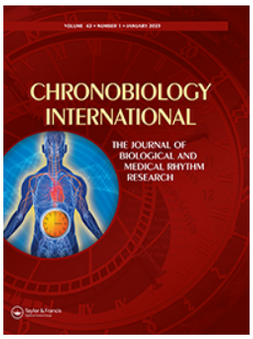

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ORIGINAL ARTICLE

Shiftwork and leisure-time physical inactivity (LTPI) among U.S. workers

Desta Fekedulegn[a], D. Leann Long[b], Samantha Service[a], Ja K. Gu[a], and Kim E. Innes[c]

[a]Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, West Virginia, USA; [b]Department of Biostatistics and Data Science, Division of Public Health Sciences, Wake Forest University School of Medicine, Winston-Salem, North Carolina, USA; [c]Department of Biostatistics and Epidemiology, School of Public Health, West Virginia University, Morgantown, West Virginia, USA

ABSTRACT

Physical inactivity may exacerbate the adverse health effects associated with shift work. We investigated the association of shift work with leisure-time physical inactivity (LTPI). A cross-sectional analysis included 33 983 adults from National Health Interview Survey who self-reported their work schedule and leisure-time physical activity. Participants were classified in to two groups as either (a) inactive or (b) insufficiently/sufficiently. Prevalence ratios were derived using SUDAAN. Analyses were stratified by sex. In this sample of U.S. workers, 27% were shift workers, 26% were physically inactive, and 47% did not meet recommended levels of leisure-time physical activity. Inactivity level was 23% higher in women than in men among shift workers but did not differ by sex among daytime workers (PR = 1.02, 95% CI: 0.96–1.07). Evening or night work was associated with higher LTPI among women but not men. LTPI was 17% higher in women working the night shift, and 24% higher in those on the evening shift compared to those working the daytime shift. These findings suggest that shift work may contribute to increased LTPI, with effects that may be particularly pronounced in women. Interventions addressing LTPI among shift workers may help mitigate the adverse health effects that have been linked to shift work in prior studies.

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Shift work; leisure-time physical inactivity; health behavior; employment; U.S. working adults; national survey; NHIS; sex

Introduction

Shift work has become more prevalent across a wide range of occupations, such as health care, manufacturing, and transportation, in part due to increased demand for 24-h services and technological advances. Generally, shift work is defined as working outside the normal daytime working hours (07:00h and 18:00h) and can include evening shifts (14:00h and 00:00h), night shift (19:00h and 07:00h) or rotating between day, evening, and night shifts (Caruso 2014; Depner et al. 2014). In the United States, nearly 20% of employed adults are engaged in shift work (Caruso 2014; McMenamin 2007). According to the Bureau of Labor Statistics (BLS), 16% of U.S. workers *usually* worked on a non-daytime schedule that includes evenings, nights, split or extended shift, or rotating shifts (BLS 2021).

Findings from a growing number of studies indicate shift work may lead to numerous adverse health outcomes. For example, a 2016 umbrella review of 38 meta-analyses and 24 systematic reviews indicated significantly increased risk overall for coronary heart disease, stroke, Type 2 Diabetes, specific types of cancer, injury, and reduced cognitive function (Kecklund and Axelsson 2016). In a more recent meta-analysis regarding the impact of shift work on cardiovascular disease, Torquati and colleagues found the risk of coronary heart disease (CHD) morbidity to be 26% higher in shift workers than those on day shift (RR = 1.26, 95% CI: 1.10–1.43) and that, after the first 5 y of shift work, the risk for CVD events increased by 7.1% for every additional 5 y of exposure, suggesting a dose–response relationship (Torquati et al. 2018). The 2019 designation of night shift work as "probably carcinogenic to humans" by the International Agency for Research on Cancer underscores the growing recognition of shift work as a significant occupational hazard (Koritala et al. 2021; Sweileh 2022; Ward et al. 2019). However, the potential relation of shift work to leisure-time physical activity (LTPA), which may have the potential to mitigate the adverse effects of shift work (Flahr et al. 2018), remains little explored in the U.S. workforce, especially on a national level (Loprinzi 2015).

Leisure-time physical activity (LTPA) is a major modifiable health behavior, with compelling evidence

CONTACT Desta Fekedulegn djf7@cdc.gov Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, HELD/BB, MS L-4050, 1095 Willowdale Rd., Morgantown, WV 26505-2888
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demonstrating the health-promoting effects contributing to chronic disease prevention (Lee et al. 2012; Warburton and Bredin 2019; Warburton et al. 2006), including for cardiovascular disease (Lee et al. 2003; Li et al. 2006, 2013; Pedersen et al. 2008; Rodriguez et al. 1994), type 2 diabetes (Folsom et al. 2000), cancer (Friedenreich and Cust 2008; Huxley et al. 2009), and osteoporosis (Berard et al. 1997). A systematic review of prospective cohort studies showed a significant positive relationship between sedentary time and all-cause mortality (Ekelund et al. 2019); subjects in the highest quartile of sedentary time (most sedentary) were nearly 3 times more likely to die of all-causes relative to those who were least sedentary (Hazard ratio = 2.63, 95% CI: 1.94–3.56). As documented in a recent World Health Organization report, people who are insufficiently active have a 20% to 30% increased risk of premature death compared to those who are sufficiently active, and physical inactivity is a leading risk factor for chronic disease mortality (World Health Organization 2020). Furthermore, evidence suggests that LTPA is associated with a decreased risk of cognitive decline (Sabia et al. 2017; Sofi et al. 2010) and may provide psychological and social benefits (Eime et al. 2013). To achieve the health benefits of PA, current global guidelines recommend a minimum of 150 min of moderate intensity physical activity each week (moderate for 150+ minutes/week or vigorous for 75+ minutes/week) (Bull et al. 2020; U.S. Department of Health and Human Services 2018). Despite these well-documented health benefits, many adults fail to achieve the recommended physical activity guidelines, especially those engaged in shift work (Monnaatsie et al. 2021). However, studies regarding the impact of shift work on LTPI are limited. According to recent data for the year 2022, inactivity level was 26.3% among U.S. adults (Healthy People 2030), while less than half (48.1%) engaged in sufficient regular physical activity.

