

Shift Work Sleep Disorder: Prevalence and Consequences Beyond that of Symptomatic Day Workers

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Study Objectives: Although there are considerable data demonstrating the impact of shift work on sleep and alertness, little research has examined the prevalence and consequences of shift work sleep disorder in comparison to the difficulties with insomnia and excessive sleepiness experienced by day workers. The present study was designed to determine the relative prevalence and negative consequences associated with shift work sleep disorder in a representative sample drawn from the working population of metropolitan Detroit.

Design: Random-digit dialing techniques were used to assess individuals regarding their current work schedules and a variety of sleep- and non-sleep-related outcomes.

Setting: Detroit tricounty population.

Participants: A total of 2,570 individuals aged 18 to 65 years from a representative community-based sample including 360 people working rotating shifts, 174 people working nights, and 2036 working days.

Measurements and Results: Using standardized techniques, individuals were assessed for the presence of insomnia and excessive sleepiness, based on DSM-IV and ICSD criteria. Those individuals with either insomnia or excessive sleepiness and who were currently working rotating or night schedules were classified as having shift work sleep disorder.

Occupational, behavioral, and health-related outcomes were also measured. Individuals who met criteria for shift work sleep disorder had significantly higher rates of ulcers (odds ratio = 4.18, 95% confidence interval = 2.00-8.72), sleepiness-related accidents, absenteeism, depression, and missed family and social activities more frequently compared to those shift workers who did not meet criteria ($P < .05$). Importantly, in most cases, the morbidity associated with shift work sleep disorder was significantly greater than that experienced by day workers with identical symptoms.

Conclusion: These findings suggest that individuals with shift work sleep disorder are at risk for significant behavioral and health-related morbidity associated with their sleep-wake symptomatology. Further, it suggests that the prevalence of shift work sleep disorder is approximately 10% of the night and rotating shift work population.

Key Words: shift work sleep disorder, insomnia, excessive sleepiness, ulcers, heart disease, shift work, night work, rotating work.

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INTRODUCTION

ALTHOUGH MORE THAN 16% OF WAGE AND SALARY WORKERS ARE SHIFT WORKERS,¹ FEW DATA ARE AVAILABLE ADDRESSING THE PREVALENCE OF SHIFT WORK SLEEP DISORDER (SWSD) AND THE FUNCTIONAL IMPAIRMENT THAT IS UNIQUELY ASSOCIATED WITH ITS 2 PRIMARY SYMPTOMS, INSOMNIA AND EXCESSIVE SLEEPINESS.² In contrast, there have been a number of laboratory and field studies that have focused on the effects of shift-work schedules on sleep and alertness. Overall, these studies have shown that individuals engaged in shift work experience disturbed sleep and excessive sleepiness relative to day workers.³⁻⁹ These symptoms are likely due to the fact that shift workers' behavioral sleep-wake schedules are out of phase and often in direct opposition to their endogenous circadian rhythms.⁹⁻¹²

The human circadian timing system is tightly entrained by exposure to environmental light.^{13,14} Normally, environmental light maintains circadian entrainment to the 24-hour day. Late evening light will phase delay rhythms while morning light will advance them.^{15,16} However, shifts in endogenous rhythms are difficult to maintain except under laboratory conditions where light exposure is restricted to atypical periods of the day and night.¹⁷⁻²⁰ Even in tightly controlled experiments using bright light to shift circadian rhythms, more than 30% of shift workers are unable to attain large phase shifts.^{21,22} Difficulty limiting light exposure to appropriate times of day is a major reason why most shift workers, even those on permanent night shifts, do not fully

adapt to the shifted sleep-wake schedule required of their work shift.²³⁻²⁷

Despite presumed universal difficulty in adapting the endogenous circadian pacemaker to the irregular sleep-wake rhythm common in shift work, there are wide individual differences in sleep disturbance and excessive sleepiness among shift workers.²⁸⁻³² For instance, studies have found that some, but not all, rotating shift workers experience more sleep disturbance or sleepiness than do day workers.³³ Some of the variability in symptomatology is likely related to differences in the amount and/or quality of sleep obtained by individuals engaged in various types of shift work. For example, night workers report reduced total sleep time as compared to both evening workers and day workers.³⁴ Given recent data demonstrating consistent individual differences in the response to sleep deprivation,^{35,36} it is also likely that there are differences in the way that an individual's sleep-wake system responds to the sleep disruption associated with shift work. There are individuals whose sleep is not substantively impaired by a rotating or night work schedule, while others may find it extraordinarily difficult to obtain adequate sleep while on schedules that require a partial or complete shift of the circadian sleep-wake cycle. Similarly, there may be individual differences in sleepiness-related impairment given a comparable level of sleep loss.³⁶

Extreme difficulty maintaining adequate sleep-wake function while on a shift-work schedule is reflected in the current nosologic system as SWSD.² Currently, the minimal criteria for SWSD includes a primary symptom of either insomnia or excessive sleepiness that is temporally associated with a work period that occurs during the habitual sleep phase. Excessive sleepiness and insomnia are not unique to shift workers and are among the most commonly reported symptoms of patients with a variety of sleep disorders. In order to begin to distinguish the characteristics of SWSD and its associated consequences, research on SWSD would benefit from comparisons with day-work samples experiencing similar symptoms. Accurately making the distinction between shift workers with a sleep disorder independent of their shift-work status and those in whom shift work is the essential component of their sleep disturbance is important.³⁷ Clinicians are faced with making this distinction for all patients with potential SWSD, but such distinctions are difficult to make. Nonetheless, morbidity associated with the differential or unique presence of insomnia or excessive sleepiness in a shift-work sample relative to a day-work sample would help to elucidate the characteristics of this disorder.

