. 42*: 193–199 (1992).
12. C. C. Caruso, E. M. Hitchcock, R. B. Dick et al., *Overtime and Extended Work Shifts: Recent Findings on Illnesses, Injuries, and Health Behaviors*, Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, OH, DHHS NIOSH Publication No. 2004-143, 2004.
13. D. Angersbach, P. Knauth, H. Loskant et al., A retrospective cohort study comparing complaints and diseases in day and shift workers, *Int Arch Occup Environ Health. 45*: 127–140 (1980).
14. L. Nylén, M. Voss, and B. Floderus, Mortality among women and men relative to unemployment, part-time work, overtime work, and extra work: A study based on data from the Swedish twin registry, *Occup Environ Med. 58*: 52–57 (2001).
15. T. M. Beers, Flexible schedules and shift work: Replacing the '9-to-5' workday? *Mon Labor Rev. 123*: 33–40 (2000).
16. C. L. Drake, T. Roehrs, G. Richardson et al., Shift work sleep disorder: Prevalence and consequences beyond that of symptomatic day workers, *Sleep. 27*: 1453–1462 (2004).
17. M. Ingre and T. Åkerstedt, Effect of accumulated night work during the working lifetime, on subjective health and sleep in monozygotic twins, *J Sleep Res. 13*: 45–48 (2004).
18. J. J. Pilcher, B. J. Lambert, and A. I. Huffcutt, Differential effects of permanent and rotating shifts on self- report sleep length: A meta-analytic review, *Sleep. 23*: 155–163 (2000).
19. P. Knauth, Extended work periods, *Ind Health. 45*: 125–136 (2007).
20. T. Hayashi, Y. Kobayashi, K. Yamaoka, and E. Yano, Effect of overtime work on 24-h ambulatory blood pressure, *J Occup Environ Med. 38*: 1007–1011 (1996).
21. T. Kageyama, N. Nishikido, T. Kobayashi et al., Long commuting time, extensive overtime, and sympathodominant state assessed in terms of short-term heart rate variability among male white-collar workers in the Tokyo megalopolis, *Ind Health. 36*: 209–217 (1998).
22. N. Nakanishi, K. Nakamura, S. Ichikawa et al., Lifestyle and the development of hypertension: A 3- year follow-up study of middle-aged Japanese male office workers, *Occup Med. 49*: 109–114 (1999).
23. J. Park, Y. Kim, H. K. Chung, and N. Hisanaga, Long working hours and subjective fatigue symptoms, *Ind Health. 39*: 250–254 (2001).
24. T. Sasaki, K. Iwasaki, T. Oka et al., Effect of working hours on cardiovascular-autonomic nervous functions in engineers in an electronics manufacturing company, *Ind Health. 37*: 55–61 (1999).
25. M. Basner, K. Fomberstein, F. M. Razavi et al., American time use survey: Sleep time and its relationship to waking activities, *Sleep. 30*: 1081–1091 (2007).

