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Original Article

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Demographics, sleep, and daily patterns of caffeine intake of shift workers in a nationally representative sample of the US adult population

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Abstract

Study Objective: Caffeine is the most widely consumed stimulant in the world, and sociodemographic factors including occupation are associated with intake. Shift work, required in various occupations, is associated with poor sleep, inadequate diet, and adverse health effects. Using a large nationally representative database, demographics, sleep, and caffeine intake of US adults working various shifts were assessed.

Methods: The 24-hour dietary recall data from NHANES 2005–2010 (N = 8,500) were used to estimate caffeine intake from foods and beverages. Work shifts were self-reported as follows: regular day shift; evening shift; night shift; rotating shift; or other shift. Regression analyses assessed associations of shift work with caffeine intake after adjustment for sociodemographic factors.

Results: Approximately 74% of employed adults were day-shift workers and 26% were nonday-shift workers. Night-shift workers slept for 6.25 ± 0.09 hours per day, somewhat less than day-shift workers who only slept 6.83 ± 0.02 hours (p < .0001). Mean 24-hour weekday caffeine intake of evening-, night-, and rotating-shift workers (217 ± 23, 184 ± 19, and 206 ± 15 mg, respectively) was similar (p > .3) to day-shift workers (203 ± 5 mg). Regardless of work schedule, individuals consumed the most caffeine during morning hours. Evening- and night-shift workers reported consuming 36%–46% less caffeine during their work hours and 72%–169% more during nonwork hours than day-shift workers (p < .01).

Conclusions: Total daily caffeine intake of shift workers is similar to nonshift workers; most caffeine is consumed in the morning regardless of shift. Because shift workers consume less caffeine during regular work hours and more during nonwork hours than day workers, they may be using caffeine to, in part, optimize off-duty alertness.

Statement of Significance

About 25% of the US population are shift workers. Shift work interferes with sleep, increases accidents, and adversely affects health. Caffeine is a popular stimulant, and it is assumed that shift workers use more; however, no epidemiological data are available to verify this. Using a large (N = 8,500), nationally representative database we found no differences in caffeine consumption between day-, evening-, night-, and rotating-shift workers. Evening- and night-shift workers consumed less caffeine during regular work hours and more during nonwork hours than day workers. The optimal pattern, risks, and benefits of caffeine intake of nondaytime-shift workers should be studied and may be different than expected.

Key words: NHANES; day shift; evening shift; night shift; rotating shift; circadian rhythms; sleep inertia; coffee

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Introduction

Caffeine, often in the form of coffee, but also in tea, cola beverages, and energy drinks, is widely consumed throughout the world. Coffee is the most popular beverage in the world after water, with approximately 1.6 billion servings consumed per day [1]. In the United States, over 80% of adults regularly consume caffeine. Average per capita intake is about 170 mg/d (approximately 1.5 cups of coffee) and has remained relatively stable for a number of years [2].

Demographic factors associated with caffeine intake include age, ethnicity, smoking status, total calorie intake, and work hours, but not physical activity, economic status, education level, and employment status [2]. Non-Hispanic blacks consume the least caffeine per day (about 80 mg/d), whereas non-Hispanic whites consume the most (approximately 194 mg/d). Asians and Hispanics are intermediate users. People 50- to 54-years-old consume more caffeine (211 mg/d) than either their 20- to 24-year-old counterparts or their older, 75- to 79-year-old peers (107 vs. 153 mg/d, respectively).

One reason caffeine appears to be widely consumed is because of its stimulant-like properties, which include improved concentration and enhanced mood when it is consumed in doses found in single servings of many beverages [1, 3–5]. About 70% of caffeine is consumed in the morning, presumably to increase alertness and enhance cognitive performance at a time of day when sleepiness is elevated due, in part, to sleep inertia [2, 6].