While the diagnostic category of SWSD has been in place for more than a decade, there has been little systematic research into the characteristics of this disorder. An important step in characterizing SWSD is to determine its prevalence and consequences among people who work various types of shifts. The present study aims to determine the prevalence of SWSD in a sample of rotating and permanent night workers drawn from the general population. Furthermore, this study compares the frequency of specific morbidities in shift workers with SWSD and day workers reporting similar sleep-wake complaints. A critical question addressed in the present study is whether SWSD is associated with any unique morbidity beyond that associated with insomnia and excessive sleepiness in a day-work sample. If so, this would provide evidence that SWSD may convey a unique risk for specific negative consequences.

PROCEDURES

Participants

Subjects were drawn from the general population of tricity metropolitan Detroit using random-digit dialing techniques. Participants completed a 20-minute telephone interview, which included questions related to work status, sleep habits, excessive sleepiness, insomnia, disability, and psychiatric history. Individuals participating in this study were drawn from the population as part of a larger ongoing epidemiologic study investigating the prevalence of excessive sleepiness. For eligibility, the calling address had to be a residence and the participant had to be an adult between the ages of 18 to 65 years. A random probability selection procedure was used to determine the sex of the target adult. If 2 or 3 adults within a target sex were present in a household, a random probability selection procedure (oldest/second, oldest/youngest) was used to determine the target respondent. If 4 or more adults of the target sex were present in the household, the last-birthday method was used to determine the target respondent. In order to maintain an unbiased sample, only individuals who could not answer the questions due to sensory or mental impairment were excluded from the sample. From 4,682 eligible participants, 3,283 interviews were obtained (response rate 70.1%). Subjects were asked to select the category that best described their current work schedule (past 2 weeks). Response choices included: "regular day shifts," "regular night shifts," "regular evening shifts," "rotating shifts," or "not working/retired." Individuals working regular night shifts and individuals working rotating shifts were selected and compared to the day workers from the sample. Individuals identifying themselves as being on regular evening shifts and those who did not work, were retired, or were unemployed were excluded. Evening workers were excluded because recent studies have shown that individuals on evening schedules get significantly more sleep than day workers.³⁴ The age and sex distribution of each study group and the total sample is shown in Table 1. Subjects were paid \$25.00 for their participation. The protocol was approved by the institutional review board of Henry Ford Hospital.

Assessment

Total sleep time was determined by 2 interview questions. Individuals reported their average nightly weekday total sleep time and weekend total sleep time over the past 2 weeks. Similarly, time in bed was determined by asking individuals their bed time and wake time for both weekdays and weekends. Sleep efficiency was calculated as the total sleep time divided by the time in bed multiplied by 100. For weekly means of each variable, a weighted average of weekend and weekday reports was calculated ($[5 \times \text{weekday total sleep time} + 2 \times \text{weekend total sleep time}] / 7$). Weekend work days and weekday non-work days were not differentiated. Sleep-parameter data were not available for the first 121 individuals (< 5%) due to delayed inclusion of specific questions. Data from these individuals were excluded from analyses beyond demographic data (Table 1). The number of caffeinated beverages consumed per day as well as the percentage of obese snorers (body mass index ≥ 30 and reported loud snoring; proxy for possible sleep apnea) were also assessed in each group (Table 1).

Insomnia was assessed using criteria based on the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* criteria for insomnia.³⁸ Specifically, in order to meet insomnia criteria, individuals must have reported difficulty falling asleep, staying asleep, or nonrestorative sleep for at least 1 month. In addition, this sleep disturbance had to occur at least "sometimes" or "often" over their lifetime and had to meet a self-reported severity criteria of at least 6 out of a possible 10 (10 = most severe) over the past 3 months.

Sleepiness was measured using the Epworth Sleepiness Scale (ESS).³⁸ This scale has been validated in previous studies^{39,40} and has been shown to discriminate between clinical samples of individuals with and without sleep disorders.⁴¹ The ESS has also been shown to predict objectively measured excessive sleepiness in the general population.⁴² In order to estimate prevalence rates of excessive sleepiness, a sample-based cutoff score was utilized. Previous studies have used a score of 10 or higher on the ESS to denote excessive sleepiness.⁴³ However, these studies have generally been performed using clinic samples. Thus, as the present study was done using a population-based sample, a score equal to the total sample mean plus 1 SD was used as the cutoff criteria for excessive sleepiness. To facilitate comparisons with clinical samples, we have also included the prevalence rates of excessive sleepiness using a cutoff of 10 or higher on the ESS.

SWSD Criteria

It is recognized that, in the clinical setting, individuals with SWSD receive a full diagnostic workup, often including an overnight polysomnogram. However, due to the large population-based sample identified, a similar diagnostic assessment was not feasible. Therefore, SWSD was defined based on minimum criteria for SWSD as outlined in the *International Classification of Sleep Disorders-Revised*.² Specifically, individuals were required to meet criteria for either excessive sleepiness or insomnia as defined above and had to be working the night shift or a rotating shift over the past 2 weeks. In addition to classifying each of the shift-work groups, we divided day workers into those who met sleepiness and insomnia criteria and those who did not.

Reports of specific medical problems were assessed with 2 questions. The first question asked participants to report if they currently had any form of heart disease. The second question asked participants to report if they currently had a stomach ulcer. These questions were selected due to the known association

between shift work and heart disease and gastrointestinal problems.^{44,45}

Morbidity related to daily functioning or quality of life was assessed using several questions. Participants were asked to report the total number of days of missed work over the past 3 months due to sleep problems; the total number of days of family or social activities missed over the past 3 months due to sleep problems; the total number of automotive accidents that they had been involved in as the driver over their lifetime; and the number of these accidents that were related to sleepiness. (Non-sleepiness-related accidents were also computed as the total number of accidents minus the number of sleepiness-related accidents.)