Despite robust but disparate lines of research on the relationship between shift work and LTPA and health, there is a need for a comprehensive assessment regarding the prevalence of leisure-time physical inactivity (LTPI) within the U.S. workforce, and the potential link between shift work and LTPI. The literature on the relationship between shift work and leisure-time physical activity remains limited. To our knowledge, only one published epidemiologic study has examined the impact of shift work on physical activity in a national sample of the U.S. labor force (Loprinzi 2015), although this investigation did not distinguish between leisure-time and occupational physical activity. Moreover, as highlighted in a recent systematic review and meta-analysis (Monnaatsie et al. 2021), results from prior studies comparing PA and sedentary behavior (SB) in shift workers versus daytime workers have been inconsistent; while some studies have reported a significant negative impact of shift work on PA (Loprinzi 2015, Nabe-Nielsen et al. 2011), others have indicated non-significant differences in PA (Hulsegge et al. 2017; Loef et al. 2018; Monnaatsie et al. 2021), while still others have reported shift workers to be more active than daytime workers (Loprinzi 2015; Marqueze et al. 2013; Monnaatsie et al. 2021). In addition, the limitations characterizing most previous studies render interpretation and/or generalization of findings challenging. The limitations include lack of sex-stratified results, small sample sizes, lack of occupational diversity, failure to distinguish between leisure-time and occupational PA, and other factors. To improve our understanding of the potentially complex relationships between shift work and LTPA, the central goal of this study was to examine the associations of shift work status (yes/no) and shift schedule (day, evening, night, rotating, and some other schedule) to leisure-time physical inactivity (LTPI) in a nationally representative sample of U.S. workers. Because gendered roles such as caregiving or other household responsibilities could affect LTPI levels (Woodward 2019), analyses were stratified by sex.

Methods

The Study Sample

The National Health Interview Survey (NHIS) is a cross-sectional in-person household survey used to monitor the health and health care of the non-institutionalized civilian population in the United States. The survey has been conducted annually by CDC's National Center for Health Statistics (NCHS) since 1957. The NHIS data is representative of the U.S. population except for individuals in long-term care facilities, correctional facilities, active-duty Armed Forces personnel, and U.S. nationals within foreign countries. For current analyses, we utilized data from 2010 to 2015 survey cycles, and a description of the survey design is specific to those years (NCHS 2011, 2016). The survey employs a multi-stage, clustered sample design with oversampling of black, Hispanic, and Asians to produce nationally representative health data. The core module for adults contains data on demographic, lifestyle, socio-economic, and health from one randomly selected adult (age ≥18 years) of each household. Each year, the NHIS core module includes supplemental questions addressing priority topics. Supplements to the 2010 and 2015 NHIS included questions on shift work among adults employed during the week preceding their

interviews (i.e. currently employed with pay). Our analyses are based on data collected from 2010 (27,157 sampled) and 2015 (33,672 sampled) survey cycles. Response rates were 60.8% for 2010 and 55.2% for 2015 (Schiller et al. 2010). The 2010 and 2015 NHIS was approved by the NCHS Research Ethics Review Board as well as the U.S. Office of Management and Budget. All respondents provided oral consent before participating. Of the 60 829 pooled respondents, analyses were restricted to those who were employed, with pay, during the week preceding the interview ($n = 34{,}563$). Respondents were excluded if their work schedule ($n = 61$) or LTPA ($n = 519$) was missing, leaving a final sample size of $n = 33{,}983$.

Assessment of Work Schedule (Shiftwork)

Exposure to shift work was determined from the single-item question: "Which of the following best describes the hours you usually work?" with the following response options: (1) a regular daytime schedule, (2) a regular evening shift, (3) a regular night shift, (4) a rotating shift, and (5) some other schedule. A binary (no, yes) shift work status variable was derived to distinguish those working a daytime schedule versus those working any non-daytime shift (i.e. evening, night, rotating, and other schedules combined). Shift schedule (with five nominal categories)/shift work status (binary) served as the exposure (independent) variable of interest. In this paper, we use the terms "shift worker" and "non-daytime worker" interchangeably to refer to those working evening, night, rotating, and other schedules combined.

Assessment of Leisure-Time Physical Inactivity (LTPI)

Leisure-time physical activity level was determined by responses to the following statement: "The next questions are about physical activities (exercise, sports, physically active hobbies . . .) that you may do in your leisure time." Participants then reported the following: (1) the frequency and duration of vigorous-intensity physical activities (i.e. activities that cause heavy sweating or large increases in breathing or heart rate) are performed for at least 10 min, and (2) the frequency and duration of light or moderate-intensity physical activities (i.e. activities that cause only light sweating or a slight to moderate increase in breathing or heart rate) performed for at least 10 min. These data were used to compute minutes of vigorous-intensity and minutes of light/moderate-intensity PA per week. Total minutes of aerobic PA per week were computed by counting 1 min of vigorous-intensity activity as 2 min of moderate-intensity activity. According to the 2008 US Department of Health and Human Services Physical Activity Guideline recommendations for adults (PAGAC 2008), being physically inactive at leisure-time was defined as "less than 10 min total per week of moderate- or vigorous-intensity lifestyle activities." However, in NHIS, light and moderate activities were reported together (not as separate questions) and hence the definition of inactivity in this study also includes light activities. In this study, a binary variable of physical inactivity (yes, no) was defined as follows: (1) inactivity was categorized as yes (coded 1) for those who reported no sessions of light/moderate or vigorous PA of at least 10-min duration per week (this group consisted of subjects who were totally inactive) and (2) inactivity was categorized as no (coded 0) for those reporting any sessions of light/moderate or vigorous PA of at least 10-min duration per week. This binary variable (inactivity: yes/no) served as the main dependent variable for modeling the effect of shift work on leisure-time physical inactivity (LTPI).

Covariates

Covariates that may be related to LTPI and shift work were treated as potential confounders. These included demographic factors (age, race/ethnicity, marital status, and education), health behaviors or lifestyle factors (smoking, alcohol consumption, and BMI), and the job characteristic work hours per week.

Statistical Analyses

Survey procedures in the SAS-callable SUDAAN software (version 11.0.1, Research Triangle Institute, Research Triangle Park, North Carolina) were used to estimate population-level summary measures, accounting for stratification and other complex design features (Korn and Graubard 1999; Mirel et al. 2013). To represent the U.S. civilian, non-institutionalized population aged ≥18 years, all prevalence estimates were weighted and adjusted to reflect the number of years of pooled data (i.e. sample weights were divided by 2). Descriptive analyses to characterize the sociodemographic characteristics of the sample and prevalence of LTPI by sociodemographic characteristics and work schedule were estimated using a PROC CROSSTAB procedure.

Associations between shift work and LTPI were examined using a weighted binary logistic regression model (PROC RLOGIST) (Bieler et al. 2010) where LTPI (yes/no) was modeled as a function of shift schedule (5 categories). Adjusted prevalence ratios (PRs) of LTPIs and associated 95% confidence intervals (CIs) were estimated

and used as measures of association. The prevalence of LTPI for each shift schedule was compared to regular daytime shift (reference). Two models were fit to calculate the prevalence ratios (PRs): an unadjusted model (Model I) and a multivariable adjusted model that accounted for demographic variables (age, race/ethnicity), education, marital status, health behaviors (smoking, alcohol use, BMI), and job characteristics (work hours per week) (Model II). We assessed whether sex modified the relationship between work schedule and LTPI by including a two-way interaction term between work schedule and sex in the statistical model. Analyses were repeated with binary shift work status (yes/no) to assess the impact of any non-daytime work schedule on LTPI.

