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Key terms: circadian rhythm; evening shift; fatigue; job-related injury; night shift; nonstandard shift schedule; occupational illness; occupational injury; risk; rotating shift; stress; work schedule

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Nonstandard shift schedules and the risk of job-related injuries

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Objectives This study assessed the extent to which working various types of nonstandard shift schedules (eg, night and evening shifts) is associated with the risk of occupational injuries or illnesses.

Methods Multivariate analyses were conducted using data from 13 years (1987 to 2000) of the National Longitudinal Survey of Youth (NLSY) encompassing 110 236 job records and over 82 000 person-years of work experience. Cox proportional hazard regression techniques were used to derive hazard ratios comparing the relative risk of suffering a work-related injury among people working night, evening, rotating, split, and irregular shifts to the risks for those working conventional day shifts, after adjustment for age, gender, occupation, industry, and region. Incidence rates were normalized using a common denominator of 100 person-years of "at-risk time" to obtain valid comparisons.

Results All of the nonstandard shift schedules, except split shifts, were found to have a higher risk for occupational injuries and illnesses than conventional day shifts. After control for the selected covariates, the calculated hazard ratios were 1.43 for evening shifts [95% confidence interval (95% CI) 1.26–1.62], 1.36 for rotating shifts (95% CI 1.17–1.58), 1.30 for night shifts (95% CI 1.12–1.52), 1.15 for irregular shifts (1.03–1.30), and 1.06 for split shifts (0.71–1.58).

Conclusions These findings suggest that nonstandard shifts are not more risky merely because of the concentration of hazardous jobs in those types of schedules or because of underlying differences in the characteristics of employees working nonstandard shifts. The results point to the need to extend targeted injury prevention programs not only to people working night shifts, but also to those who work evenings.

Key terms circadian rhythm; evening shift; fatigue; night shift; occupational injury; occupational illness; rotating shift; stress; work schedule.

The United States (US) Department of Labor estimates that approximately 15 million Americans (14% of the private-sector workforce) work on evening, night, or rotating shifts or on other forms of shift work that differ from conventional day shifts (1–2). [We refer to these unconventional shift schedules as *nonstandard shifts*.] In the United States, men, African-Americans, and young workers are more likely to work nonstandard shifts than women, Caucasians, and older workers (1–2). The use of nonstandard shifts varies by industry and fluctuates according to economic conditions. US industries commonly scheduling nonstandard shifts include health care, transportation, education, retail, food products, and police, fire, and emergency services (1–2).

Evidence suggests that working nonstandard shifts can adversely affect workers' health (3–8). Several studies have attributed such effects primarily to disruptions in the body's system for regulating circadian rhythms, the so-called *biological clock*, which helps to stabilize metabolic, endocrine, sleep, and other physiological functions (9–12). Nonstandard shifts have been associated with sleep disturbances (13–15), digestive system and eating problems (7, 16–18), depression and other psychological or nervous disorders (19–20), cardiovascular disease (7, 20–23), certain types of cancer (24–26), and miscarriage (27–29). It has been suggested that working nonstandard shifts can exacerbate the effects of various systemic diseases including diabetes mellitus and epilepsy (7, 20). Nonstandard shift work has also been linked to a variety of social effects, including isolation, problems with family relationships (20, 30–32), alcohol and tobacco use (33), absenteeism (34–36), and decreased vocational performance (13–14, 37, 38).

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Several studies have examined the relationship between the type of shift schedule (eg, day, evening, night, rotating) and the risk of workplace accidents (39–48). Other studies have investigated whether workplace accidents are related to shift duration (49–51), time of day within a shift (52–54), or the number of successive shifts worked over several days or nights (55–56). One researcher recently attempted to aggregate the effects of the various features of shift work (type, duration, time of day, and successive shifts) into a summary "risk index" (57). Several reviews have been published summarizing existing research concerning the association between shift work and industrial accidents (58–60).

Despite these research efforts, much is still unknown about the influence of shift work on the risk of accidents and job-related injury.[3] Many of the existing research findings are incomplete and inconsistent. For example, some studies have concluded that night shifts have the greatest level of risk (43, 47), while others have found that evening shifts (42) or rotating shifts (41, 45–46) are the most dangerous. Other studies have not detected any evidence of a relationship between the type of shift and injury risk (14, 60–62) or have found that conventional day work is the most dangerous (44).