Depression was assessed during the phone interview using the Diagnostic Interview Schedule.⁴⁶ This measure has been validated in previous studies and corresponds closely to clinical assessments of major depression.⁴⁷ Scoring of the Diagnostic Interview Schedule was based on lifetime *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* criteria for major depression. A measure of mood/personality was assessed using the short form of the Eysenck Neuroticism Scale.⁴⁸

Analyses

First, sleep-related variables (total sleep time, sleep efficiency, excessive sleepiness, etc.) were compared across each of the 3 work groups (day, night, and rotating) and follow-up posthoc comparisons were performed if a significant main effect of group was present. For continuous variables, 1-factor analysis of covariance (ANCOVA) was used to compare data between groups with age as the covariate. Posthoc comparisons were performed using the least significant difference procedure when significant main effects or interactions were present. χ^2 analyses were performed on categorical variables. The second set of analyses was performed to examine the impact of group and the presence of symptoms on the specific outcome variables. A 2-factor ANCOVA was performed with Work Group (day, night, and rotating) and Insomnia (presence or absence) as factors, and Sleepiness as the dependent measure. We hypothesized that shift workers who reported insomnia would report a greater degree of sleepiness compared to those who did not report insomnia. The presence of *either* symptom (sleepiness or insomnia) was then assessed and both shift-work groups were divided into those who met minimum criteria for SWSD (Symptoms) and those who did not (as outlined above). The χ^2 and ANCOVA were performed on

Table 1—Demographic Characteristics of Each Day/Night Worker Sample

Demographic Characteristics	Day Workers (n = 2036)	Permanent Night Workers (n = 174)	Rotating Workers (n = 360)	Total Sample (N = 2,570)	Tricounty Census Data (N = 4,043,467)
Men, %	52.7	54.6	46.1	51.9	48.5
Women, %	47.3	45.4	53.9	48.1	51.5
Age, years*	41.2 ± 11.6	38.8 ± 12.1	36.0 ± 12.3	40.3 ± 11.9	36.6†
Caffeine, cups/day	2.7 ± 3.0	3.1 ± 3.2	2.7 ± 2.7	2.7 ± 3.0	-
Obese snorers, %	3.0	5.0	3.1	3.2	-

*Significant difference between groups ($P < .03$ for all) Data are presented as mean ± SD.
†Age value was taken from total population mean age in 2000 census.
Obese snorers refers to the percentage of individuals with a body mass index ≥ 30 and "loud snoring"
Caffeine includes total cups per day of coffee and other caffeinated beverages.

morbidity measures to determine if shift workers who met SWSD criteria had significantly greater morbidity as compared to shift workers without SWSD. Following these analyses, the third group—day workers—were also divided with regard to symptoms of either insomnia or daytime sleepiness. Logistic regression and 2-factor ANCOVA were performed. These analyses included Work Group (day, night, or rotating) and Symptoms (present or absent) as separate factors. An interaction on these analyses would indicate that insomnia or excessive sleepiness produces differential morbidity in 1 or more of the groups. Finally, for variables where interactions were significant (differential morbidity), a follow-up ANCOVA was performed to determine which particular symptom or combination of symptoms was driving the morbidity identified.

RESULTS

Table 1 shows demographic data for the 3 work groups and corresponding 2000 census values where available. There were small, but statistically significant, age differences between groups. Night workers were significantly younger than the day workers and older than the rotating workers $F_{2,2550} = 32.2, P < .05$ for all). Age was used as a covariate in analyses in order to account for these differences. There were no significant differences in sex ($\chi^2 = 5.8, P > .05$), caffeine intake ($F_{2,2554} = 1.3, P > .05$), or the percentage of obese snorers between groups ($\chi^2 = 1.4, P > .05$).

Habitual sleep and related data for each group are shown in Table 2. Group differences were found for several sleep-related parameters, as detailed in the last column of Table 2. The most consistent differences were found between the night-worker and the day-worker samples with decreased total sleep time, decreased sleep efficiency, and an increased prevalence of insomnia and daytime sleepiness in night workers.

A work-group analysis of sleepiness in those experiencing

insomnia and those who did not experience insomnia was undertaken. A significant main effect of Work Group was present ($F_{2,2429} = 3.2, P = .04$). Both night and rotating workers experienced significantly more sleepiness than day workers ($P < .01$). A main effect of Insomnia was also found ($F_{1,2429} = 37.8, P < .001$), as individuals with insomnia reported significantly more daytime sleepiness (10.4 ± 5.5) than those not reporting insomnia (7.8 ± 4.3). Thus, both the effects of insomnia as well as shift work were independent and additive in terms of excessive sleepiness. There was no Group \times Insomnia interaction ($P = .46$).

Prevalence of SWSD

Using the minimum criteria for SWSD, 32.1% of night workers and 26.1% of rotating workers met the criteria (Table 2). However, 18% of day workers reported at least 1 symptom (insomnia or excessive sleepiness). When determining prevalence rates for SWSD, it is important to identify the differential prevalence of these symptoms in each shift-worker sample in comparison to the day-worker sample. This value will be more representative of the prevalence of such symptoms uniquely related to shift work. Thus, the “true prevalence” (ie, differential prevalence) of insomnia or excessive sleepiness in the night- and rotating-worker sample was 14.1% and 8.1%, respectively. The corresponding overall “true prevalence” of SWSD was 10.0% of shift workers between the ages of 18 and 65 (Table 2).