Sensitivity analysis

Because women traditionally perform a disproportionate share of caregiving and other household duties, which could constrain the time available to participate in LTPA, sensitivity analyses were performed (a) to test whether the associations among females were robust by childbearing age and (b) by caregiving status (i.e. being a parent to one or more minor children in the household).

Results

Sociodemographic Characteristics

The study sample comprised 33 983 employed participants, representing a population of 139 million U.S. workers aged 18 years or older. Sociodemographic characteristics of the sample are shown in Table 1. Twenty-seven percent of the workers were engaged in shift work (schedules other than the regular daytime shift). Overall, 27% of the workers were physically inactive during their leisure-time. As illustrated in Table 1, daytime and shift workers differed significantly in distribution of both demographic and lifestyle characteristics. Compared to workers in the daytime shift, a significantly greater proportion of shift workers were male (55.3% vs. 51.9%), younger (18–44 years) (64.9% vs. 53.7%), black (13.8% vs. 9.9%), and current smokers (20.5% vs. 15.5%). In contrast, a significantly lower proportion were married (54.6% vs. 68.4%), had college degrees (25.6% vs. 39.9%), drank alcohol (71.4% vs. 75.0%), and worked 35–40 h per week (38.2% vs. 53.2%) compared to daytime workers (Table 1).

Prevalence of Shift Work and LTPI by Demographic and Lifestyle Characteristics

The prevalence of both shift work and LTPI varied significantly across all demographic and lifestyle characteristics (Table 2). For example, prevalence of shift work was 10% higher in men than in women and 30% higher in black workers compared to white workers. With respect to LTPI, the prevalence was 8% lower in males than in females and 49% higher in adults ≥65 relative to those 18–44 years of age. LTPI prevalence was 54% higher among black adults, and 66% higher among Hispanics compared to non-Hispanic white adults. LTPI showed a strong inverse association with education (Table 2, p for trend <0.0001); a higher level of education is associated with lower levels of physical inactivity. Further stratification of the prevalence of shift work and LTPI by race-sex subgroups is shown in supplemental Table S1.

Prevalence of LTPI by Shift Schedule and Shift Work Status

The prevalence of LTPI varied significantly across categories of shift schedules in both male and female workers (Figure 1). Among females, inactivity prevalence ranged from highs of 37.8% (evening shift), 35.4% (night shift), and 29.0% (rotating shift), to lows of 26.0% (day shift) and 23.0% (some other schedule) (Figure 1A). In males, LTPI prevalence ranged from a high of 32.4% (night shift) to lows of 26.0% (evening shift), 25.1% (day shift), and 23.3% (some other schedule). When the shift schedule was assessed as a binary variable (daytime vs. non-daytime shifts), the prevalence of LTPI varied significantly by shift work status only among female workers (Figure 1B), with LTPI prevalence significantly higher among non-daytime vs. regular day shift workers (30.8% versus 26.0%, $p < 0.0001$). Additional details are provided in supplemental Table S2.

Sex differences in LTPI for evening, rotating, and overall non-daytime shift schedules were statistically significant and were not altered by covariate adjustment (supplemental Table S2). Inactivity levels were 45% higher in women than men who worked the evening shift (PR = 1.45, 95% CI: 1.19–1.77), 29% higher for those who worked the rotating shifts (PR = 1.29, 95% CI: 1.13–1.47), and 25% higher for those who worked a non-daytime shift schedule (PR = 1.25, 95% CI: 1.14–1.37), while no significant sex differences in LTPI were observed in workers on day or night shift or some other schedule.

Association of Shift Schedule and Shift Work Status with LTPI

All Workforce

The prevalence of LTPI was 32% higher among individuals working on regular night shift compared to those working

Table 1. Sociodemographic characteristics of U.S. workers aged ≥18 years by shift work status – national health interview survey (NHIS), the United States, 2010 and 2015.

	All workers			Shift work status		
Characteristics	Sample Size (n)[a]	Estimated U.S. Population[b]	Proportion (%)[c]	Daytime workers[c] (*n* = 24,984)	Shift workers[c] (*n* = 8,999)	*p*-value[d]
Total	33,983	139,250,825		73.3 (72.6–74.0)	26.7 (26.0–27.4)	
Sex						<0.0001
Male	16,733	73,507,612	52.8 (52.1–53.5)	51.9 (51.1–52.7)	55.3 (53.9–56.6)	
Female	17,250	65,743,213	47.2 (46.5–47.9)	48.1 (47.3–48.9)	44.8 (43.4–46.1)	
Age group (yrs.)						<0.0001
18–44	18,944	78,904,376	56.7 (55.9–57.4)	53.7 (52.8–54.5)	64.9 (63.6–66.2)	
45–64	13,086	54,192,804	38.9 (38.2–39.6)	38.9 (38.2–39.6)	30.6 (29.4–31.9)	
≥65	1,953	6,153,645	4.4 (4.2–4.7)	4.4 (4.2–4.7)	4.5 (4.0–5.0)	
Race/Ethnicity						<0.0001
White, non-Hispanic	20,256	92,335,499	66.3 (65.4–67.2)	67.2 (66.3–68.1)	63.9 (62.4–65.4)	
Black, non-Hispanic	4,476	15,254,930	11.0 (10.4–11.5)	9.9 (9.4–10.5)	13.8 (12.8–14.8)	
Asian, non-Hispanic	2,142	7,457,768	5.4 (5.0–5.7)	5.7 (5.3–6.1)	4.5 (3.9–5.1)	
Other, non-Hispanic	782	2,715,595	2.0 (1.7–2.2)	1.7 (1.5–2.0)	2.5 (2.1–3.1)	
Hispanic	6,327	21,487,033	15.4 (14.8–16.1)	15.5 (14.8–16.2)	15.3 (14.3–16.4)	
Marital status						<0.0001
Married/Living with partner	18,423	89,966,087	64.7 (63.9–65.4)	68.4 (67.6–69.2)	54.6 (53.1–56.0)	
Widowed/Divorced/Separated	6,667	18,019,787	13.0 (12.6–13.4)	13.0 (12.6–13.5)	12.8 (12.0–13.5)	
Never married	8,834	31,117,793	22.4 (21.7–23.0)	18.6 (17.9–19.3)	32.7 (31.4–34.1)	
Education						<0.0001
Less than High school	3,423	12,364,250	8.9 (8.5–9.4)	8.6 (8.1–9.1)	9.9 (9.1–10.7)	
High school or GED	7,717	32,109,815	23.1 (22.5–23.7)	21.8 (21.1–30.6)	26.9 (25.7–28.1)	
Some College	10,819	44,297,481	31.9 (31.2–32.6)	29.8 (29.1–30.6)	37.6 (36.3–39.1)	
College degree	11,938	50,065,422	36.1 (35.2–36.9)	39.9 (38.9–40.9)	25.6 (24.3–26.9)	
Smoking status						<0.0001
Current	5,827	23,448,410	16.9 (16.3–17.4)	15.5 (14.9–16.2)	20.5 (19.4–21.6)	
Former	6,446	26,550,558	19.1 (18.6–19.6)	19.6 (18.9–20.2)	17.8 (16.9–18.9)	
Never	21,660	89,078,715	64.1 (63.4–64.7)	64.9 (64.1–65.7)	61.7 (60.4–63.0)	
Alcohol consumption						<0.0001
Never	5,511	21,985,905	15.9 (15.3–16.5)	15.1 (14.5–15.7)	18.2 (17.1–19.3)	
Former	3,574	13,887,621	10.1 (9.6–10.5)	9.9 (9.4–10.4)	10.4 (9.6–11.3)	
Current	24,620	102,365,217	74.0 (73.3–74.8)	75.0 (74.2–75.8)	71.4 (70.1–72.7)	
Body mass index (BMI)						0.0097
Normal (18.5–24.9)	11,184	46,522,459	34.8 (34.1–35.6)	34.4 (33.6–35.3)	36.1 (34.7–37.4)	
Overweight (25–29.9)	11,787	48,066,332	36.0 (35.3–36.7)	36.7 (35.8–37.5)	34.2 (32.9–35.5)	
Obesity (30+)	9,618	38,947,695	29.2 (28.5–29.9)	29.0 (28.2–29.8)	29.8 (28.5–31.0)	
Work hours/week						<0.0001
<35	7,511	30,908,989	22.6 (22.0–23.3)	18.2 (17.4–18.9)	35.0 (33.5–36.5)	
35–40	16,591	67,367,784	49.3 (48.6–49.9)	53.2 (52.4–54.1)	38.2 (36.8–39.5)	
41–48	3,036	12,368,754	9.0 (8.6–9.5)	9.7 (9.2–10.2)	7.2 (6.6–8.0)	
49–54	2,789	12,058,336	8.8 (8.4–9.3)	9.5 (9.0–10.0)	6.9 (6.2–7.7)	
≥55	3,483	14,091,323	10.3 (9.9–10.7)	9.5 (9.0–9.9)	12.7 (11.7–13.7)	
Inactive (LTPI)[e]	9,183	36,235,114	26.0 (25.2–26.8)	25.5 (24.7–26.4)	27.4 (26.1–28.9)	0.0112
Sufficiently active[f]	17,751	74,252,045	53.3 (52.6–54.1)	53.7 (52.8–54.6)	52.4 (50.9–53.9)	0.1739

