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Shiftwork, Sleep Habits, and Metabolic Disparities: Results from the Survey of the Health of Wisconsin

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Abstract

Background—With the expanding demand for a 24-hour society, the prevalence of sleep deprivation and other sleep-related health problems is increasing. Shiftwork is an occupational health risk of growing significance because of its high prevalence and because of its potential role as a determinant of socioeconomic-related health disparities.

Aims—The aim of this study was to examine the associations of shiftwork with overweight status and type 2 diabetes, and explore whether a history of sleep problems mediates or modifies these associations.

Participants and Methods—A cross-sectional study was conducted among 1,593 participants in the Survey of the Health of Wisconsin (2008–12) who were employed and reported work characteristics (traditional schedule or shiftwork) and sleep habits and history of sleep problems (insomnia, insufficient sleep, wake time sleepiness). Objective measures of body mass index (BMI) and type 2 diabetes were used.

Results—Shiftworkers were more overweight than traditional-schedule workers (83% vs. 71% with BMI≥25) and reported more sleep problems, such as insomnia symptoms (24% vs. 16%), insufficient sleep (53% vs.43%), and sleepiness (32% vs. 24%). The associations between shiftwork and being overweight or diabetic were stronger among those reporting insufficient sleep, but the interaction was not statistically significant.

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Conflict of Interest

The authors of this manuscript do not have any competing financial interests in relation to the work described.

Author Contributorship: MLG conducted the analyses and wrote the manuscript. Authors consulted on the study design, implementation, and interpretation drawing from their content or analytical expertise including; KCM led data collection efforts in SHOW and consulted on measurement and assessment of environmental and occupational exposures, outcomes and health disparities, FJN, AS and CDE on cardiometabolic health, MP on statistical analysis, FJN, PEP, and MCW on survey methods, and FJN and PEP on sleep dysfunction. All authors contributed to manuscript development.

Conclusions—Shiftworkers face disparities in metabolic health, particularly those with insufficient sleep. Improved understanding of the relationship between sleep and metabolic states can inform healthcare providers' and employers' efforts to screen high-risk individuals and intervene with workplace wellness initiatives to address these disparities.

Keywords

shiftwork; insufficient sleep; obesity; type 2 diabetes; health disparities

Introduction

The increasing demands of a 24-hour society have extended the traditional work day beyond the typical 9am to 5pm (1). Such job demands require an employee to depart from the normal biological rhythms of nighttime and daytime activities such as sleep/wake cycles, physical activity, or dietary intake. The resulting disturbances, can have a range of tangible social and biological consequences, such as increased stress and heightened risk of injury and disease. (2, 3) Animal studies support our growing understanding that disruptions in biological rhythms can shift normal molecular response mechanisms, altering homeostasis and leading to a range of adverse health effects including cancer and premature mortality (4). Job demands at non-traditional hours may also heighten an individual's risk of diverging from the biological rhythms that optimize cardiovascular or metabolic function (5, 6).

"Alternate shift" employees are particularly vulnerable as their jobs require them to work night, flex, extended, or rotating shifts. These types of schedules are common in emergency and hospital healthcare settings, production, transportation, and shipping occupations. Shiftworkers comprise nearly 15% of the workforce nationwide and are more commonly men, minorities, and individuals with lower educational attainment (2).

In comparison with traditional schedule workers, shiftworkers face significant health disparities with higher morbidity and mortality. Notably, they are more prone to cancers and a range of cardiometabolic disorders, including metabolic syndrome, type 2 diabetes (T2D), obesity, and adverse cardiovascular events (2, 7–10). Recent studies have reported that shiftworkers have elevated levels of triglycerides and cholesterol, and higher insulin resistance than traditional schedule workers (11–13).

Sleep problems and insufficient sleep are common among shiftworkers. U.S. National survey data show that the prevalence of insufficient sleep (<7 hrs/day) is as high as 44% among shiftworkers compared to approximately 30% among employees who work day shifts (14). Sleep disorders including insufficient sleep have also been found to adversely affect metabolic health. For example, glucose homeostasis is negatively impacted by both reduced sleep quality and moderate sleep restriction (16). Therefore, sleep problems may explain a relationship between shiftwork and metabolic dysfunction, and may play a role in shiftworker health disparities; however, few studies have examined this in employed persons selected from a general population sample.