26. C. A. Everson, Comparative research approaches to discovering the biomedical implications of sleep loss and sleep recovery, in *Basics of Sleep Guide*, C.J. Amlaner, D. Phil, and P.M. Fuller, Eds., Sleep Research Society, Westchester, IL, 2009.
27. National Sleep Foundation, How much sleep do we really need? www.sleepfoundation.org/how-much-sleep-do-we-really-need (accessed June 7, 2010).
28. N. Goel, H. Rao, J. S. Durmer, and D. F. Dinges, Neurocognitive consequences of sleep deprivation, *Semin Neurol. 29*: 320–339 (2009).
29. H. J. Moller, L. Kayumov, E. L. Bulmash et al., Simulator performance, microsleep episodes, and subjective sleepiness: Normative data using convergent methodologies to assess driver drowsiness, *J Psychosom Res. 613*: 335–342 (2006).
30. J. S. Durmer and D. F. Dinges, Neurocognitive consequences of sleep deprivation, *Semin Neurol. 25*: 117–129 (2005).
31. J. J. Pilcher, L. E. McClelland, D. D. Moore et al., Language performance under sustained work and sleep deprivation conditions, *Aviat Space Environ Med. 785*: Suppl B25–B38 (2007).
32. V. Venkatraman, Y. M. L. Chuah, S. A. Huettel, and M. W. L. Chee, Sleep deprivation elevates expectation of gains and attenuates response to losses following risky decisions, *Sleep. 305*: 603–609 (2007).
33. J. T. Arnedt, J. Owens, M. Crouch et al., Neurobehavioral performance of residents after heavy night call vs. after alcohol ingestion, *JAMA. 2949*: 1025–1033 (2005).
34. D. Dawson and K. Reid, Fatigue, alcohol and performance impairment, *Nature. 388*(6639): 235 (1997).
35. A. M. Williamson and A. M. Feyer, Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication, *Occup Environ Med. 57*: 649–655 (2000).
36. National Highway Traffic Safety Administration, On DWI laws in other countries. www.nhtsa.gov/people/injury/research/pub/DWIothercountries/dwiothercountries.html (accessed July 7, 2010), 2000.
37. H. P. Van Dongen, G. Maislin, J. M. Mullington, and D. F. Dinges, The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation, *Sleep. 262*: 117–126 (2003).
38. A. E. Dembe, J. B. Erickson, R. G. Delbos, and S. M. Banks, The impact of overtime and long work hours on occupational injuries and illnesses: New evidence from the United States, *Occup Environ Med. 62*: 588–597 (2005).
39. B. de Castro, K. Fujishiro, T. Rue et al., Associations between work schedule characteristics and occupational injury and illness, *Int Nurs Rev. 57*(2): 188–194 (2010).
40. R. R. M. Gershon, J. M. Pearson, M. F. Sherman et al., The prevalence and risk factors for percutaneous injuries in registered nurses in the home health care sector, *Am J Infect Control. 37*: 525–533 (2009).
41. P. T. Bushnell, A. Colombi, C. C. Caruso, and S. Tak, Work schedules and health behavior outcomes at a large manufacturer, *Ind Health. 48*: 395–405 (2010).
42. P. Frost, H. A. Kolstad, and J. P. Bonde, Shift work and the risk of ischemic heart disease—A systematic review of the epidemiologic evidence, *Scand J Work Environ Health. 35*: 163–179 (2009).
43. L. C. Antunes, R. Levandovski, G. Dantas et al., Obesity and shift work: Chronobiological aspects, *Nutr Res Rev. 23*: 155–168 (2010).
44. K. Nakamura, S. Shimai, S. Kikuchi et al., Increases in body mass index and waist circumference as outcomes of working overtime, *Occup Med (Lond). 48*: 169–173 (1998).
45. M. Shields, Long working hours and health, *Health Rep. 11*: 33–48 (1999).
46. K. Spiegel, E. Tasali, R. Leproult, and E. Van Cauter, Effects of poor and short sleep on glucose metabolism and obesity risk, *Nat Rev Endocrinol. 5*: 253–261 (2009).
47. R. L. Sack, Jet lag, *N Engl J Med. 362*: 440–447 (2010).