Many existing studies have serious methodological shortcomings, including small sample sizes, unique industry-specific circumstances that limit the generalizability of the findings, and the failure to account for potential confounding factors. For example, jobs performed during nonstandard shifts may be inherently more dangerous, or people working nonstandard schedules may have different personal characteristics (eg, age, gender, or underlying health status) that affect their injury risk. In addition, few studies have involved large sample sizes or study populations representing a mix of industries and occupations. A recent comprehensive review of the existing literature on shift work and workplace accidents found "few truly useful papers for analysis" and observed that "even the few detailed studies examined point to the continuing discrepancies and uncertainties regarding research data in this field [p 34]" (59).

Our study attempts to advance this field of knowledge by providing information about the accident hazards of shiftwork schedules among a large population of American workers. We examined the reported incidence of work-related injuries and illnesses among a nationally representative sample of 10 793 working adults from industries throughout the United States. The study spans 13 years of work history and draws upon information contained in 110 236 job records. Incidence rates for work-related injuries among workers in five types of nonstandard shift schedules (evening, night, spilt, rotating, and irregular) were compared with the rates of those working conventional day schedules. Multivariate analyses were employed to control for the influence of workers' age and gender, geographic region, industry sector, and occupation.

The primary study hypothesis (based on previous research and theoretical considerations regarding the effects of circadian rhythms) is that working night, evening, or rotating shifts increases the likelihood of suffering occupational injuries or illnesses when compared with working conventional day schedules, after salient personal factors and the inherent accident risks of the workers' jobs and industries have been controlled for. In our estimation, there was insufficient evidence to formulate an a priori hypothesis about the relative risks associated with split or irregular shifts. Our study examined only the relationship between the type of workshift and accident incidence; we did not consider the potential impact of time of day within shifts or the effects of working successive shifts over several days or nights. Results from a separate study concerning the accident risks associated with shift duration and overtime schedules using data from this cohort have been reported previously (49).

The ultimate aim of this research is to collect information about the extent to which particular types of work schedules affect the risk of occupational injuries so that strategies can be formulated to mitigate the risks and prevention programs can be directed towards the most vulnerable worker populations.

Study population and methods

This study used data from the National Longitudinal Survey of Youth (NLSY), sponsored by the US Bureau of Labor Statistics (63). The NLSY cohort is comprised of 12 686 men and women who were 14 to 22 years of age when first surveyed in 1979. Follow-up interviews with NLSY respondents have been conducted annually from 1979 through 1994 and biannually since 1996.

The NLSY collected information on respondents' sociodemographic characteristics, household composition, education, training, detailed work histories, job and employer characteristics, income and assets, health insurance status, incidence of work-related injuries and illnesses, episodes of work disability, and the respondents' social and domestic functioning. NLSY provided sampling weights for each response to reflect the national distribution of American adults in this age range.

3 The word "injury" is often used as a generic term covering both work-related injuries and illnesses in occupational reporting systems in the United States. We have adopted this usage in the title and text of this article.

This study examined the experience of these persons between 1987 through 2000. During these years, 10 793 members of the cohort reported working in at least one job. A job record was created for each job held by an individual during each survey period. Altogether 110 236 job records were available for analysis, encompassing a total of 89 729 person-years of accumulated worktime. Each job record contained extensive self-reported information about the characteristics of the job, including the date of beginning work in the job, the end date (if applicable), job responsibilities and activities, occupational category, employer's industry sector, job location, customary work schedule, usual daily job starting and ending times, and commuting time.

The NLSY asked respondents to indicate the type of shift schedule usually worked in each job, using the following question: "Which of the following categories best describes the hours you work at this job?" The alternative responses were (i) regular day shift, (ii) regular evening shift, (iii) regular night shift, (iv) shift rotates (changes periodically from days to evenings), (v) split shift (consists of two distinct periods each day), (vi) irregular schedule or hours, or (vii) other.

The NLSY questionnaire did not provide a precise definition for day, evening, or night shifts, and thus the respondents answered the question based on their own understanding of the nature of their shift schedule. The NLSY adopted their shiftwork categories from the corresponding categories used by the US Census Bureau in its monthly Current Population Survey (CPS). The CPS categories are commonly used in employment and shiftwork studies in the United States, and they reflect the Census Bureau's understanding of how shift work terminology is generally used in American industry (64). The CPS shiftwork question is the same as that of the NLSY, except the CPS describes evening shifts as those occurring "anytime between 2 PM and Midnight" and night shifts as those occurring "anytime between 9 PM and 8 AM."