To address this gap, we examine the relationship between shiftwork exposure and sleep problems in a population-based sample of working adults. We also examined the association

of shiftwork with overweight or T2D status as markers of adverse metabolic health. We further explored the potential modifying role for insufficient sleep in these associations to see whether the putative relation between shiftwork and poor metabolic health is mitigated in workers who obtain sufficient sleep.

Participants and Methods

Study sample

We used cross-sectional data from The Survey of the Health of Wisconsin (SHOW) collected in years 2008–2012. SHOW is a population based health examination survey that includes home- and clinic-based interviews and physical exams. Details on survey methods have been previously published (17). In summary, participants were recruited using a two-stage probability sample from the non-institutionalized 21–74 year old adult population of Wisconsin. SHOW data include basic clinical parameters including exam-based anthropometry (height, weight, waist/hip ratio), blood pressure, blood chemistry and cell counts measures. In addition, SHOW data include self-reported physical health history, demographics, behavioral and occupational health. The UW-Madison Health Sciences Institutional Review Board approved all SHOW protocols and informed consent documents.

Definition of outcomes

Height and weight measured at the exam were used to compute body mass index (BMI) [weight (kg)/height $(m)^2$]. Weight status was categorized using Centers for Disease Control and Prevention (CDC) standard guidelines (18): BMI < 18.5 (underweight), 18.5 ≤ BMI < 25 (healthy weight), 25 ≤ BMI < 30 (overweight), BMI ≥ 30 (obese). Type two diabetes (T2D) was defined by self-report of physician-diagnosed T2D or glycated hemoglobin (HbA1c) ≥ 6.5% (19) as measured from a blood sample obtained at the physical exam.

Exposure assessment

Shiftwork was defined as night shift, rotating shift, or other alternate shift using self-report data on employment status and exposure to non-traditional sleep patterns via shiftwork . Measures of sleep habits and sleep duration (e.g., insufficient sleep) were captured using validated questions previously used in the National Health and Nutrition Examination Survey (NHANES) and the Wisconsin Sleep Cohort Study (20). “Insomnia” was defined based on the participant reporting difficulty in falling asleep; response categories were ‘never’ or ‘rarely’ (once/month), ‘sometimes’ (2–4 times/month), ‘often’ (5–15 times/month), and ‘almost always’ (16–30 times/month). This item was dichotomized into ‘often/almost always’ (≥5 times/month) versus ‘sometimes/rarely’ (<5 times/month) (21). Average daily sleep duration was estimated from the following questions: “Over the past month, how many hours and minutes do you think you actually slept? (This may be different than the time you spent in bed.) On a typical workday? On a typical non-work day?” Average daily sleep duration was computed as [(5 × workday sleep) + (2 × weekend sleep)]/7. Insufficient sleep was defined as average daily sleep duration <7 hours/day. Sleep debt was estimated in hours as the average amount of weekend sleep minus the average amount of weekday sleep (22). The Epworth Sleepiness Scale was used to assess subjective wake time sleepiness (16);

as in previous studies (23, 24), an Epworth score >10 was used to define 'excessive sleepiness.'

Study Participants

Participants who did not report working at least one day in a typical week over the past month (n=767) were excluded from our study resulting in a potential sample size of 1,808. Participants reporting diagnosis of diabetes other than type 2 were excluded from analyses (type 1, gestational, n=33). A total of 375 participants, 20% of 1,808, had missing clinical or sleep data. Therefore, 1,593 participants were included in analyses pertaining to overweight/obesity and 1,400 participants in analyses pertaining to T2D.

Statistical Analyses

All analyses were conducted using SAS version 9.2 accounting for the complex survey design. Presence versus absence of overweight/obesity and/or T2D among participants was modeled using PROC SURVEYLOGISTIC.

Potential confounders of the relationship between metabolic outcomes (overweight/obese or HbA1c) and shiftwork exposure included age (continuous), race/ethnicity, gender, and educational attainment. Covariates were retained in the final model if associated with the outcome (p-value < 0.1) or if their inclusion changed the estimated main effects of interest by more than 10%.