Outcome Variables

Within the 2 shift-work groups, those who met SWSD criteria and those who did not were compared on each measure of morbidity (Table 3). No interactions were present for any of the variables ($P > .05$ for all), indicating that experiencing significant morbidity related to SWSD did not depend on the type of shift work in which one engaged. Importantly, for nearly all variables assessed, SWSD was associated with significantly greater mor-

Table 2—Sleep-related Parameters Across Each Shift/Day Worker Sample

Sleep Parameter	Day Workers (n = 1950)	Night Workers (n = 162)	Rotating Workers (n = 337)	Total Sample all Workers (n = 2449)	Post-hoc comparisons
Total sleep time, h	6.8 \pm 1.2	6.1 \pm 1.5	6.7 \pm 1.5	6.7 \pm 1.3	N<D
Time in bed, h	7.4 \pm 1.1	7.3 \pm 2.1	7.6 \pm 1.6	7.5 \pm 1.3	-
Sleep efficiency, %	91.5 \pm 14.4	88.2 \pm 28.0	90.5 \pm 19.0	91.2 \pm 16.3	N<D
WE-WD difference, min	57.2 \pm 85.6	60.9 \pm 102.6	39.3 \pm 102.0	55.0 \pm 89.5	R<D
ESS score	8.0 \pm 4.5	9.2 \pm 5.2	8.6 \pm 4.6	8.1 \pm 4.5	N>D, R>D
ESS \geq 10, %	32.7	44.8	35.8	34.0	N>D, N>R
ESS \geq 13, %	15.5	24.7	20.3	16.8	N>D, R>D
Insomnia, %	8.6	18.5	15.7	10.2	N>D, R>D
Prevalence of insomnia or ES, %	18.0	32.1	26.1	20.1	N>D, R>D
“True Prevalence” of SWSD (%)	0	14.1	8.1	10.0	N>D, R>D

Data are presented as mean \pm SD. Omnibus and posthoc comparisons were evaluated at $\alpha = .05$; total sleep time and time in bed are weighted weekly means.

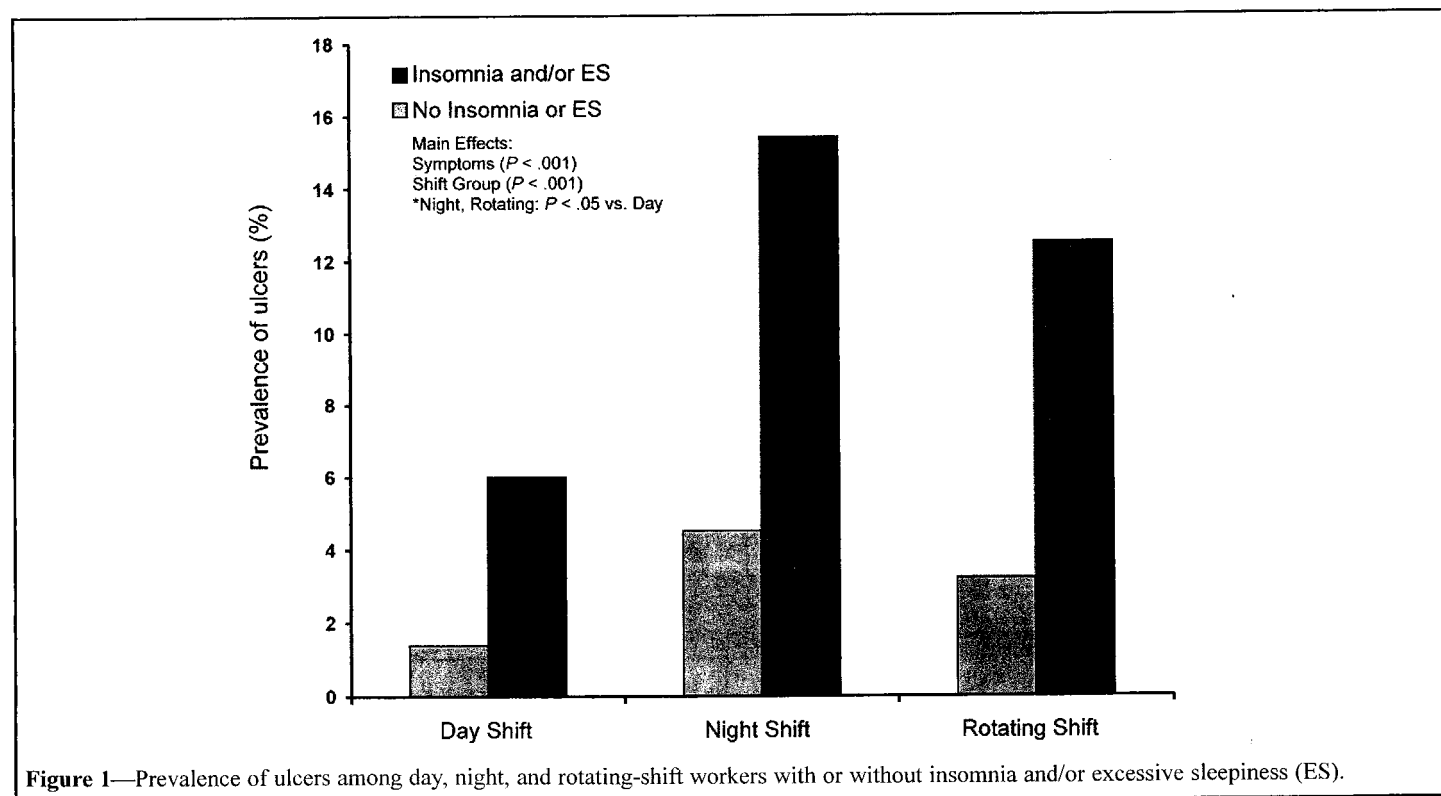
N refers to night shift; D, day shift; R, rotating shift; WE-WD; weekend total sleep time minus weekday total sleep time; see text for insomnia criteria; sleep efficiency is defined as total sleep time / time in bed \times 100; “True prevalence” of shift work sleep disorder (SWSD) is defined as the differential prevalence of insomnia or excessive sleepiness (ES, an ESS [Epworth Sleepiness Scale] score \geq 13) between each respective shift-work and day-work sample. Data for “true prevalence” in the total sample are 18.0%-(mean of rotating and night samples, 28.1%) = 10.0.