48. C. C. Caruso, S. L. Lusk, and B. W. Gillespie, Relationship of work schedules to gastrointestinal diagnoses, symptoms, and medication use in auto factory workers, *Am J Ind Med. 46*: 586–598 (2004).
49. A. Knutsson and H. Boggild, Gastrointestinal disorders among shift workers, *Scand J Work Environ Health. 36*: 85–95 (2010).
50. E. S. Schernhammer, F. Laden, F. E. Speizer et al., Night-shift work and risk of colorectal cancer in the nurses' health study, *J Natl Cancer Inst. 95*: 825–828 (2003).
51. S. M. Rohr, S. G. Von Essen, and L. A. Farr, Overview of the medical consequences of shift work, *Clin Occup Environ Med. 3*: 351–361 (2003).
52. S. Puttonen, M. Harma, and C. Hublin, Shift work and cardiovascular disease—Pathways from circadian stress to morbidity, *Scand J Work Environ Health. 36*(2): 96–108 (2010).
53. D. L. Brown, D. Feskanich, B. N. Sanchez et al., Rotating night shift work and the risk of ischemic stroke, *Am J Epidemiol. 169*(11): 1370–1377 (2010).
54. K. Straif, R. Baan, Y. Grosse et al., Carcinogenicity of shift-work, painting, and fire-fighting, *Lancet Oncol. 8*: 1065–1066 (2007).
55. S. P. Megdal, C. H. Kroenke, F. Laden et al., Night work and breast cancer risk: A systematic review and meta-analysis, *Eur J Cancer. 41*: 2023–2032 (2005).
56. M. Conlon, N. Lightfoot, and N. Kreiger, Rotating shift work and risk of prostate cancer, *Epidemiology. 18*: 182–183 (2007).
57. T. Kubo, K. Ozasa, K. Mikami et al., Prospective cohort study of the risk of prostate cancer among rotating-shift workers: Findings from the Japan Collaborative Cohort Study, *Am J Epidemiol. 164*: 549–555 (2006).
58. J. Schwartzbaum, A. Ahlbom, and M. Feychting, Cohort study of cancer risk among male and female shift workers, *Scand J Work Environ Health. 33*: 336–343 (2007).
59. G. Costa, E. Haus, and R. Stevens, Shift work and cancer—Considerations on rationale, mechanisms, and epidemiology, *Scand J Work Environ Health. 36*: 163–179 (2010).
60. L. M. Frazier and D. A. Grainger, Shift work and adverse reproductive outcomes among men and women, *Clin Occup Environ Med. 3*: 279–292 (2003).
61. A. Shechter, F. O. James, and D. B. Boivin, Circadian rhythms and shift working women, *Sleep Med Clin. 3*(1): 13–24 (2008).
62. A. Sood, Medical screening and surveillance of shift workers for health problems, *Clin Occup Environ Med. 3*: 339–349 (2003).
63. J. M. Harrington, Health effects of shift work and extended hours of work, *Occup Environ Med. 58*: 68–72 (2001).
64. S. L. Ettner and J. G. Grzywacz, Workers' perceptions of how jobs affect health: A social ecological perspective, *J Occup Health Psychol. 6*: 101–113 (2001).
65. K. Iwasaki, T. Sasaki, T. Oka, and N. Hisanaga, Effect of working hours on biological functions related to cardiovascular system among salesmen in a machinery manufacturing company, *Ind Health. 36*: 361–367 (1998).
66. S. P. Proctor, R. F. White, T. G. Robins et al., Effect of overtime work on cognitive function in automotive workers, *Scand J Work Environ Health. 22*: 124–132 (1996).
67. O.-L. Siu and I. Donald, Psychosocial factors at work and workers' health in Hong Kong: An exploratory study, *Bull Hong Kong Psychol Soc. 34/35*: 30–56 (1995).
68. M. van der Hulst, M. van Veldhoven, and D. Beckers, Overtime and need for recovery in relation to job demands and job control, *J Occup Health. 48*: 11–19 (2006).
69. E. Kleppa, B. Sanne, and G. S. Tell, Working overtime is associated with anxiety and depression: The Hordaland Health Study, *J Occup Environ Med. 50*: 658–666 (2008).
70. Y. Suwazono, S. Nagashima, Y. Okubo et al., Estimation of the number of working hours critical for the development of mental and physical fatigue symptoms in Japanese male workers—Application of benchmark dose method, *Am J Ind Med. 50*(3): 173–182 (2007).