The primary outcome of interest in this study was the self-reported incidence of a work-related injury or illness. It was based on a respondent's affirmative response to the following question: "I would like to ask you a few questions about any injuries or illnesses you might have received or gotten while you were working on a job. Since [date of last interview] have you had an incident at any job that resulted in an injury or illness to you?"

Because of NLSY funding restraints, a question concerning work-related incidents was not included in the 1991 survey, and therefore this year of data was excluded from our study. During the 13-year observation period, 3834 work-related injuries and illnesses were reported by the cohort members, 2339 occurring in conventional day shifts and 1495 in nonstandard shifts. The mean age of those in conventional day shifts was 31.1 years, and that of the workers in nonstandard shifts was 32.1 years. The mean total family income was USD 30 823 and USD 32 398, respectively for the two groups, and their annual wages at the time of injury was USD 18 550 and USD 22 594, respectively. The amount of completed schooling averaged 12.5 years and 12.7 years, respectively, for the two groups (those working conventional day shifts and those working nonstandard shifts). Other basic characteristics of the injured workers and their injuries are summarized in table 1.

Crude (unadjusted) occupational injury and illness incidence rates for each survey period were calculated by dividing the total number of work-related injuries and illnesses reported in jobs having each type of nonstandard shift schedule by the total accumulated person time worked in the jobs. Rate ratios, reflecting the relative risk of reporting the occurrence of an occupational injury or illness, were calculated by dividing the incidence rate in nonstandard shift jobs by the incidence rate in jobs with conventional day schedules. Therefore, for example, in a particular survey period, if 300 injuries were reported to have occurred in jobs containing 3000 person-years of nonstandard shiftwork time and 200 injuries were reported to have occurred in jobs containing a total of 4000 person-years of conventional day-shift time, then the crude rate ratio would be 2.0, calculated as follows: (300 injuries/3000 nonstandard-shift person-years) ÷ (200 injuries/4000 day-shift person-years) = 10.0 injuries per 100 nonstandard-shift person-years ÷ 5.0 injuries per 100 day-shift person-years = crude rate ratio of 2.0.

To adjust for the influence of selected covariates, we carried out multivariate analyses to calculate hazard ratios for each nonstandard shift category using Cox proportional hazard regression techniques, which are used to analyze the effect of multiple risk factors over the time preceding the occurrence of an event. These analyses generate hazard rates that can be applied as described earlier to derive hazard ratios, which can be interpreted similarly to relative risks. Our analyses using the Cox proportional hazard techniques included all of the accumulated person-time spent in nonstandard shift work preceding the first injury in a particular job during a survey period, disregarding subsequent injuries and associated workshift time in the job following the injury. Rate ratios and hazard ratios for the entire study period were computed using injury and person-time data aggregated across all of the survey years. After we excluded 6805 person-years of worktime that were subsequent to the first injury in a job, a total of 82 924 person-years of job history were available for analysis in the final Cox proportional hazard regression models.

Each regression model included the accumulated person-time for one of the five nonstandard shift

categories as the primary independent variable, accumulated person-time in conventional day schedules as the referent variable, the reporting of a work-related injury or illness as the dependent variable, and the following covariates: age (22–43), gender (male, female), region (northeast, south, north central, west), occupational grouping (high risk versus low risk), and industry grouping (high risk versus low risk). High-risk occupations included US Census (1970) Occupation Classification Codes 401–575, 601–715, and 740–785 (craftsmen, foremen, operatives, and laborers), and high-risk industries included US Census (1970) Industrial Classification Codes 067–077 and 107–398 (construction and manufacturing sectors) (65). The occupation and industry codes selected for inclusion in the high-risk categories have traditionally higher than average occupational injury and illness incidence rates, as reported by the US Bureau of Labor Statistics (66).