bidity in comparison to individuals without SWSD ($P < .05$). The only exceptions to this pattern were for non-sleepiness-related accidents and heart disease where there were no differences between individuals with or without SWSD ($P > .15$ for both). In terms of risk, the odds ratio for ulcers in night workers with SWSD was 3.82 (95% confidence interval [CI] = 1.18-12.32), and the odds ratio for ulcers in rotating workers with SWSD was 4.30 (95% CI = 1.67-11.09). For the combined group of shift workers with SWSD, the odds ratio for ulcers was 4.18 (95% CI = 2.00-8.72). A main effect of Shift Type (night vs rotating) was present for days of missed work, indicating that rotating workers missed work more frequently than night workers ($P = .04$). There were no other significant main effects of Shift Type.

The next set of analyses was aimed at determining the effects that were unique to shift workers with SWSD. That is, to assess what morbidities related to insomnia or excessive sleepiness are greater in shift workers as compared to day workers. These were important analyses in that, if unique effects were observed, either as independent contributions (2 main effects) or interactive (significant interaction), one could conclude that insomnia or excessive sleepiness does produce morbidity in shift workers beyond that seen in day workers experiencing those same symptoms. Data for the prevalence of ulcers are displayed in Figure 1. The analysis revealed a main effect for Group ($P < .001$), with both night workers (odds ratio = 3.13, 95% CI = 1.62-6.05) and rotating workers (odds ratio = 2.32, 95% CI = 1.32-4.06) having an elevated prevalence rate of ulcers when compared to day workers. There was also a main effect of Symptoms ($P < .001$), indicating that individuals with insomnia or excessive sleepiness had elevated rates of ulcers (odds ratio = 4.55, 95% CI = 2.47-8.37). Thus, both work shift and sleep-wake symptoms independently contribute to the increased prevalence of ulcers seen in shift workers. There was no Group \times Symptoms interaction ($P = .97$). For depression, there was only a main effect of Symptoms, indicating that individuals with insomnia or excessive daytime

sleepiness had greater rates of depression (odds ratio = 2.57, 95% CI = 2.01-3.27) but no main effect of Group ($P = .12$). Thus, shift work per se is not associated with depression. There was only a main effect of Group for heart disease ($P = .01$), indicating that individuals on night (odds ratio = 2.57, 95% CI = 1.24-5.30) and rotating (odds ratio = 2.01, 95% CI = 1.06-3.83) shifts had greater rates of heart disease compared to day workers, but no main effect of Symptoms was present. Thus, work shift, rather than sleep-wake symptoms, is associated with the increased prevalence of heart disease in shift workers.

In evaluating the continuous outcome measures, the following had a significant main effect of Symptoms: missed work ($F_{1,2421} = 37.09, P < .001$), missed family and social activities ($F_{1,2419} = 130.10, P < .001$), sleepiness-related accidents ($F_{1,2438} = 15.55, P < .001$), and neuroticism ($F_{1,2420} = 140.07, P < .001$). In each case, Symptoms were associated with greater impairment. Main effects of Group were present for missed work ($F_{2,2421} = 14.47, P < .001$), as well as missed family and social activities ($F_{2,2419} = 25.27, P < .001$). Thus, both main effects were present for missed work and missed family and social activities. For the analysis of days of missed work, there was also a significant Group \times Symptoms interaction ($F_{2,2421} = 7.19, P = .001$). Posthoc comparisons revealed that rotating workers with SWSD missed significantly more days of work in comparison to day workers with symptoms of insomnia or excessive sleepiness ($P = .009$). For missed family or social activities, there was also a Group \times Symptom interaction ($F_{2,2419} = 18.84, P < .001$). Posthoc comparisons revealed that night workers as well as rotating workers with SWSD missed significantly more family or social activities over the past 3 months in comparison to day workers with insomnia or excessive sleepiness ($P < .05$ for both) (Figure 2). For the additional outcome variables (accidents and neuroticism), no significant interactions were found, nor were there additive effects of both Symptoms and Shift. Only main effects of Symptoms



were found for sleepiness-related accidents and neuroticism.

The symptom complex (ie, distribution of symptom combinations) was also determined. These final analyses examined the distribution of morbidity among each symptom profile for the analyses, which revealed unique morbidity related to SWSD (ulcers, missed days of work, and missed family/social activities). The distribution of each of the 4 possible symptom profiles within each group is shown in Table 4. In the first analysis, days of missed work was examined. There was a significant Group × Symptom Profile interaction ($F_{6,2415} = 9.48, P < .001$) (Figure 3).