Caffeine increases arousal in a dose-dependent manner [7], and its effects are more pronounced in fatigued compared with rested individuals, as well in those who must perform boring/repetitious activities as opposed to highly motivating/interesting tasks [8]. Nonsleep-deprived adults engaged in long, monotonous activities can experience substantial performance benefits when caffeine is administered in doses of 30–300 mg [3, 9–13]. Sleep-deprived individuals experience significant alertness and performance improvements with doses ranging from 200 to 600 mg [14–16].

A segment of the population that may particularly benefit from caffeine's alertness and performance-enhancing properties are shift workers [17]. Between 26 and 38 million adults (18%–26% of the population) in the United States are considered to be shift workers [18]. These individuals are often required to sleep at times when humans are normally awake and to work at times when humans are normally asleep [19]. As a result, many suffer from sleep restriction as well as disrupted circadian rhythms [20, 21], and, as predicted by the two-process model of sleep/wake regulation [22], interactions between internal circadian and homeostatic processes increase the risk that they will experience significant alertness and cognitive performance decrements at work [23, 24]. Night workers, in particular, suffer from reduced productivity and compromised safety on the job [25]. In fact, personnel who work at night are at 30%–50% greater risk of being involved in an accident than those on other shifts, and shift workers, in general, are more likely to die in fatal occupational accidents [26, 27]. Thus, it is not surprising alertness-enhancing strategies such as caffeine consumption are often recommended to these individuals [24, 28]. Although, controlled workplace studies have not been conducted to definitively establish the benefits or risks of caffeine in shift-work operations, numerous laboratory investigations demonstrate caffeine significantly reduces nighttime sleepiness and substantially improves performance [24].

The widely accepted two-process model of sleep/wake regulation proposes that sleepiness and alertness are primarily regulated by an interaction of the two processes referred to as the homeostatic or S process and the circadian or C process [29, 30]. The increase in sleep pressure that occurs throughout the day (the S process) is a function of the amount of wake time since the last sleep period. The relative increase in nighttime sleepiness (the C process) occurs because of diurnal fluctuations in internal physiological rhythms. Shift workers are often sleepy at night because of both factors—they have been awake for a long time prior to starting work and are working at a time when their physiology is programmed for sleep. Caffeine clearly reduces the nighttime expression of the increased homeostatic drive for sleep (and the resulting propensity toward the increase in unintended on-the-job sleep lapses) that night workers experience from being awake several hours longer than their daytime counterparts prior to reporting for work [31]. Caffeine may also affect the circadian process [32]. Data from laboratory simulations indicate that 250–400 mg of caffeine, taken as a single dose at the beginning of night shift (around midnight) significantly increases alertness until approximately 5:30 am without degrading subsequent daytime sleep if sleep begins at 9:00 am [33].

Limited data are available on caffeine intake of shift workers, but a review of studies describing countermeasures for the negative effects of night work concluded caffeine "can prevent impairment in functioning due to sleep loss on night-shifts" and "normally a dose of 2–4 mg/kg in the beginning of the night shift is recommended" [34]. In a small study (N = 36) conducted with male and female night-shift (N = 18) and day-shift (N = 18) nurses and security guards, night-shift workers reported using more stimulants such as caffeine than their day-working counterparts [35]. A survey of faculty, residents, and nurses employed at an urban university medical center emergency department reported that 72% of respondents across all three groups drank coffee prior to their night shifts to improve wakefulness [36]. Assessment of caffeine use by Australian shift-working nurses and midwives indicated that since starting as shift workers, the percentage consuming more than 400 mg/d of caffeine increased from 15% to 33%, with mean consumption equal to four caffeinated beverages per day [37]. A 2015 study of long-haul truck drivers (N = 54) found consumption of caffeine and use of other sleepiness countermeasures was more prevalent among night-shift workers than workers on any other shift [38].