71. N. Kawakami, S. Araki, N. Takatsuka et al., Overtime, psychosocial working conditions, and occurrence of non-insulin dependent diabetes mellitus in Japanese men, *J Epidemiol Community Health. 53*: 359–363 (1999).
72. Y. Liu, H. Tanaka, and The Fukuoka Heart Study Group, Overtime work, insufficient sleep, and risk of non-fatal acute myocardial infarction in Japanese men, *Occup Environ Med. 59*: 447–451 (2002).
73. S. Sokejima and S. Kagamimori, Working hours as a risk factor for acute myocardial infarction in Japan: Case-control study, *BMJ. 317*: 775–780 (1998).
74. C. C. Caruso and T. R. Waters, A review of work schedule issues and musculoskeletal disorders with an emphasis on the healthcare sector, *Ind Health. 46*: 523–534 (2008).
75. P. Tuntiseranee, J. Olsen, A. Geater, and O. Kor-anantakul, Are long working hours and shift-work risk factors for subfecundity? A study among couples from southern Thailand, *Occup Environ Med. 55*: 99–105 (1998).
76. E. L. Mozurkewich, B. Luke, M. Avni, and F. M. Wolf, Working conditions and adverse pregnancy outcome: A meta-analysis, *Obstet Gynecol. 95*: 623–635 (2000).
77. A. E. Rogers, W. Hwang, L. D. Scott et al., The working hours of hospital staff nurses and patient safety, *Health Aff. 23*: 202–212 (2004).
78. C. P. Landrigan, J. M. Rothschild, J. W. Cronin et al., Effect of reducing interns' work hours on serious medical errors in intensive care units, *N Engl J Med.* 351: 1838–1848 (2004).
79. W. G. Sirois, The secret cost of fatigue. www.circadian.com/download/15_the_secret_cost_of_fatigue.pdf (accessed March 2008), 2007.
80. M. R. Rosekind, K. B. Gregory, M. M. Mallis et al., The cost of poor sleep: Workplace productivity loss and associated costs, *J Occup Environ Med. 521*: 91–98 (2010).
81. National Sleep Foundation, Who is at risk? http://drowsydriving.org/about/ whos-at-risk/ (accessed July 7, 2010).
82. Baker Panel, *The Report of the BP U.S. Refineries Independent Safety Review Panel.* www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/SP/STAGING/local_assets/assets/pdfs/Baker_panel_report.pdf (accessed December 3, 2010), 2007.
83. M. M. Mitler, M. A. Carskadon, C. A. Czeisler et al., Catastrophes, sleep, and public policy: Consensus report, *Sleep. 11*: 100–109 (1988).
84. Peter D. Hart Research Associates, *The Nurse Shortage: Perspectives from Current Direct Care Nurses and Former Direct Care Nurses.* www.aft.org/pubs-reports/healthcare/Hart_Report.pdf (accessed on June 7, 2006), 2001.
85. P. C. Zee and F. W. Turek, Sleep and health—Everywhere and in both directions, *Arch Intern Med. 166*: 1686–1688 (2006).
86. K. Spiegel, R. Leproult, and E. Van Cauter, Impact of sleep debt on metabolic and endocrine function, *Lancet. 354*: 1435–1439 (1999).
87. F. A. J. L. Scheer and S. A. Shea, Fundamentals of the circadian system, in *Basics of Sleep Guide*, 2nd edn., C.J. Amlaner and P.M. Fuller, Eds., Sleep Research Society, Westchester, IL, 2009.
88. P. Lavie, Ultrashort sleep-waking schedule. III. 'Gates' and 'forbidden zones' for sleep, *Electroencephalogr Clin Neurophysiol. 63*: 414–425 (1986).
89. P. C. Zee and B. S. Lu, Insomnia and circadian rhythm sleep disorders, *Psychiatr Ann. 38*: 583–589 (2008).
90. J. Arendt, Shift work: Coping with the biological clock, *Occup Med (Lond). 60*: 10–20 (2010).
91. C. Cajochen, Alerting effects of light, *Sleep Med Rev. 116*: 453–464 (2007).
92. V. L. Revell and C. I. Eastman, How to trick mother nature into letting you fly around or stay up all night, *J Biol Rhythms. 20*: 353–365 (2005).
93. T. Kantermann, M. Juda, C. Vetter, T. Roenneberg, Shift-work research: Where do we stand, where should we go? *Sleep Biol Rhythms. 8*: 95–105 (2010).
94. N. J. Wesensten, G. Belenky, D. R. Thome et al., Modafinil vs. caffeine: Effects on fatigue during sleep deprivation, *Aviat Space Environ Med. 756*: 520–525 (2004).