[a]Unweighted sample size.
[b]Population estimates after application of sampling weights.
[c]Weighted population proportions and 95% confidence intervals (CIs). Proportions might not sum to 100 because of rounding. Shift workers refer to those engaged in evening, night, rotating shift, or some other schedule combined (i.e. non-daytime workers).
[d]P-value comparing distribution of the characteristic (covariate) between daytime workers and shift workers.
[e]According to the 2008 Physical Activity Guidelines for Americans, [1]Leisure-time physical inactivity (LTPI) is defined as <10 minutes per week of moderate intensity physical activity (i.e. not being engaged in regular leisure-time physical activity); [f]Sufficient level of aerobic physical activity (sufficiently active) is defined as at least 150 minutes per week of moderate intensity or at least 75 minutes per week of vigorous intensity or an equivalent combination.

on regular day shift (PR = 1.32, 95% CI: 1.20–1.27) (Table 3, Model I); this effect was attenuated but remained significant after further adjustment for education, marital status, lifestyle factors (smoking, alcohol use, and BMI), and work hours per week (PR = 1.13, 95% CI: 1.01–1.26) (Table 3, Model II). Individuals on regular evening shift also had a 23% higher prevalence of LTPI compared to those on day shift (PR = 1.23, 95% CI: 1.11–1.37) (Table 3, Model I), although this effect was no longer significant after multivariable adjustment (PR = 1.09, 95% CI: 0.98–1.20) (Table 3, Model II). Likewise, when shift work status was analyzed as a binary variable (regular daytime versus shift workers), prevalence of LTPI was 8% higher among shift workers (PR = 1.08, 95% CI: 1.02–1.14, Table 3, Model I), with this effect eliminated by multivariable adjustment (PR = 1.02, 95% CI: 0.97–1.08) (Table 3, Model II).

Sex Stratified

Sex significantly modified the association of shift schedule with LTPI (interaction p-value = 0.0033, Table 3). For

Table 2. Prevalence of shift work and leisure-time physical inactivity (LTPI) by sociodemographic characteristics among U.S. workers aged ≥18 years – national health interview survey (NHIS), the United States, 2010 and 2015.