Posthoc analyses revealed that rotating workers with both insomnia and excessive sleepiness missed work more frequently than day workers with those same symptoms ($P = .03$). Other groups were comparable with regard to the number of days of missed work given their symptom complex. Thus, it appears that for missed work, only the combination of both insomnia and excessive sleepiness conveys any unique morbidity. For missed family and social activities, there was also a significant Group × Symptom Profile interaction ($F_{6,2413} = 12.96, P < .001$). Posthoc tests revealed that the presence of insomnia was the only symp-

Table 3—Morbidity and Sleep Measures in Shift Workers Who Met or Did Not Meet Criteria for SWSD and Day Workers with and Without Symptoms of Insomnia or Excessive Sleepiness

	Permanent Night Workers		Rotating Workers		Day Workers	
	No SWSD (n = 110)	SWSD (n = 52)	No SWSD (n = 249)	SWSD (n = 88)	No symptoms (n = 1598)	Symptoms (n = 352)
Ulcers, %	4.5	15.4*	3.2	12.5*	1.4	6.0
Heart disease, %	6.4	7.7	4.4	5.7	3.1	4.0
Missed work, no. days	0.3 ± 0.9	1.0 ± 2.3*	0.6 ± 2.8	3.3 ± 12.8*	.20 ± 1.1	1.2 ± 4.6
Missed family/social activities, no. days	1.5 ± 9.0	8.6 ± 21.7*	1.0 ± 4.2	10.1 ± 22.7*	.60 ± 3.1	3.6 ± 11.6
Depression, %	14.5	32.7*	13.7	31.8*	11.8	25.0
Neuroticism score	2.6 ± 2.8	5.1 ± 2.8*	3.0 ± 2.8	5.2 ± 3.4*	2.5 ± 2.5	4.9 ± 3.5
Sleepiness-related accidents, no.	0.04 ± 0.2	0.1 ± 0.4*	0.1 ± 0.2	0.2 ± 0.5*	.06 ± .27	.17 ± .63
Non-sleepiness-related accidents, no.	1.6 ± 1.8	1.2 ± 1.3	1.6 ± 1.7	1.4 ± 1.6	1.8 ± 1.9	1.7 ± 1.7
Total sleep time, h	6.4 ± 1.4	5.5 ± 1.6*	6.7 ± 1.3	6.5 ± 2.0	6.9 ± 1.1	6.2 ± 1.4
Time in bed, h	7.5 ± 2.0	7.1 ± 2.2	7.5 ± 1.5	7.6 ± 2.0	7.5 ± 1.0	7.3 ± 1.4
Sleep efficiency, %	88.7 ± 22.0	86.3 ± 39.7	91.7 ± 17.5	87.5 ± 23.0	92.4 ± 12.7	86.8 ± 18.8

Data are presented as mean ± SD.

*Significant difference between individuals meeting criteria for shift work sleep disorder (SWSD) and those who did not meet criteria (main effect of SWSD was only tested if the omnibus - F value or χ^2 was significant); Depression was determined using the Diagnostic Interview Schedule based on *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* criteria; For missed work as well as missed family and social activities, the number of days refers to days missed during the past 3 months.

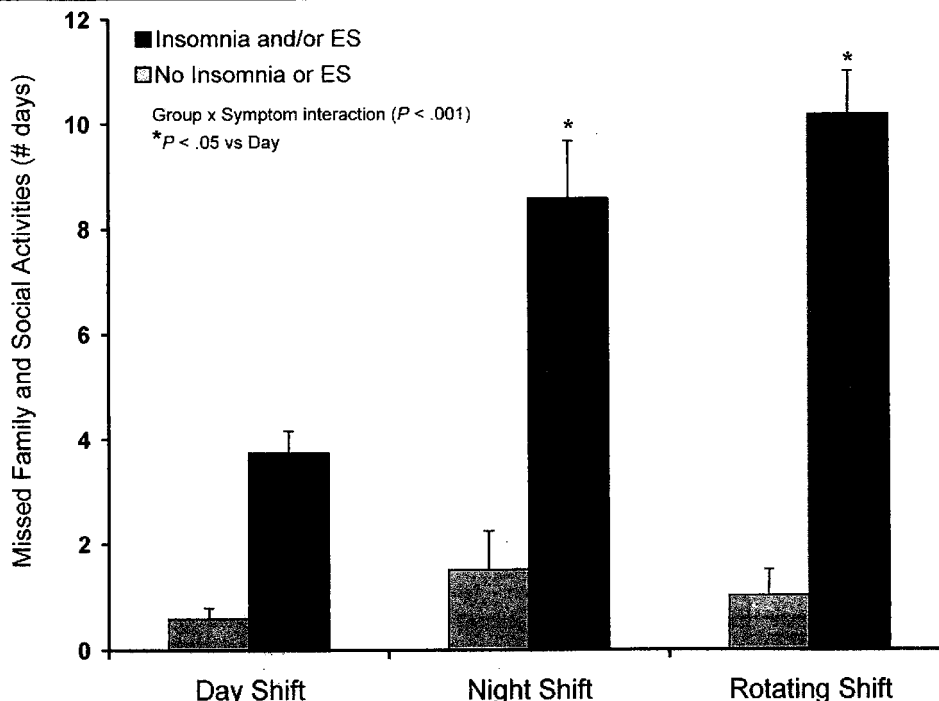


Figure 2—Mean number of days of days of missed family and social activities (± SEM) during the past 3 months in day, night, and rotating-shift workers with or without insomnia and/or excessive sleepiness (ES).

tom that introduced any unique effects beyond that observed in the day-worker sample. Specifically, rotating workers who reported insomnia missed more family and social activities in comparison to day workers with insomnia ($P = .003$). The difference between night workers who reported insomnia and day workers with insomnia approached significance ($P = .07$).