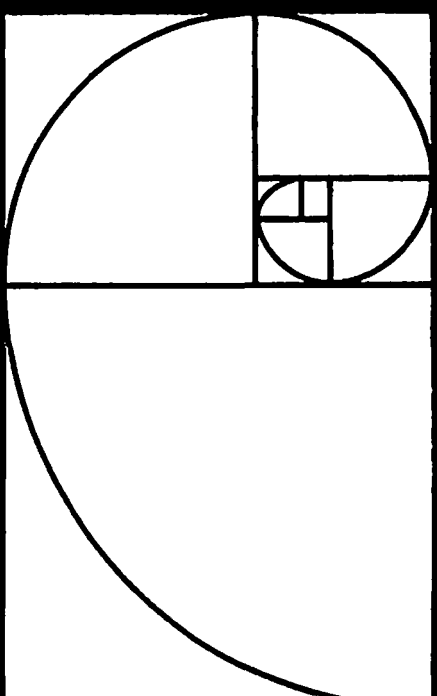
95. H. P. Landolt and D. J. Dijk, Genetic basis of sleep in healthy humans, in *Principles and Practice of Sleep Medicine*, 5th edn., M.H. Kryger, T. Roth, and W.C. Dement, Eds., Elsevier, St. Louis, MO, 2011, p. 175.
96. S. J. Crowley, C. Acebo, and M. A. Carskadon, Sleep, circadian rhythms, and delayed phase in adolescence, *Sleep Med. 8*: 602–612 (2007)
97. J. F. Duffy, D. J. Dijk, E. B. Klerman et al., Later endogenous circadian temperature nadir relative to an earlier wake time in older people, *Am J Physiol.* 275(5 Pt 2): R1478–R1487 (1998).
98. R. L. Sack, D. Auckley, R. R. Auger et al., Circadian rhythm sleep disorders: Part 1, basic principles, shift work and jet lag disorders, *Sleep. 30*: 1460–1483 (2007).
99. J. F. Duffy, Shift work and aging roles of sleep and circadian rhythms, *Clin Occup Environ Med. 3*: 311–332 (2003).
100. J. Axelsson, G. Kecklund, T. Åkerstedt et al., Sleepiness and performance in response to repeated sleep restriction and subsequent recovery during semi-laboratory conditions, *Chronobiol Int. 25*(2): 297–308 (2008).
101. G. Belenky, N. J. Wesensten, D. R. Thorne et al., Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: A sleep dose-response study, *J Sleep Res. 12*(1): 1–12 (2003).
102. J. R. Schwartz and T. Roth, Neurophysiology of sleep and wakefulness: Basic science and clinical implications, *Curr Neuropharmacol. 64*: 367–378 (2008).
103. National Sleep Foundation, Detection and prevention. http://drowsydriving.org/about/detection-and-prevention/ (accessed July 7, 2010).
104. S. Pallesen, B. Bjorvatn, N. Mageroy et al., Measures to counteract the negative effects of night work, *Scand J Work Environ Health. 36*: 109–120 (2010).
105. R. R. Rosa and M. J. Colligan, *Plain Language About Shiftwork*, Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Biomedical and Behavioral Science, Cincinnati, OH, DHHS NIOSH Publication No. 97-145, 1997.
106. M. Sallinen and G. Kecklund, Shift work, sleep, and sleepiness—Differences between shift schedules and systems, *Scand J Work Environ Health. 36*(2): 121–133 (2010).
107. T. H. Monk, What can the chronobiologist do to help the shift worker? *J Biol Rhythms. 15*: 86–94 (2000).
108. H. R. Colten and B. M. Altevogt, *Sleep Disorders and Sleep Deprivation an Unmet Public Health Problem*, National Academies, Washington, DC, 2006.
109. American Petroleum Institute, *Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries*, American Petroleum Institute, Washington, DC, 2010.
110. J. A. Caldwell, M. M. Mallis, J. L. Caldwell et al., Fatigue countermeasures in aviation, *Aviat Space Environ Med. 801*: 29–59 (2009).
111. T. I. Morgenthaler, T. Lee-Chiong, C. Alessi et al., Practice parameters for the clinical evaluation and treatment of circadian rhythm sleep disorders, *Sleep. 30*: 1445–1459 (2007).
112. M. Patlak, *Your Guide to Healthy Sleep*, U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, NIH Publication No. 06-5271, 2005.
113. National Sleep Foundation, www.sleepfoundation.org (accessed July 7, 2010), n.d.d.
114. National Sleep Foundation, Summary of findings of 2007 sleep in America poll. www.sleepfoundation.org/sites/default/files/Summary_Of_Findings%20-%20FINAL.pdf (accessed July 7, 2010), n.d.e.
115. A. Sharifian, M. Firoozeh, G. Pouryaghoub et al., Restless legs syndrome in shift workers: A cross sectional study on male assembly workers, *J Circadian Rhythms. 7*: 12 (2009).
116. M. Takahashi, The role of prescribed napping in sleep medicine, *Sleep Med Rev. 73*: 227–235 (2003).