	Shift work[a]		Leisure time inactivity (LTPI)[b]	
Characteristics	Prevalence (95% CI)	PR (95% CI)[c]	Prevalence (95% CI)	PR (95% CI)
Total	26.7 (26.0–27.4)		26.0 (25.2–26.8)	
Sex				
Male	27.9 (27.0–28.9)	**1.10 (1.05–1.16)**	25.0 (24.0–26.0)	**0.92 (0.88–0.96)**
Female	25.3 (24.4–26.2)	Referent	27.2 (26.2–28.2)	Referent
p-value[d]	<0.0001		0.0004	
Age group (yrs.)				
18–44	30.6 (29.7–31.5)	Referent	23.9 (22.9–24.8)	Referent
45–64	21.0 (20.1–22.0)	**0.69 (0.65–0.72)**	28.1 (26.8–29.3)	**1.18 (1.11–1.24)**
≥65	27.1 (24.7–29.6)	**0.89 (0.80–0.97)**	35.6 (33.0–38.3)	**1.49 (1.37–1.62)**
p-value	<0.0001		<0.0001	
Race/Ethnicity				
White, non-Hispanic	25.7 (24.8–26.6)	Referent	22.3 (21.3–23.2)	Referent
Black, non-Hispanic	33.5 (31.6–35.5)	**1.30 (1.22–1.39)**	34.3 (32.1–36.5)	**1.54 (1.43–1.29)**
Asian, non-Hispanic	22.3 (20.1–24.6)	**0.87 (0.78–0.97)**	25.7 (23.2–28.4)	**1.16 (1.04–1.29)**
Other, non-Hispanic	34.6 (30.3–39.2)	**1.34 (1.18–1.53)**	22.4 (18.0–27.3)	1.00 (0.81–1.24)
Hispanic	26.5 (25.0–28.0)	1.03 (0.96–1.10)	37.0 (35.2–38.8)	**1.66 (1.56–1.77)**
p-value	<0.0001		<0.0001	
Marital status				
Married/Living with partner	22.5 (21.7–23.3)	Referent	25.4 (24.4–26.4)	Referent
Widowed/Divorced/Separated	26.3 (24.9–27.7)	**1.17 (1.10–1.24)**	31.5 (30.0–33.1)	**1.24 (1.17–1.31)**
Never married	39.0 (37.5–40.5)	**1.73 (1.65–1.82)**	24.6 (23.2–26.0)	0.97 (0.90–1.04)
p-value	<0.0001		<0.0001	
Education				
Less than High school	29.6 (27.5–31.8)	Referent	48.4 (45.9–50.9)	**3.31 (3.05–3.59)**
High school or GED	31.0 (29.5–32.6)	1.05 (0.96–1.14)	36.1 (34.6–37.7)	**2.47 (2.31–2.65)**
Some College	31.5 (30.3–32.6)	1.06 (0.98–1.15)	25.2 (24.1–26.3)	**1.72 (1.60–1.85)**
College degree	18.9 (18.0–19.8)	**0.64 (0.59–0.70)**	14.6 (13.8–15.5)	Referent
p-value	<0.0001		<0.0001	
Smoking status				
Current	32.4 (30.8–34.1)	Referent	35.0 (33.3–36.7)	**1.44 (1.37–1.52)**
Former	24.9 (23.5–26.4)	**0.77 (0.71–0.83)**	23.9 (22.6–25.5)	0.99 (0.93–1.05)
Never	25.7 (24.9–26.5)	**0.79 (0.75–0.84)**	24.3 (23.4–25.1)	Referent
p-value	<0.0001		<0.0001	
Alcohol consumption				
Never	30.6 (28.9–32.3)	Referent	38.9 (37.1–40.7)	**1.77 (1.67–1.87)**
Former	27.6 (25.7–29.6)	**0.90 (0.83–0.99)**	34.7 (32.5–36.9)	**1.58 (1.47–1.69)**
Current	25.7 (25.0–26.5)	**0.84 (0.79–0.89)**	22.0 (21.2–22.8)	Referent
p-value	<0.0001		<0.0001	
Body mass index (BMI)				
Normal (18.5–24.9)	27.6 (26.4–28.8)	Referent	22.9 (21.8–23.9)	Referent
Overweight (25–29.9)	25.4 (24.4–26.4)	**0.92 (0.87–0.97)**	24.0 (22.9–25.1)	1.05 (0.99–1.11)
Obesity (30+)	27.2 (26.0–28.5)	0.99 (0.93–1.05)	31.2 (29.9–32.6)	**1.37 (1.29–1.45)**
p-value	0.0097		<0.0001	
Work hours/week				
<35	40.9 (39.2–42.6)	Referent	26.5 (25.3–27.9)	Referent
35–40	20.4 (19.5–21.4)	**0.50 (0.47–0.53)**	27.2 (26.3–28.2)	1.03 (0.97–1.08)
41–48	21.1 (19.1–23.1)	**0.52 (0.46–0.57)**	23.5 (21.5–25.6)	**0.88 (0.80–0.97)**
49–54	20.7 (18.9–22.7)	**0.51 (0.46–0.56)**	20.7 (18.8–22.8)	**0.78 (0.71–0.87)**
≥55	32.4 (30.3–34.6)	**0.79 (0.73–0.86)**	25.2 (23.5–27.0)	0.95 (0.88–1.03)
p-value	<0.0001		0.0020	

Values in the table are weighted proportions and 95% confidence intervals (CIs).
[a]Those who reported working on schedules other than the regular daytime shift (i.e. evening, night, rotating, or other schedules combined).
[b]According to the 2008 Physical Activity Guidelines for Americans, Leisure-time physical inactivity (inactive) is defined as <10 minutes per week of moderate intensity physical activity (i.e. not being engaged in regular leisure-time physical activity).
[c]PR = Prevalence ratio (unadjusted).
[d]*p*-values compare prevalence of shift work and LTPI across levels of demographic and lifestyle characteristics.

example, working the evening or the night shift was associated with significantly higher prevalence of LTPI in female, but not male workers. Specifically, females who worked the evening shift had a 24% higher prevalence of LTPI (PR = 1.24, 95% CI: 1.09–1.40, Table 3, Model II), and those on night shift had 17% higher prevalence of LTPI (PR = 1.17, 95% CI: 1.01–1.36, Table 3, Model II) compared to their counterparts on daytime shift. In men, there were no significant differences in the prevalence of LTPI between those working the night or evening shift and those on daytime shift (evening versus day: PR = 0.96, 95% CI: 0.82–1.13; night versus day: PR = 1.10, 95% CI: 0.94–1.29, Table 3, Model II). In addition, males on rotating shift had a 13% lower prevalence of LTPI compared to

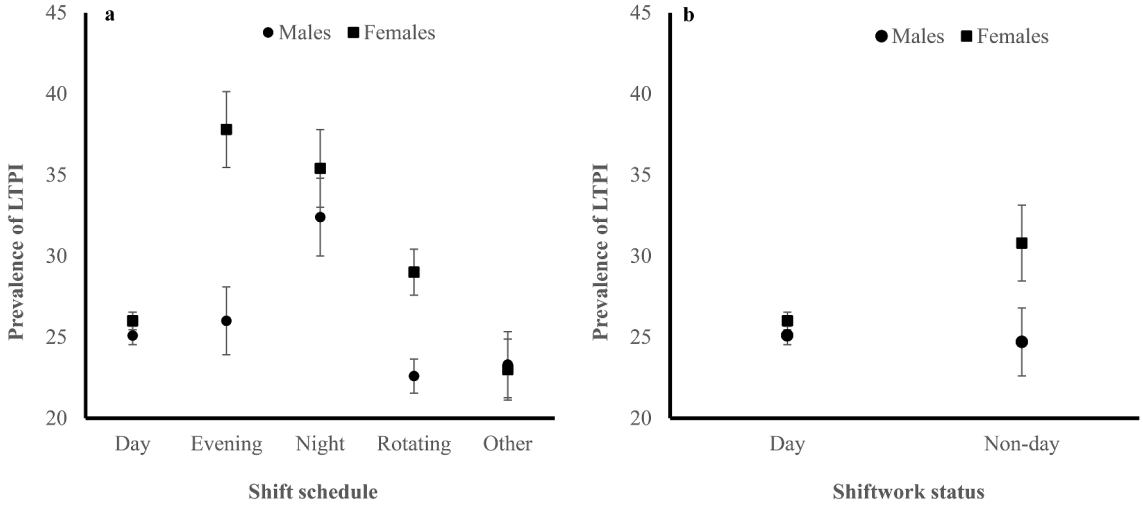

Figure 1. Prevalence of leisure-time physical inactivity (LTPI) by shift schedule (five nominal categories) and shift work status (yes/no) in male and female workers – national health interview survey (NHIS), United States, 2010 and 2015. Prevalence estimate (marker symbol) ± standard error is shown.