Although these data suggest shift workers may be using more caffeine than day workers, data from large national health surveys, as opposed to individual work sites, of consumption of caffeine by various types of shift workers are not available [39, 40]. Therefore, we conducted a study to assess caffeine intake of nonday-shift and day-shift workers in the United States. We used a very large, comprehensive, nationally representative database of the adult population (N = 8,500) from the National Health and Nutrition and Examination Surveys (NHANES). The NHANES is a continuous cross-sectional survey of the nationally representative, noninstitutionalized civilian population conducted by the Centers for Disease Control (CDC) to monitor health and dietary status of the US population [41]. Additional NHANES data are released every 2 years and include an in-home survey and physical examination conducted in a mobile facility. Because consecutive NHANES surveys are conducted using the same state-of-the-art techniques and standardized procedures, large data sets can be obtained by combining multiple years of data. The NHANES survey has contributed extensively to population-based nutrition surveillance and nutrition monitoring that guides nutrition policy and assesses associations between nutrition and numerous health outcomes.

Methods

Database and sample

Cross-sectional data from NHANES were used for this study. A detailed description of the subject recruitment, survey design, and data collection procedures are available online (http://www.cdc.gov/nchs/nhanes/about_nhanes.htm). Briefly, the data are collected using a stratified multistage cluster sampling probability design and are released on approximately 10,000 participants every 2 years. Participants are interviewed in their homes for demographic, socioeconomic, dietary (24-hour dietary recall), and general health information, followed by a comprehensive health examination conducted in a mobile examination center [42].

The current analysis combined adult data from NHANES 2005–2006, 2007–2008, and 2009–2010 (data on employment and work hours were not collected in surveys conducted after 2010). The combined sample included 14,360 adults aged 19- to 70-years-old and excluded pregnant or lactating females (N = 564), those with incomplete or missing data (N = 684) or zero kcal intake (N = 2), and adults with no available work shift data (N = 5,170). Data for 4,616 unemployed adults were also used for comparison with employed adults. All data used in this study are publicly available at http://www.cdc.gov/nchs/nhanes/. All participants provided written informed consent, and the NHANES study protocol was approved by the Research Ethics Review Board of the National Center for Health Statistics and the US Army Research Institute of Environmental Medicine Human Use Review Committee approved this study.

Caffeine intake analysis

The amount of caffeine consumed on all days of the week and on weekdays only was estimated from consumption of all caffeine-containing foods and beverages in the diet and was based on the first 24-hour dietary recall collected. The estimate did not include dietary supplements and medicines which are very minor sources of daily caffeine intake [43, 44]. As part of the 24-hour dietary recall interview, participants were specifically asked whether the beverages they consumed were caffeine-free.

Shift work exposure

Shift work status/work schedule was determined by response to the NHANES question: "Which of the following best describes the hours you usually work at your main job or business?" The response options were as follows: (1) regular daytime schedule defined as work anytime between 6:00 am and 6:00 pm; (2) regular evening-shift defined as work anytime between 2:00 pm and midnight; (3) regular night shift defined as work anytime between 5:00 pm and 8:00 am the next day; (4) rotating-shift defined as a work shift that changes periodically from days to evenings or nights; or (5) other shift defined as a split shift consisting of two distinct work periods each day, an irregular schedule arranged by the employer, or any other nontraditional schedule [42].

Estimation of sleep time

Self-reported sleep duration was assessed from the NHANES question: "How much sleep do you usually get at night on weekdays or workdays?" Responses were coded as number of hours of sleep time [42].

Statistics

Analyses used SAS 9.2 (SAS Institute, Inc., Cary, NC) and SUDAAN release 11.0 (Research Triangle Institute, Research Triangle Park, Durham, NC) to account for the complex survey design of NHANES, and all estimates were weighted using appropriate sample weights to adjust for oversampling of selected groups (which are of particular public health interest; these change from cycle to cycle), survey nonresponse of some individuals, and day of the week when the interview was conducted. Individuals who reported they did not consume any caffeine were included in analyses when appropriate.

Mean ± *SE* for various demographic variables were determined for those in each work shift. Regression analyses were also conducted to assess associations of shift work with caffeine intake on all days and on weekdays only adjusting for age, age^2, gender, race/ethnicity, current smoking status (yes/no), work hours, calories consumed, and greater than median alcohol intake (yes/no). Work time caffeine intake was determined by summing caffeine intake during the time frames associated with the day shift, evening shift, and night shift (the only shifts where time frames were specified); nonwork caffeine intake was determined by subtracting total caffeine intake from work intake. Regression analyses, adjusted for covariates above, were used to assess differences in work/nonwork caffeine intake. A p-value of less than .05 was considered statistically significant.