Crude incidence rates and rate ratios were calculated with SAS (version 8.0) statistical software (67). The ProQuest software system was used to create a database of jobs and person-time exposure records (68), and Cox proportional hazard regression analyses were carried out on that database using Stata SE (version 7) statistical software (69). Sample weights were applied to derive nationally representative estimates for American workers in the NLSY cohort age range. Because the hazard ratio calculations were based on a sample rather than on the entire target universe (Americans aged 14–22 years as of 1979) of the NLSY, the results were subject to sampling error. To account for sampling effect, we estimated 95% confidence intervals (95% CI) around the hazard ratios by applying Taylor approximation techniques using SUDAAN (version 7.5) analytical software (70).

Results

The incidence rates of reported occupational injuries and illnesses per 100 worker-years, by type of shift schedule, for each NLSY survey period are summarized in table 2. The incidence rates for nonstandard shift schedules generally exceeded the rates for conventional day schedules for all of the survey years. In addition, the rates for every shift schedule, including conventional day schedules, tended to decrease over the 13-year course of the study.

Table 3 presents the unadjusted rate ratios and the adjusted and unadjusted hazard ratios and 95% confidence intervals for the injuries or illnesses reported in jobs with nonstandard shift schedules versus jobs with conventional day schedules, using aggregated data for the entire study period (1987–2000). Night, evening,

Table 1. Characteristics of workers injured in conventional and nonstandard shifts in 1987–2000—weighted data from the National Longitudinal Survey of Youth. (US = United States)

Characteristic	Workers with injuries occurring in conventional day shifts (N=2339) (%)	Workers with injuries occurring in nonstandard shifts (N=1495) (%)
Gender		
Male	57.4	62.4
Female	42.6	37.6
Race		
Black	11.3	12.5
Non-Black	88.7	87.5
Hispanic ethnicity		
Hispanic	6.5	6.7
Non-Hispanic	93.5	93.3
US region of residence		
Northeast	16.2	18.0
North Central	30.2	33.3
South	31.0	30.0
West	22.6	18.8
Area of residence		
Urban	75.0	72.0
Rural	25.0	28.0
Occupation		
Professional and technical	12.7	9.7
Managers, officials, proprietors	8.9	10.7
Sales workers	2.2	2.2
Clerical	13.2	9.4
Craftsmen, foremen	22.1	13.1
Operatives	16.8	21.8
Laborers, except farm	9.6	8.3
Service workers	13.4	22.5
Other	1.1	2.3
Industry		
Agriculture, forestry, fisheries	3.6	3.2
Mining	0.4	1.6
Construction	13.8	5.3
Manufacturing	20.6	26.3
Transportation and communication	6.6	7.6
Wholesale and retail trade	18.3	21.0
Finance, insurance, real estate	2.9	1.3
Business, repair services	5.5	6.7
Personal services	3.5	3.0
Entertainment, recreation	1.2	2.8
Professional and related services	18.3	13.2
Public administration	5.3	8.0
Type of injury or illness		
Musculoskeletal conditions	33.9	34.0
Fractures	6.9	8.6
Cuts and bruises	24.8	25.0
Burns	3.4	4.1
Other traumatic injuries	10.8	12.4
Insect bites	1.3	0.8
Sexually transmitted diseases	0.7	0.4
Disorders of peripheral nervous system	2.5	2.4
Other occupational diseases	11.5	9.2
Miscellaneous	4.2	3.1
Worker covered by union contract	18.0	25.0
Job satisfaction		
Like the job (very much or fairly well)	84.6	82.0
Dislike the job (very much or somewhat)	15.4	18.0

Table 2. Incidence rates of reported occupational injuries and illnesses per 100 worker-years by type of shift schedule in 1988–2000—weighted data from the National Longitudinal Survey of Youth.

Work schedule	Year								
	1988	1989	1990	1992	1993	1994	1996	1998	2000
Routine night shift	8.86	12.64	8.48	11.43	8.39	6.78	8.47	6.14	3.57
Routine evening shift	14.80	11.31	8.44	12.94	12.26	7.38	6.15	4.94	4.93
Rotating shift	14.07	7.61	7.84	10.16	8.61	5.49	6.41	5.77	4.69
Split shift	.[a]	.[a]	8.46	6.04	5.35	6.70	5.47	7.63	3.11
Irregular schedule	10.90	8.19	8.02	6.82	7.21	6.32	4.35	4.45	4.11
Routine day shift	8.15	7.37	6.62	7.25	6.41	5.26	4.53	3.98	3.13

[a] The split shift category was added in 1990.