Table 3. Association of shift schedule/shift work status with leisure-time physical inactivity (LTPI) among employed civilian U.S. workers 18 years and older stratified by Sex - National Health Interview Survey (NHIS), the United States, 2010 and 2015.

		Prevalence ratio (PR) and 95% confidence interval (CI)		
		All workers	Males	Females
Model I	Shift schedule			
	Regular day time	Referent	Referent	Referent
	Regular evening time	**1.23 (1.11–1.37)**	1.04 (0.88–1.22)	**1.46 (1.28–1.65)**
	Regular night-time	**1.32 (1.20–1.47)**	**1.29 (1.11–1.49)**	**1.37 (1.19–1.56)**
	Rotating shift	1.00 (0.93–1.07)	**0.90 (0.82–0.99)**	**1.12 (1.01–1.24)**
	Some other schedule	0.91 (0.80–1.03)	0.93 (0.78–1.10)	0.89 (0.75–1.04)
	Shift work status			
	Daytime	Referent		
	Non-daytime	**1.08 (1.02–1.14)**	0.98 (0.91–1.06)	**1.19 (1.10–1.28)**
Model II	Shift schedule			
	Regular day time	Referent	Referent	Referent
	Regular evening time	1.09 (0.98–1.20)	0.96 (0.82–1.13)	**1.24 (1.09–1.41)**
	Regular night-time	**1.13 (1.01–1.26)**	1.10 (0.94–1.29)	**1.17 (1.01–1.36)**
	Rotating shift	0.99 (0.92–1.06)	**0.87 (0.78–0.96)**	**1.12 (1.01–1.25)**
	Some other schedule	0.93 (0.83–1.06)	0.93 (0.78–1.10)	0.92 (0.78–1.10)
	Shift work status			
	Daytime	Referent		
	Non-daytime	1.02 (0.97–1.08)	0.93 (0.86–1.00)	**1.13 (1.05–1.22)**

Leisure-time physical inactivity (LTPI) is defined as <10 minutes per week of moderate intensity physical activity (i.e. those who did not report any moderate or vigorous intensity physical activity beyond basic movement from daily life activities); Model I: unadjusted model; Model II: multivariable model adjusted for basic demographic factors (age, sex, race/ethnicity), education, marital status, health behaviors (smoking, alcohol use, BMI), and job characteristic (work hours per week). Interaction p-value between shift schedule and sex (in model II) was 0.0033. Interaction p-value between shift work status and sex (in model II) was 0.0005.

those on daytime shift (PR = 0.87, 95% CI: 0.78–0.95, Table 3, Model II) while among females, prevalence of LTPI was 12% higher for those on rotating shift compared to those on daytime shift (PR = 1.12, 95% CI: 1.01–1.24, Table 3, Model II).

Sex likewise significantly modified the association between the binary shift work status (daytime versus non-daytime) and LTPI (interaction p-value = 0.0005, Table 3). Among female but not male workers, prevalence of LTPI was significantly higher among workers on non-daytime shifts compared to those on regular daytime shift (for females: PR = 1.13, 95% CI: 1.05–1.22; for males: PR = 0.93, 95% CI: 0.86–1.00) (Table 3, Model II).

Sensitivity Analyses

Impact of Child-Bearing Age

According to the Centers for Disease Control and Prevention (CDC), reproductive age (i.e. child-bearing

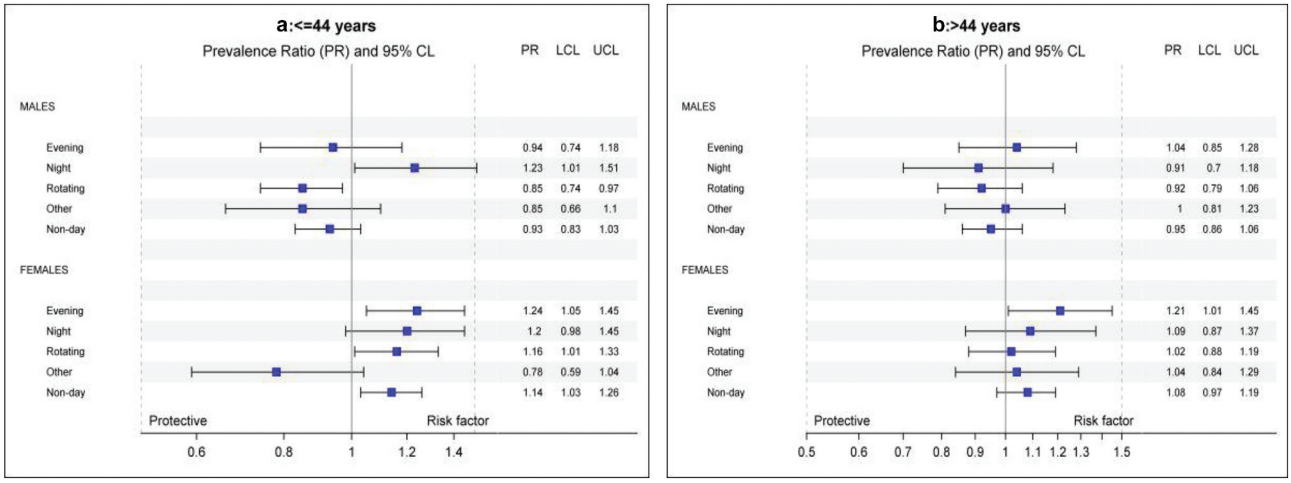

Figure 2. Association of shift schedule and shift work status with leisure-time physical inactivity (LTPI) stratified by child-bearing age (≤44 years versus >44 years) and sex. Comparisons were made between each of the shift schedule categories (evening, night, rotating, other) versus the daytime schedule (reference group) as well as non-daytime shift (evening, night, rotating, and other combined) versus the daytime shift (reference group). Prevalence ratios (PRs) were adjusted for basic demographic factors (age, sex, race/ethnicity), education, marital status, health behaviors (smoking, alcohol use, BMI), and job characteristic (work hours per week). - national health interview survey (NHIS), United States, 2010 and 2015. Interaction p-value between sex and shift schedule (5 categories) ($p = 0.0093$ for ≤44 years; $p = 0.6357$ for >44 years). Interaction p-value between sex and shift work status (2 categories) ($p = 0.0041$ for ≤44 years; $p = 0.1274$ for >44 year).

years) is generally considered to be between the ages of 15 and 44 (NCCDPHP 2014). Child-bearing age could be a proxy indicator of the presence of minor children in the household that may impact LTPI. To test whether the associations of shift schedule and shift work status to LTPI were robust in both older and younger adults, analyses were stratified by child-bearing age (≤44 versus >44 years, Figure 2). Results suggest that the effects of shift schedule or shift work status on LTPI differed by age. Among those aged ≤44 years (Figure 2A), the effects of shift schedule and shift work status on LTPI varied significantly by sex; interaction p-value between sex and shift schedule = 0.0093 and between sex and shift work status = 0.0041. Among younger female workers, the prevalence of LTPI was significantly higher among non-daytime workers vs. those working regular days (PR = 1.14, 95% CI: 1.03–1.26). In contrast, in older workers (>44 years), there was no evidence for a modifying effect of sex on the associations of shift schedule or shift work status to LTPI (both interaction p-values >0.05) (Figure 2B); among old workers, there was no significant difference in prevalence of LTPI between daytime and non-daytime workers regardless of sex. Overall, the association of shift work status to LTPI appears stronger in female workers aged ≤44 years (childbearing age) than in those aged 45 or older.