To explore whether sleep explains or moderates the relationship between shiftwork and metabolic health, average daily sleep duration, insomnia, excessive wake time sleepiness or sleep debt, were included in models as continuous variables. Sleep duration was also modeled as a quadratic given the previously reported curvilinear relationship between sleep duration and cardiometabolic health (25); however, the quadratic term was not statistically significant and was excluded from the model (results not shown). We also assessed insufficient sleep as a potential modifier of the relationship between shiftwork and indicators of metabolic health. For these analyses, associations between shiftwork and indicators of metabolic health were assessed stratified by average daily sleep duration (<7hrs/day—insufficient sleep—vs. ≥7hrs/day). Two-sided P-values were obtained using standard Wald tests with robust standard errors.

To assess the influence of outlying sleep duration values on results, we conducted sensitivity analyses on truncated datasets that retained participants with average daily sleep duration ranging from ≥5 hours to <9 hours (*n*= 1,523).

Results

Table 1 provides descriptive statistics for participants who reported traditional work schedules compared to those who reported shiftwork schedules. On average, shiftworkers were older and less educated than those with traditional work hours. There was no statistically significant difference in gender, race or ethnicity between traditional schedule workers and shiftworkers (Table 1).

A higher prevalence of adverse markers of metabolic health was observed among those who reported shiftwork vs. work schedules during traditional hours (Table 2). The combined overweight and obesity prevalence was significantly higher among shiftworkers than traditional schedule workers (83% vs. 71%, respectively p-value=0.0004); this was primarily the result of 38% higher prevalence of overweight in shiftworkers (48%) than in traditional schedule workers (35%). The prevalence of T2D was also higher, but not significantly, among shiftworkers (7.6% vs. 4.9%).

The prevalence of sleep problems was significantly higher in shiftworkers than in traditional schedule workers. Rates of excessive sleepiness (31.8% vs. 24.4%, p-value=0.05), insomnia (23.6% vs. 16.3%, p-value=0.02), and insufficient sleep (average daily sleep duration <7 hours, 53.0% vs. 42.9%, p-value=0.03) were all greater among shiftworkers. Sleep debt did not significantly differ between shiftworkers and traditional schedule workers (average 0.83 hours, 95% CI=0.64 – 1.02 vs. average 0.94 hours, 95% CI=0.85 – 1.03; t-test p-value=0.68). However, preliminary analyses among night shiftworkers, a small subset of shiftworker participants, suggested that these individuals may experience substantially greater sleep debt compared to traditional schedule workers (data not shown).

In adjusted models, the relationship between exposure to shiftwork and being overweight/obese remained statistically significant (adjusted OR=2.07, 95% CI=1.31–3.28) (Table 3). Exposure to shiftwork was related to 44% higher odds of T2D after controlling for age, gender, race, and education but the association was not statistically significant (adjusted OR=1.44, 95% CI=0.64–3.24). Though sample sizes were small, preliminary analyses were also conducted among subtypes of shiftwork, including participants working night shifts, rotating shifts, or a shiftwork schedule other than these two (e.g., flex or extended shifts). No substantial differences were observed in the effect size for type 2 diabetes among subtypes (data not shown). Among shiftworker subtypes, effect estimates for overweight/obesity were similar overall but suggestive of a higher risk of being overweight/obese with greater misalignment of the body clock and work schedules, such as with night shiftworkers (adjusted OR=3.07, 95% CI=0.99–9.44) compared to rotating shiftworkers (adjusted OR=2.22, 95% CI=1.22–4.06).

Adding each of the sleep variables to the model independently did not materially change the strength of the association between shiftwork and either being overweight/obese or having T2D (Table 4). Adjusted models including shiftwork, showed overweight/obesity to be less likely among adults with longer average daily sleep duration (adjusted OR=0.76, 95% CI=0.58–1.00), and slightly more likely with higher subjective sleepiness (adjusted OR=1.06, 95% CI=1.03–1.11). Moreover, the frequency of insomnia was marginally significantly associated with being overweight/obese (adjusted OR=1.14, 95% CI=0.99–1.31). Sleep debt was not associated with being overweight/obese in adjusted models.