DISCUSSION

Results from the present study suggest that the prevalence of insomnia or excessive sleepiness is 32% and 26% in night and rotating shift workers, respectively. Given that the summed prevalence of these symptoms in the general population is approximately 18%, this amounts to a "true prevalence" of SWSD of approximately 10% of night and rotating workers. Because 6.4% of all workers are night or rotating workers,¹ it is estimated that approximately 1% of the working population would meet the criteria for SWSD. Although no estimates of the population prevalence of SWSD have been published to our knowledge, our results are considerably less than clinical estimates of 2% to 5% of the population.² Our data are consistent with 2 recent studies showing that circadian rhythm and other sleep disorders are more prevalent in night-shift workers compared with day workers and that insomnia, excessive sleepiness, and circadian rhythm disorders are associated with significant morbidity (accidents and absenteeism) in shift-work samples.^{4,33}

Previous studies have demonstrated copious behavioral, health, and social morbidity associated with shift work.^{4,6,45,49-53} However, we are unaware of studies that have examined these outcomes in shift workers meeting criteria for SWSD relative to those who do not. As one might expect, the present study findings support the notion that a large part of the negative sequelae associated with shift work is related to insomnia and daytime sleepiness, at least in terms of risk. Three patterns of morbidity emerged. First, certain morbidity is directly attributable to shift work. This is evident in the shift-work main-effect only findings (see discussion of heart disease below). Second, the presence of *both* main effects (shift work and symptoms) indicates an additive independent relationship where individuals with SWSD have increased morbidity as they carry both risk factors (see discussion of ulcers below). Finally, interactions indicate a *multiplicative* effect, where individuals with SWSD had increased morbidity that is not explained by the additive effects of shift work and symptoms of insomnia or excessive sleepiness (see discussion of missed work below). This pattern of results shows that individuals with SWSD have much higher rates of morbidity crossing several domains in comparison to shift workers without SWSD. In most cases, the elevated morbidity was greater than that seen for day workers with similar symptoms.

It has long been recognized that individuals exposed to shift work are at greater risk for experiencing gastrointestinal symp-

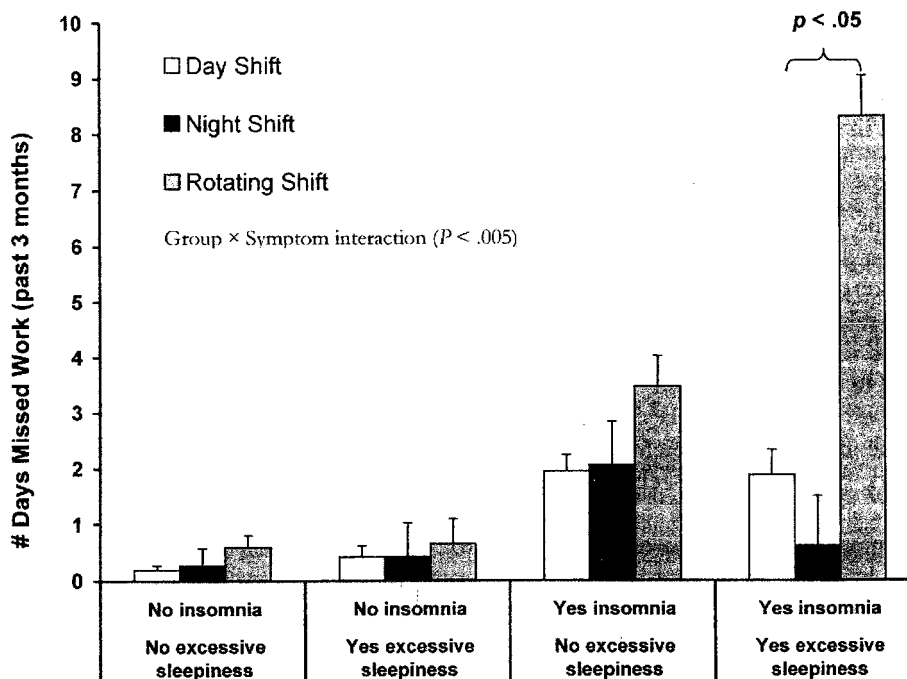


Figure 3—Mean number of days of missed work during the past three months (\pm SEM) in day, night, and rotating-shift workers grouped by each symptom combination of insomnia and/or excessive sleepiness (ES).

Table 4—Distribution of Symptom Profiles in People Working Days, Nights, and Rotating Shifts

Symptom profile	Day Workers (n = 1950)	Night Workers (n = 162)	Rotating Workers (n = 337)	Total Sample (N = 2,449)
No insomnia or sleepiness, %	78.6	64.2	68.5	76.3
Insomnia without sleepiness, %	6.1	10.5	10.1	6.9
Sleepiness without insomnia, %	12.8	17.3	15.7	13.5
Insomnia and sleepiness, %	2.5	8.0	5.6	3.3

toms and ulcers.^{45,53} The present study links a large part of this morbidity to the insomnia and excessive sleepiness found in this population. However, morbidity independently related to shift work was also demonstrated, suggesting that both factors play a role. It has been shown that shift work is associated with increased secretion of gastrin and pepsinogen,⁵⁴ and it has been speculated that such increases may mediate the elevated risk for both gastric and duodenal ulcers in shift workers. It is possible that elevations of gastrin and pepsinogen levels also accompany the sleep disturbance and ensuing sleepiness in SWSD. For heart disease, the present findings indicate a risk related to shift work but not specific to insomnia or excessive sleepiness symptoms. This effect remained significant after controlling for additional risk factors (body mass index, smoking status, hypertension, alcohol intake and diabetes, $P < .05$). This finding is consistent with previous research that has shown an increased risk for cardiovascular disease in shift workers compared with day workers.⁵⁵⁻⁵⁹ Further research is needed to identify what aspects of shift work may convey such increased risk. Although findings in animals suggest that chronic shifts of the circadian system can exacerbate the mortality associated with cardiomyopathic heart disease,⁶⁰ it is unclear what, if any, aspects of the circadian system may account for the elevation of heart disease in shift workers. In addition to circadian disruption, night workers in the present study are likely experiencing a chronic sleep debt, as evidenced by reduced sleep efficiency and reduced total sleep time in comparison to day workers. This chronic sleep debt may account for their high levels of excessive sleepiness, as has been demonstrated in recent studies,⁶¹⁻⁶³ and could potentially contribute to the cardiovascular effects. Specifically, a recent study has demonstrated an elevation in C-reactive protein, an inflammatory marker of cardiovascular morbidity, following 10 days of partial sleep deprivation.⁶⁴ However, in a secondary analysis of the present data, total sleep time was not a significant predictor of heart disease ($P = .83$). Other data support the possibility that cardiac morbidity in shift workers may be mediated through the effects of shift work on sleep-related cardiac autonomic activity.⁵²