117. M. Takahashi, H. Fukuda, and H. Arito, Brief naps during post-lunch rest: Effects on alertness, performance, and autonomic balance, *Eur J Appl Physiol Occup Physiol. 782*: 93–98 (1998).
118. A. T. Wertz, J. M. Ronda, C. A. Czeisler, and K. P. Jr. Wright, Effects of sleep inertia on cognition, *JAMA. 195*: 163–164 (2006).
119. T. Roehrs and T. Roth, Caffeine: Sleep and daytime sleepiness, *Sleep Med Rev. 122*: 153–162 (2008).
120. National Sleep Foundation, Getting enough sleep can save your life on the roads. http://drowsydriving.org/2010/05/getting-enoughsleep-can-save-your-life-on-the-roads/ (accessed July 10, 2010), n.d.f.
121. P. K. Schweitzer, A. C. Randazzo, K. Stone et al., Laboratory and field studies of naps and caffeine as practical countermeasures for sleep-wake problems associated with night work, *Sleep. 291*: 39–50 (2006).
122. M. Terman, Blue in the face, *Sleep Med. 103*: 277–278 (2009).
123. C. Anderson and J. A. Horne, A high sugar content, low caffeine drink does not alleviate sleepiness but may worsen it, *Hum Psychopharmacol. 215*: 299–303 (2006).
124. D. Burdakov, L. T. Jensen, H. Alexopoulos et al., Tandem-pore K+ channels mediate inhibition of orexin neurons by glucose, *Neuron. 505*: 711–722 (2006).
125. A. Lowden, U. Holmback, T. Åkerstedt et al., Performance and sleepiness during a 24 h wake in constant conditions are affected by diet, *Biol Psychol. 653*: 251–263 (2004).
126. A. Lowden, C. Moreno, U. Holmbäck et al., Eating and shift work—Effects on habits, metabolism and performance, *Scand J Work Environ Health. 362*: 150–162 (2010).
127. W. Vanlaar, H. Simpson, D. Mayhew, and R. Robertson, Fatigued and drowsy driving: A survey of attitudes, opinions and behaviors, *J Safety Res. 393*: 303–309 (2008).
128. J. A. Caldwell and J. L. Caldwell, Fatigue in military aviation: an overview of U.S. military-approved pharmacological countermeasures, *Aviat Space Environ Med. 76*(7 Suppl): C39–C51 (2005).
129. D. S. Carlson and P. L. Perrewe, The role of social support in the stressor-strain relationship: An examination of work-family conflict, *J Manag. 25*: 513–540 (1999).
130. J. H. Greenhaus, A. G. Bedeian, and K. W. Mossholder, Work experiences, job performance, and feelings of personal and family well-being, *J Vocat Behav. 31*: 200–215 (1987).
131. H. B. Presser, Nonstandard work schedules and marital instability, *J Marriage Fam. 62*: 93–110 (2000).
132. H. Bøggild, Settling the question—The next review on shift work and heart disease in 2019, *Scand J Work Environ Health. 35*(3): 157–161 (2009).

Occupational Ergonomics

Theory and Applications

Second Edition



edited by

Amit Bhattacharya

James D. McGlothlin

CRC Press

Occupational Ergonomics

Theory and Applications

Second Edition

edited by

Amit Bhattacharya

University of Cincinnati Medical College
Cincinnati, Ohio

Co-Founder, OsteoDynamics, Inc.
Cincinnati, Ohio

James D. McGlothlin

Purdue University
West Lafayette, Indiana

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an informa business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
Version Date: 20120112

International Standard Book Number: 978-1-4398-1934-0 (Hardback)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

ERGONOMICS AND HUMAN FACTORS

In the fifteen years since the publication of **Occupational Ergonomics: Theory and Applications**, significant advances have been made in this field. These advances include the impact of aging and obesity on workplace, the role of ergonomics in promoting healthy workplaces and healthy life styles, the role of ergonomic science in the design of consumer products, and much more. The caliber of information and the simple, practical ergonomics solutions in the second edition of this groundbreaking resource, though, haven't changed.

See What's New in the Second Edition:

- Enhanced coverage of ergonomics in the international arena
- Emerging topics such as healthcare ergonomics and economics of ergonomics
- Coverage of disability management and psychosocial rehabilitation aspects of workplace and its ergonomics implication
- Current ergonomics solutions from "research to practice"
- Synergy of healthy workplaces with healthy lifestyles
- Impact of physical agents on worker health/safety and its control
- Additional problems with solutions in the appendix

The book covers the fundamentals of ergonomics and the practical application of those fundamentals in solving ergonomic problems. The scope is such that it can be used as a reference for graduate students in the health sciences, engineering, technology, and business as well as professional practitioners of these disciplines. Also, it can be used as a senior-level undergraduate textbook, with solved problems, case studies, and exercises included in several chapters. The book blends medical and engineering applications to solve musculoskeletal, safety, and health problems in a variety of traditional and emerging industries ranging from the office to the operating room to operations engineering.

CRC Press
Taylor & Francis Group
an informa business
www.taylorandfrancisgroup.com
6000 Broken Sound Parkway, NW
Suite 300, Boca Raton, FL 33487
711 Third Avenue
New York, NY 10017
2 Park Square, Milton Park
Abingdon, Oxon OX14 4RN, UK