Similarly, adjusted models retaining shiftwork as the main exposure, showed the odds of prevalent T2D to be lower with longer average daily sleep duration and higher with elevated subjective sleepiness, but with borderline statistical significance. The frequency of reported insomnia symptoms and sleep debt were not significantly associated with prevalent T2D, accounting for shiftwork exposure and other covariates (Table 4). Results from sensitivity

analyses excluding participants reporting average daily sleep duration <5 hours or ≥9 hours did not differ from the overall results (not shown).

Table 5 shows that the association between shiftwork and being overweight was stronger and statistically significant among participants who reported insufficient sleep (OR=2.58 p-value=0.007) than among those reporting sufficient sleep. However, the interaction was not statistically significant. Compared to those reporting sufficient sleep, the association between shiftwork and being T2D was also stronger among participants with insufficient sleep (OR=1.41 vs. 1.17) although the formal test for interaction was not statistically significant.

Discussion

Our findings contribute to ongoing research about the risks of occupational shiftwork and associated disparities in metabolic health. To our knowledge, the results presented here are the first utilizing a population-based sample of employed adults and among the first to systematically assess the potential role of sleep behaviors in the metabolic health disparities of shiftworkers. We found that shiftworkers were significantly more likely than traditional schedule workers to be overweight/obese and experience sleep problems, such as insomnia, insufficient sleep, or excessive wake time sleepiness.

Experiencing sleep problems was positively associated with being overweight/obese or diabetic, but did not fully explain the relationship between shiftwork and these outcomes. The relationship between shiftwork and overweight status appeared to be stronger among those who reported insufficient sleep than in the overall study population. These findings suggest that shiftworkers who obtain sufficient sleep may be partially protected against adverse metabolic consequences of shiftwork. Though effect modification was not statistically significant, this may be due to limited power and warrants further study.

This study adds to a growing body of literature that suggests shiftworkers are a potentially vulnerable segment of the workforce at increased risk of poor metabolic health and related sleep disturbances (25–29). A limited number of studies have specifically addressed shiftwork and sleep duration in relation to indicators of metabolic health. For example, recent studies among employed adults whose jobs require alternate shifts, such as policemen or nurses, have found an association between shiftwork and increased cardiometabolic risks (11–13), even when considering sleep problems in the relationship (31–34).

Our study findings also show trends similar to previous research documenting an association between sleep problems and metabolic health. For example, both reduced sleep quality and moderate sleep restriction have been linked to altered glucose homeostasis (15, 16). Research implicating a role for average sleep duration in metabolic outcomes has recently emerged in the literature (35). In fact, there is evidence to suggest a curvilinear relationship between sleep duration (both short and long) and obesity risk factors, biomarkers of obesity risk (e.g., leptin levels) and BMI (31, 36–38). A similar relationship between sleep-related problems and T2D has also been reported, suggesting that short sleep duration is associated with T2D (39–43). The putative negative effects of long sleep duration on diabetic status

remain controversial (44). This may be a result of the relatively few study participants reporting long sleep duration (<4% reported 9 or more hours on average). Others have questioned the biological plausibility of a relationship between long sleep duration and adverse metabolic outcomes, and suggest that sleep deprivation is of greater public health importance given its high prevalence (31, 45). Our findings extend results implicating an increased likelihood of being overweight/obese or diabetic for adults reporting short sleep duration.

While mechanisms and pathways of association between shiftwork and metabolic dysfunction are still under investigation, there is growing evidence to support a biologically plausible explanation. The underlying biologic pathway between shiftwork and adverse metabolic outcomes has been posited to include a causal link between metabolic regulation and the molecular function of the circadian clock (4–6, 46). Experimental studies in animal models with genetically or environmentally disrupted circadian clocks have demonstrated relationships between circadian clock function and the development of metabolic diseases, such as T2D, metabolic syndrome, and non-alcoholic fatty liver disease (NAFLD) (4–6, 46–48).

Several underlying social and behavioral mechanisms have also been proposed to explain the observed health disparities in metabolic and body weight outcomes among shiftworkers. For example, due to the time-dependence of their work schedules, shiftworkers may be less likely to eat meals at home with family, and have reduced participation in team sports (8, 49). Additionally, compared to traditional schedule workers, shiftworkers have been reported to eat higher-calorie diets or more sugar-sweetened caffeinated beverages during work shifts in order to stay alert (49, 50).