Table 3. Unadjusted rate ratios and adjusted and unadjusted hazard ratios and 95% confidence intervals (95% CI) for injuries or illnesses reported in jobs with nonstandard shift schedules versus conventional day schedules—weighted data from the National Longitudinal Survey of Youth aggregated for 1987–2000.[a]

Work schedule	Unadjusted rate ratio	95% CI	Unadjusted hazard ratio	95% CI	Adjusted[b] hazard ratio	95% CI
Conventional day shift	1.00	.	1.00	.	1.00	.
Routine night shift	1.32	1.17–1.49	1.46	1.26–1.70	1.30	1.12–1.52
Routine evening shift	1.45	1.31–1.59	1.44	1.27–1.63	1.43	1.26–1.62
Rotating shift	1.22	1.09–1.37	1.34	1.15–1.55	1.36	1.17–1.58
Split shift	1.10	0.82–1.49	1.06	0.73–1.54	1.06	0.71–1.58
Irregular schedule	1.04	0.95–1.13	1.02	0.91–1.14	1.15	1.03–1.30

[a] N=110 236 job records for the rate ratios and 109 087 for the hazard ratios.
[b] Cox proportional hazard regression model with age, gender, occupation, industry, and region as covariates.

rotating, and irregular shift schedules were found to have an increased risk of occupational injuries and illnesses when they were compared with conventional day shifts after age, gender, occupation, industry, and region were controlled for. Evening shifts carried the greatest injury risk (43% elevated risk), followed closely by rotating (36%) and night shifts (30%), in that order. Irregular shifts were found to have only a slightly elevated injury risk (hazard ratio 1.15, 95% CI 1.03–1.30). No effect was observed for split shifts.

The values of the calculated rate ratios and hazard ratios were similar. Adjustment for covariates did little to change the basic findings. The adjusted hazard ratio of 1.30 (95% CI 1.12–1.52) for night shifts was somewhat less than the unadjusted hazard ratio of 1.46 (95% CI 1.26–1.70) for night shifts. Our calculations indicated that this difference was due primarily to the influence of the occupation variable in the regression model.

Discussion

The results of this study corroborate the findings of previous research indicating that workers in nonstandard shift schedules have a greater risk of occupational injuries and illnesses than those in conventional day shifts. The magnitudes of the risk estimates in our analysis are generally similar to those calculated in previous studies. Folkard & Tucker (58) have estimated that working night shifts carries a 30.4% increased risk and that afternoon shifts have an 18.3% greater risk. Gold et al (41) found a relative risk for work injuries and errors of 1.88 (95% CI 0.88–4.02) for nurses in night shifts and 1.97 (95% CI 1.07–3.63) for those in rotating shifts. Horwitz & McCall (42) found an 84% increased risk for evening shift workers and a 58% increased risk for night shift workers when they were compared with conventional day schedule workers. These studies, along with ours, indicate an increased risk of between 18% and 97% for nonstandard shifts. Our results are approximately in the middle of this range (1.43 for evening shifts and 1.30 for night shifts).

Adjustment for age, gender, occupation, industry, and region in the analysis did not substantially change the magnitude of the calculated hazard ratios. Thus it is unlikely that the higher accident rates seen in nonstandard shifts are merely the result of more hazardous jobs being performed in nonstandard shifts or demographic differences in the employee population working those schedules. Our findings are consistent with the hypothesis that nonstandard shifts are more hazardous because of fatigue, sleepiness, stress, and other consequences of disrupted circadian rhythms.

We found that the hazard ratios for night, evening, and rotating shifts were similar (1.30, 1.43, and 1.36,

respectively) with overlapping 95% confidence intervals. Nevertheless, our finding that the risks of working evening shifts are a bit greater than night and rotating shifts is somewhat surprising. Most other studies in this field have concluded that night and rotating shifts are more dangerous than evening shifts, a conclusion that is consistent with biological considerations about the effects of circadian rhythms and disrupted sleep patterns. One recent study involving US hospital workers also found a comparatively greater occupational injury risk for evening shift workers (42). The authors of that study speculated that variations in specific nursing tasks or staffing levels in the evening shift may have contributed to this result.