Impact of Caregiving

To examine the role of caregiving on the association between shift schedule/shift work status and LTPI, we performed two sets of analyses. First, we compared the revalence of being a parent to at least one minor child (a proxy measure of caregiving, available only in the 2015 NHIS data) by shift schedule and sex (supplemental Figure S1). Prevalence of being a parent to at least one minor child was higher in females than males; 28% higher in females working on evening shift (PR = 1.28, 95% CI: 1.05–1.55), 23% higher in females on rotating shift (PR = 1.23, 95% CI: 1.10–1.38), and 24% higher in females on non-daytime shift (PR = 1.24, 95% CI: 1.13–1.36) compared to their male counterparts.

Second, to test whether caregiving to minor children potentially explains the sex disparity in the impact of shift schedule/shift work on LTPI, we performed an analysis additionally adjusting for a proxy measure of caregiving (i.e. being a parent to 1+ minor children) (Supplemental Table S2). The association of shift schedule/shift work status with LTPI was robust to adjustment for caregiving status; among females but not in males, prevalence of LTPI was significantly higher in those working on evening (PR = 1.28, 95% CI: 1.09–1.51), night (PR = 1.24, 95% CI: 1.01–1.53), or non-daytime shift (PR = 1.12 95% CI: 1.01–1.25) compared to those on daytime shift after additionally adjusting for caregiving (Supplemental Table S3).

Discussion

This study sought to examine the association of shift schedule and shift work status to leisure-time physical

inactivity (LTPI) in a nationally representative sample of employed men and women. Our findings indicate that 47% of the U.S. labor force did not meet recommended levels of leisure-time aerobic physical activity, including 26% who were physically inactive. In the overall workforce, LTPI was 13% higher among night shift workers compared to those on regular daytime shifts. Furthermore, sex modified the association between shift schedule and LTPI; among females, working the evening shift was associated with a 24% increased prevalence of LTPI and working the night shift was associated with a 17% increased prevalence of LTPI, after accounting for demographic characteristics, health behaviors, and work hours. Similarly, female shift workers (those on evening, night, rotating, and other schedules combined) had a 13% higher prevalence of LTPI compared to their counterparts working regular daytime shifts. In contrast, the association of shift work status to LTPI was not significant in male workers. The results suggest that shift work may be an important risk factor for LTPI, especially among female workers.

While the exact biological mechanisms are not entirely understood, it is commonly hypothesized that associations between shift work and negative health outcomes (e.g. CVD and diabetes) result from circadian rhythm disruptions and associated sleep disturbances (Arendt 2010; James et al. 2017). Persistent circadian misalignment and sleep restriction could impair several physiological processes that contribute to the development of cardiometabolic diseases (Kervezee et al. 2020). In addition, behavioral risk factors (e.g. physical inactivity) have been hypothesized to mediate the relationship between shift work and adverse health outcomes (Hulsegge et al. 2017). However, findings from previous studies comparing physical activity between shift workers and daytime workers have been inconsistent (Monnaatsie et al. 2021).

Some studies reported no significant differences in leisure-time physical activity levels between shift workers and daytime workers. A large epidemiologic study (Loef et al. 2017; $n = 6{,}512$), based on self-reported assessment of PA, reported that shift workers spent more time walking than non-shift workers, but there were no significant differences between the two groups with respect to other types of leisure-time PA (e.g. cycling, chores, other moderate-to-vigorous exercises. A study based on objective assessment of PA (Hulsegge et al. 2017; $n = 812$) reported that shift workers had similar leisure-time PA patterns as daytime workers (difference in percentage of time spent in moderate-to-vigorous leisure-time PA between night versus day shift workers = 0.1, 95% CI: −0.6–-0.8). A study of health-care workers employed in hospitals (Loef et al. 2018; $n = 479$) concluded that objectively assessed leisure-time PA levels (walking, running, stair-climbing, and cycling) of shift workers were similar to those of non-shift workers. These results are consistent with our findings in the overall workforce and male workers but not in female workers. A recent meta-analysis comparing *overall* PA in shift workers versus non-shift workers (Monnaatsie et al. 2021) concluded that there was no statistically significant difference between shift workers and non-shift workers in terms of meeting physical activity guidelines (OR = 0.84, 95% CI: 0.68–1.03; pooled data from 12 studies) or time spent in moderate-to-vigorous physical activity (standardized mean difference = −0.1, 95% CI: −0.4–0.20; pooled data from 12 studies). It is worth noting, however, that some of the evidence by Monnaatsie and colleagues includes studies that did not distinguish between leisure-time PA and occupational PA and therefore it is not directly comparable to our study.

Results from other studies (Nabe-Nielsen et al. 2011; Ma et al. 2011; Kolbe-Alexander et al. 2019; Loprinzi 2015) appear to support the hypothesis that shift work is associated with decreased levels of leisure-time physical activity. For example, a study of U.S. workers based on 2005–2006 NHANES survey (Loprinzi 2015; $n = 1{,}536$) showed that shift workers (those on evening or night shift) were engaged in significantly less sustained (bouts of) moderate-to-vigorous PA (both occupational and leisure-time combined) compared to those working on regular daytime schedules. In a prospective study of Danish female health-care workers, fixed night work was associated with lower odds of becoming physically active at leisure-time (Nabe-Nielsen et al. 2011); among those who were sedentary at baseline, the odds of becoming physically active at the end of the 2-y follow-up was 92% smaller in those working on fixed night shift compared to those on a fixed day shift (OR = 0.08, 95% CI: 0.01–0.75). These results are congruent with our finding that, relative to female workers on daytime shifts, those on fixed night shift were significantly more likely to be physically inactive during their leisure time.