This study offers further evidence to suggest that there are potential differences in metabolic vulnerability among shiftworkers with important strengths and limitations. Two particular strengths of this study are that it draws from a general population sample and primary outcomes (overweight and diabetes status) were defined according to objective markers (measured weight, height, and HbA1c). However, data are cross-sectional limiting causal interpretations of associations between metabolic disorders and occupational or behavioral factors. There is also the potential for unmeasured confounding factors that could influence both exposures to shiftwork and/or short sleep duration and metabolic health. Further investigation of the work environment with regard to type of shiftwork, rotation direction, or duration of shiftwork exposure over the life course is needed. In addition, measures of social jetlag or sleep debt (51, 52), particularly among subtypes of shiftworkers (e.g., night vs. rotating) are important considerations for future research. We were unable to adjust for the aforementioned work-related exposures or occupational behaviors that may also confound the outcome. Previous studies suggest a lack of metabolic adaptation post shiftwork exposure (53, 54), which suggest that exposures outside of the workplace may be of equal or greater importance.

Another potential limitation is that previous research has documented the potential for systematic biases in self-report of sleep duration (55). In our study we observed differences in the frequency of missing data reported on sleep duration among shiftworkers vs.

traditional schedule workers, with shiftworkers less likely to report average sleep duration. This may be due to the variability in shiftworkers' sleep schedules impacting participant recall, and the differential number of missing values has the potential to bias our findings as well. As has been suggested by others, it is plausible that both short sleep duration and shiftwork employment are markers of exposure to life-course inequities resulting in significant health disparities (45, 56).

Conclusions

In conclusion, shiftworkers are a vulnerable segment of our workforce with increased risks of sleep problems and poor cardiometabolic health. The findings of this study, in combination with a growing body of evidence, can inform workplace wellness initiatives that aim to mitigate the effects of shiftwork on cardiometabolic health and reduce health disparities in the workforce. Workplace initiatives that are supportive of employees getting sufficient sleep may hold promise in addressing obesity. These findings warrant further exploration of sleep interventions as a way to address persistent and prevailing health disparities.

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Table 1

Distribution of socio-demographic variables among shiftworkers and traditional schedule workers: Survey of the Health of Wisconsin, 2008–2012, n=1, 593.

Variable	N	Traditional worker (n=1,381)	Shiftworker (n=212)	p-value
Age				
21–39 years	615	44%	43%	
40–59 years	797	49%	43%	0.017
≥60 years	181	7%	14%	
Male gender	718	52%	58%	0.125
Non-white race/ethnicity	153	11%	13%	0.59
Education[1]				
<High school	58	3%	5%	
HS grad/GED	283	17%	22%	0.001
Some college	659	40%	49%	
College	593	40%	22%	

[1]Education categories ‘HS grad/GED’ refer to having attained a high-school graduate’s levels of knowledge, and “Some college” refers to having completed one or more years of post-secondary education that did not terminating in a degree.

Table 2

Prevalence of sleep characteristics and indicators of metabolic health among shiftworkers and traditional schedule workers: Survey of the Health of Wisconsin, 2008–2012.

Variable	N	Traditional worker (n=1,381)	Shiftworker (n=212)	p-value
		Percent (95% Confidence Limits)		
Overweight[1]	464	34.7 (31.4–37.9)	47.9 (41.8–53.9)	0.001
Obese	497	36.0 (32.8–39.1)	35.4 (28.9–41.9)	
Diabetes[2]	77	4.9 (3.2–6.5)	7.6 (3.4–11.9)	0.20
Insufficient sleep[3]	718	42.9 (39.3–46.4)	53.0 (45.8–60.1)	0.03
Excessive wake time sleepiness[4]	403	24.4 (21.6–27.3)	31.8 (24.9–38.6)	0.05
Insomnia[5]	272	16.3 (13.3–19.1)	23.6 (18.2–29.1)	0.02

[1] Overweight: 25 ≤ BMI < 30; obese: BMI ≥ 30.