Aspects of morbidity related to quality of life did show multiplicative effects. That is, individuals with SWSD experienced impairments in quality of life beyond that which would be expected given their shift-work status and sleep-related symptoms. The elevated work absenteeism and impaired social aspects of quality of life related to symptoms of insomnia or excessive sleepiness were exacerbated by shift work. Furthermore, it appears that this differential increase in morbidity in shift workers is related to insomnia in the case of social consequences and the combined effects of insomnia and excessive sleepiness in the case of missed work. This pattern of results suggests that both symptoms convey important information and should be considered in clinical management.

There are several limitations of the present study. First, while we chose to leave the epidemiologic nature of the study intact, it will be important for future studies to determine if these relationships are maintained using more clinically based case-control samples of individuals with SWSD. Also, the representative community-based methodology of the present study did not allow us to objectively verify the presence or location of ulcers using radiographic examinations. However, the prevalence rate found for ulcers was consistent with that of other population-based

studies and studies involving shift workers.⁵³ Thus, we believe the present results are likely to provide an accurate reflection of ulcers and their relative prevalence in our subpopulations. Accident rates were also not verified independent of subjective reports. However, it is unclear if other methodologies would produce more reliable results as many minor accidents are not reported and would be missed when using conventional police or department of state databases. Although a 70.1% response rate puts some limits on generalizability, this response is in line with other representative population-based studies^{42,65,66} and is unlikely to significantly impact the results.⁶⁷ Practical limitations also prevented us from assessing physiologic measures of sleepiness using standard techniques such as the Multiple Sleep Latency Test.⁶⁸ Although Multiple Sleep Latency Test measurement may have produced more reliable and sensitive assessments of sleepiness, such enhancements of methodology would likely lead to even more robust findings and significance for several of the outcomes that approached significance. Another limitation involves the fact that we did not determine where in the work rotation each of the rotating workers was at the time of interview, though we did know that the worker was on a "rotating" schedule during the past 2 weeks. Previous data suggest that the average duration of a work rotation is a week or less, depending on occupation. Thus, it is likely that most of the rotating workers assessed were currently working a schedule out of sync with their endogenous biologic rhythm.

Another potential limitation was that individuals on an "evening" shift were not included as part of the present paper. This decision was made on the basis of data that suggest that workers on an evening shift obtain significantly more sleep than individuals on day shifts. A recent meta-analysis showed that evening workers average approximately 7.6 hours of sleep per night,³⁴ considerably greater than the day workers in the present study at 6.8 hours per night. Nonetheless, a separate analysis was performed to compare the evening workers ($n = 152$) to the day-worker sample on measures of sleep habits and the prevalence of insomnia and excessive sleepiness as potential SWSD symptoms. In terms of sleep habits, evening workers spent significantly **more** time in bed (7.7 hours vs 7.4 hours, $P = .002$), had an equivalent sleep efficiency (92.1% vs 91.5%, $P = .81$) and, thus, reported a significantly **greater** amount of total sleep time (7.0 hours vs 6.8 hours, $P = .03$) in comparison to day workers. The prevalence of insomnia (12.5% vs 8.6%, $P = .11$) as well as excessive sleepiness (17.1% vs 15.5%, $P = .59$) was not significantly different between the evening-and day-worker samples, respectively. Finally, the prevalence of SWSD symptoms as a whole (insomnia or excessive sleepiness) was not significantly different between the evening and day workers (21.5% vs 18.0%, $P = .30$). Thus, evening-shift workers are less likely to have a sleep debt than any of the groups included in our analyses. Moreover, the timing of most evening shifts and the levels of sleep disturbance suggest that significant circadian disruption is unlikely for this group.

The distinction between shift workers meeting criteria for SWSD and those who do not is an important one because previous studies have shown that not all shift workers experience sleep-wake symptoms.³³ Indeed, there appears to be a subgroup of individuals (ie, SWSD) with an elevated vulnerability to certain detrimental effects of shift work. Specifically, the present results suggest that a number of morbidities in shift workers are

related to sleep-wake symptoms (eg, depression), whereas others are related to shift work independent of sleep-wake symptoms (eg, heart disease). The present results also support the view that there are certain negative outcomes for which sleep-wake symptoms and shift work make independent additive or multiplicative contributions (eg, ulcers, missed work). This latter pattern of morbidity would appear to be especially disconcerting from a clinical perspective because individuals with SWSD would appear to be at a substantially high risk for experiencing these negative consequences. Future studies should help to identify the mechanisms that lead to these patterns of morbidity and determine appropriate treatment strategies that may limit such negative outcomes. Indeed, differences in basal circadian amplitude^{69,70} and phase⁷¹ have been implicated as components related to shift-work tolerance, including sleep disturbance, sleepiness, and digestive problems. Other investigators have found evidence for hormonal involvement in dissatisfaction with shift work.⁷² Clearly, additional studies are needed to determine the mechanisms responsible for individual vulnerability to the negative consequences of shift work. Future work may benefit from the measurement of noncircadian variables as well, such as an elevated vulnerability to sleep disturbance in response to stress.⁷³

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