On the other hand, there are, albeit limited, data to suggest that, in certain populations, shift workers may be more active than non-shift workers (Loprinzi 2015; Marqueze et al. 2013). For example, in a national sample of American adults (Loprinzi 2015), workers on rotating shifts were found to engage in significantly more light intensity physical activity (including leisure-time and occupational PA combined) than daytime workers. Similarly, a small cross-sectional study of truck drivers (31 irregular shift workers, 26 daytime workers)

reported that self-reported level of sufficient leisure-time physical activity (≥150 min/wk.) was higher among shift workers compared to daytime workers (25.8% versus 3.8%), while insufficient leisure-time physical activity (<10 min/wk.) was lower in shift workers compared to daytime workers (48.4% versus 88.5%) (Marqueze et al. 2013). Consistent with these findings, our data also indicate that male workers on rotating shift were significantly less likely to be physically inactive compared to those on daytime schedule (PR = 0.87, 95% CI: 0.78–0.96). More specifically, our data also indicate that among young (≤44 years) male workers, prevalence of LTPI was 23% higher in those working the regular night shift (PR = 1.23, 95% CI: 1.01–1.51) but 15% smaller in those working the rotating shift schedule (PR = 0.85, 95% CI: 0.74–0.97) compared to their counterparts working the regular daytime shift. It is possible that a rotating shift that enables workers to rotate between day, evening, and night shifts while allowing employees to take extended periods off work after prolonged assignment on unfavorable shifts could improve work-life imbalance and provide an opportunity to recharge and engage in leisure time physical activity.

Studies comparing specific LTPI measures of sedentary behavior (SB) between shift workers versus daytime workers are few, and findings have been inconsistent. In a study of working U.S. adults, Loprinzi (2015) reported that those on rotating shifts engaged in significantly less sedentary behavior (leisure-time and occupational combined) compared to daytime workers, a finding broadly consistent with our results in male rotating shift workers demonstrating a reduced likelihood of LTPI. However, while we analyzed leisure-time PA as a separate variable, Loprinizi combined leisure time with occupational PA, rendering comparisons between the studies challenging. Conversely, a Danish study (Hulsegge et al. 2017) reported no significant difference between daytime and shift workers in the percentage of time spent in sedentary behavior at leisure-time (61.1% for dayshift workers and 62.4% for night shift workers. A study of health-care workers (Loef et al. 2018) found no significant differences in proportion of leisure-time spent in sedentary behavior between shift workers and daytime workers (61.4% versus 59.5%). A recent meta-analysis (Monnaatsie et al. 2021) reported that time spent in sedentary behavior was significantly lower in shift workers than non-shift workers (pooled data from 7 studies with all but one assessing PA via a device). However, in this same study, meta-analysis using the six device-based studies showed no significant differences in sedentary behavior between shift and non-shift workers. Similarly, results from our study for the overall work force shows no significant difference in LTPI between non-daytime and daytime workers (PR = 1.02, 95% CI: 0.97–1.08). However, workers on night shifts were 13% more likely to be inactive compared to those on daytime schedule.

Overall, findings of our study suggest that sex may modify the effect of shift schedule and shift work status on leisure-time physical inactivity (LTPI). Females engaged in shift work are 13% more likely to be inactive compared to their counterparts on daytime shift while no significant differences were observed between the two groups in male workers. Specifically, females on evening and night shift are 24% and 17% more likely to be inactive compared to those on daytime shift, respectively, while no differences were found in males. Our study also indicates that males on rotating shift had 13% lower prevalence of LTPI compared to those on daytime shift. But among females, our data show that the prevalence of LTPI was 12% higher for those on rotating shift compared to those on day shift.

It is worth noting that there are several factors that could contribute to the inconsistencies in result between the current study and prior studies of shift schedule/shift work and physical activity including variations in (a) shift schedules compared (shift worker versus daytime worker, rotating versus daytime, evening versus daytime, night versus daytime, etc.), (b) type of occupation of the study participants (uniform versus diverse), (c) sample size, (d) type of PA (leisure-time versus occupational versus both combined) (e) definition of outcome measures of PA (prevalence of meeting the PA guideline versus time spent in moderate-to-vigorous activity versus time spent in sedentary behavior versus prevalence of being inactive), (f) measurement tools used for assessment of physical activity (device-based versus self-report), (g) questionnaires used for assessment of self-reported PA, and (h) cut points used for classifying physical activity (e.g. sustained versus overall moderate-to-vigorous PA). For example, Loprinzi (2015) reports significantly lower *sustained* moderate-to-vigorous PA in shift workers than those on regular daytime schedule but no differences between the two groups in terms of *overall* moderate-to-vigorous PA. Similarly, a study by Monnaatsie et al. (2021) reported significantly lower SB in shift workers compared to those on day shift (pooled data from 7 studies) but the difference between the two groups was no longer statistically significant when the analysis was restricted to the 6 studies that utilized devices for assessment of PA. Future studies comparing physical activity and sedentary behaviors in shift and daytime workers should consider standardized protocols for assessment of shift work and a device-based assessment of PA.

The major strength of this study is that it is based on a large, nationally representative sample that includes U.S. workers from a diverse array of industry and occupation categories. In addition, many covariates (demographic variables and health behaviors) were collected as part of NHIS, allowing us to adjust for multiple potential confounders. Our study distinguishes leisure-time PA from occupational PA and includes sensitivity analyses allowing assessment of potential modifying effects of age and sex. We acknowledge the following limitations. Work schedule, leisure-time physical activity, and covariate data are all self-reported. Subjective assessment of leisure-time physical activity via questionnaires may result in misclassification due to social desirability bias (Troiano et al. 2008) in which participants tend to overestimate their physical activity (Sylvia et al. 2014), difficulty in accurately assigning intensity to reported activities, and limited ability to recall frequency and duration of PA. Thus, confirmation of findings with objective device-based PA assessments is needed. The analysis was based on a cross-sectional assessment of participants' work shift and leisure-time PA, limiting casual inference. Because shift work tenure was unspecified, we were unable to examine whether LTPI was higher among those with longer tenures.

Conclusions

In summary, this study presents evidence that shift work may contribute to leisure-time physical inactivity. Further, the relationship of shift work to leisure-time inactivity varied with sex. This study also adds to the body of knowledge regarding the continuing high prevalence of inactivity/insufficient activity in the U.S. workforce. Overall, our work has established firm associations between shift work and leisure-time physical inactivity, thereby highlighting the need for inclusion of physical activity in health promotion interventions to address the higher inactivity level among shift workers, especially among female workers. In conclusion, the findings from the current study supports the assertion by Loprinzi (2015) that physical activity and sedentary behavior interventions ought to be tailored based on shift schedules. Increasing leisure-time physical activity may have the potential to mitigate the adverse effects of shift work on chronic disease. Additional longitudinal research is clearly warranted to further evaluate the potentially complex links between shift work and LTPI, to better understand the possible modifying effects of sex and age, and ultimately, to inform strategies to support increased PA and associated reduction in chronic disease risk.

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