[2] Type 2 diabetes: self-report of physician-diagnosed diabetes or HbA1c 6.5; sample size for prevalence n=1,400.

[3] Average daily sleep duration <7hr.

[4] Epworth Sleepiness Scale ≥ 10.

[5] Difficulty in falling asleep or initiating sleep reported often/always (≥5 times per month).

Table 3

Adjusted odds ratios (95% confidence limits) of indicators of metabolic health for employed adults exposed to traditional or shiftwork hours: Survey of the Health of Wisconsin, 2008–2012.

	Overweight/Obese[1] (n=1,593)	Type 2 Diabetes[2] (n=1,400)
Occupation		
Shiftworker vs. Traditional worker	2.07 (1.31–3.28)	1.44 (0.64–3.24)
Age,		
Per 10 years	1.38 (1.23–1.54)	1.94 (1.57–2.41)
Gender		
Male vs. female	2.10 (1.53–2.89)	1.75 (0.99–3.07)
Education		
<HS vs. College	0.92 (0.45–1.91)	1.84 (0.58–5.80)
HS grad/GED vs. College	1.26 (0.89–1.91)	1.63 (0.72–3.71)
Some College vs. College	1.65 (1.17–2.31)	1.02 (0.50–2.09)
Race/ethnicity		
Minority vs. non-Hispanic Caucasian	0.91 (0.44–1.88)	1.63 (0.59–4.49)

[1] BMI ≥ 25.

[2] Self-report of physician-diagnosed diabetes or HbA1c≥6.5; sample size for prevalence n=1,400.

Table 4

Adjusted odds ratios (95% confidence limits) of indicators of metabolic health for employed adults exposed to traditional or shiftwork hours by sleep characteristics: Survey of the Health of Wisconsin, 2008–2012.

Overweight/Obese (BMI≥25) (n=1,593)				
Model Variables [a]	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Occupation Shiftworker vs. Traditional worker	2.02 (1.28–3.22)	2.04 (1.29–3.24)	2.02 (1.27–3.22)	2.06 (1.28–3.33)
Average Daily Sleep Duration Per Hour	0.76 (0.58–1.00)	n/a	n/a	n/a
Subjective sleepiness Per Epworth Score Unit	n/a	1.06 (1.03–1.11)	n/a	n/a
Insomnia Per monthly symptom frequency (4-point scale)	n/a	n/a	1.14 (0.99–1.31)	n/a
Average Sleep Debt Per hour	n/a	n/a	n/a	0.95 (0.84–1.07)

Type 2 Diabetes (self-report and/or HbA1c≥6.5) (n=1,400)				
Model Variables [a]	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Occupation Shiftworker vs. Traditional worker	1.37 (0.60–3.11)	1.47 (0.65–3.30)	1.46 (0.65–3.27)	1.42 (0.63–3.18)
Avg Daily Sleep Duration Per Hour	0.49 (0.27–0.89)	n/a	n/a	n/a
Subjective sleepiness Per Epworth Score Unit	n/a	0.94 (0.88–1.01)	n/a	n/a
Insomnia Per monthly symptom frequency (4-point scale)	n/a	n/a	1.05 (0.83–1.34)	n/a
Avg Sleep Debt Per hour	n/a	n/a	n/a	1.22 (0.88–1.69)

[a] Model also includes age (continuous), gender, education, race/ethnicity.

[a] Model also includes age (continuous), gender, education, race/ethnicity.

n/a = not included in the model.

Table 5

Adjusted odds ratios of indicators of metabolic health associated with shiftwork, stratified according to sleep duration: Survey of the Health of Wisconsin, 2008–2012.

	Overweight/Obese (BMI≥25)	**Type 2 Diabetes (self-report and/or HbA1c ≥ 6.5)**
Sleep Duration Stratum	*Adjusted Odds Ratio [a] (95% Confidence Interval)*	
Sufficient sleep (≥ 7 hr/day)	1.72 (0.84–3.50)	1.17 (0.21–6.49)
Insufficient sleep (< 7 hr/day)	2.58 (1.30–5.11)	1.41 (0.65–3.06)
P-value for Interaction	0.15	0.32

[a] Model also includes age (continuous), gender, education, race/ethnicity.