To some extent, the decline in incidence rates between 1988 and 2000 observed in our study reflects the general decline in occupational injury and illness rates reported nationally during that period. Data of the US Bureau of Labor Statistics indicate that occupational injury and illness rates decreased by 29% during that period, from an average of 8.6 to 6.1 reportable cases annually per 100 workers (71). Possible causes for that decline include safer workplaces and a shift from manufacturing to service-oriented jobs, which typically have lower average injury rates (72). Another factor affecting the relatively larger injury-rate decline (60–67%) observed in our study is the aging of our cohort, the members of which were 23 to 31 years of age in 1988 and 35 to 43 years of age as of 2000. Younger workers generally have higher incidence rates than older ones, in part because workers tend to move into lower-risk occupations (eg, managerial and administrative) as they age.

Strengths and limitations

This analysis has several important advantages over previous studies. For example, it was based on a large sample size and an extended (13-year) period of longitudinal observation, we used a nationally representative sample of American workers in diverse employment settings, we controlled for the potential confounding effects of occupation, industry, age, gender, and region, and we employed several techniques, including a Cox proportional hazard analysis for estimating the magnitude of risk.

We also normalized the observed incidence rates by using a denominator of 100 worker-years, thus avoiding a common methodological flaw made in some previous shiftwork studies. For example, other studies have observed more injuries among workers in nonstandard shifts, but have failed to account for the total number of people working each type of shift or the duration of time spent in the shifts by these workers. This study controled for that effect by deriving risk ratios which compared the propensity to suffer injuries by workers in each shift schedule during a standardized period of "at risk" time.

This study was based on self-reported information. There were no means for validating workers' responses externally, and thus our results may be subject to recall errors. In this respect, the NLSY has advantages over other self-reported surveys in that the cohort had been surveyed regularly since 1979 and thus was familiar with the questionnaire, the survey process, and the information required.

The NLSY was not designed to be a survey about work-related injuries and illnesses or demanding work schedules—its primary objective was to evaluate participants' long-term labor market transitions and wage history. The survey thus avoids problems of information bias that typically plague attempts to ask injured workers about job conditions and workplace accidents. Unlike surveys focusing on occupational injury reporting, it is unlikely that respondents to the NLSY were attempting intentionally or unintentionally to justify the legitimacy of a work-related disorder or to establish its compensability under workers' compensation laws. These issues are unrelated to the main concerns of NLSY, and thus the data obtained are presumably less susceptible to contamination by such considerations.

The NLSY did not provide precise definitions for each type of shift schedule, and thus each respondent used his or her own judgment to assign it into one of the available shift categories. This approach may have resulted in some misclassification, although there is no reason for assuming that the misclassification would have systematically biased the results towards any particular shift category. Random misclassification would tend to underestimate our resulting risk estimates.

Our control of age, gender, occupation, industry, and region in the analysis is a strength of this study. However, many other potential covariates—such as workers' education and income levels, family composition, and health status—were not included in the analysis, and thus their influence was not assessed. We also did not analyze differences in risk between industry sectors or occupational classifications. The study was based on data from workers who were 22 to 43 years of age during the study period. Older workers may react differently to fatigue, stress, and other aspects of shift work than younger workers do. Therefore, our results are not necessarily generalizable to workers of all ages.

Other potentially useful information was not available in the NLSY dataset. We did not have information available on the hour at which the injury occurred, the kinds of job activities being performed, or the event leading up to the injury. Our aim in this study was to estimate the relative injury risks involved in specific

types of nonstandard shift schedules. We did not evaluate other potentially hazardous aspects of shift schedules, such as the amount of time spent within a shift prior to the injury, the risks involved in working successive shifts over several days or nights, the duration of each shift, or the total number of hours worked per day or per week by the respondents. It is likely that these other characteristics of shift work also affect the risk of injury. In a future study, we plan to investigate these interactive effects, particularly the combined effect of shift duration and type of shift.

Policy implications

Our research indicates that appropriate prevention efforts ought to target workers in evening, night, and rotating shifts. For example, employers need to assure adequate staffing of safety personnel and first-aid providers for such shifts. Relevant injury prevention programs currently provided for day and night shift workers should be extended to cover people working evening shifts as well. Special injury prevention measures should be considered to help people cope with the effects of working nonstandard hours, such as rest breaks, sleep aids, behavioral counseling, light therapy, and pharmacological treatment.

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