Results

Demographics

Approximately 73.5% of employed adults were day-shift workers and about 26.5% were nonday-shift workers. Of the nonday-shift employed adults, 21% worked an evening-shift, 17% worked the night shift, 32% were employed on rotating shifts, and 30% worked some other shift (Table 1). Compared with day-shift workers, the evening-, night-, and rotating-shift workers were younger, less likely to be non-Hispanic (NH) white, and more likely to be NH black and of a lower economic status (poverty income ratio [PIR] < 1.35). In addition, fewer shift workers were members of a higher economic status group (PIR > 1.85) (Table 1). There were several differences in the proportion of current smokers and total hours worked between nonday-shift workers (evening-, night-, or rotating-shift workers) and day-shift workers. Night-shift workers had a higher proportion of current smokers, and evening- and rotating-shift workers worked somewhat fewer work hours than day-shift workers. Compared with day-shift workers, a higher proportion of evening-, rotating- and other-shift workers worked less than 20 hours per week and a

Table 1. Demographic characteristics of employed adults by work shift in NHANES 2005–2010

Variable	All employed (*n* = 8,500)	Work shift: Day (*n* = 6,245; 73.5%)	Evening (*n* = 478; 5.6%)	Night (*n* = 389; 4.6%)	Rotating (*n* = 715; 8.4%)	Other (*n* = 673; 7.9%)
Age	41.3 ± 0.2[a]	42.4 ± 0.2	**35.7 ± 1.0***	**35.8 ± 0.9***	**36.9 ± 0.9***	42.4 ± 0.7
Gender = % Male	54.5 ± 0.6	54.1 ± 0.7	55.2 ± 3.3	56.1 ± 3.7	51.7 ± 3.0	**59.3 ± 2.5****
Ethnicity						
% Mexican American	8.67 ± 0.87	8.72 ± 0.91	9.20 ± 1.89	11.4 ± 1.6	10.9 ± 1.3	**4.63 ± 0.96***
% Other Hispanic	4.46 ± 0.65	4.59 ± 0.68	4.80 ± 1.12	5.13 ± 1.41	4.51 ± 0.82	2.88 ± 0.79
% Non-Hispanic white	70.5 ± 1.9	71.8 ± 1.9	**61.3 ± 4.3****	**59.2 ± 3.8***	**64.1 ± 2.6****	76.0 ± 2.1
% Non-Hispanic black	10.4 ± 0.9	9.08 ± 0.88	**16.6 ± 2.4***	**16.6 ± 2.4***	**15.2 ± 1.5***	10.4 ± 1.4
% Other ethnicities	5.98 ± 0.51	5.79 ± 0.60	8.12 ± 1.87	7.66 ± 1.79	5.32 ± 1.12	6.15 ± 1.52
Economic status						
% PIR < 1.35	14.4 ± 0.7	12.5 ± 0.7	**22.8 ± 2.8***	**21.6 ± 2.5***	**22.7 ± 1.8***	13.7 ± 1.8
% 1.35 ≤ PIR ≤ 1.85	8.40 ± 0.43	7.89 ± 0.48	**14.7 ± 2.2***	10.1 ± 1.7	9.66 ± 1.28	6.98 ± 1.08
% PIR > 1.85	77.2 ± 0.9	79.6 ± 0.9	**62.5 ± 3.2***	**68.3 ± 3.3***	**67.6 ± 2.4***	79.3 ± 2.0
% Current smokers	21.1 ± 0.9	19.9 ± 0.9	25.8 ± 3.1	**32.7 ± 3.2***	22.8 ± 2.7	20.6 ± 2.1
Hours worked last week	41.5 ± 0.3	41.7 ± 0.2	**38.1 ± 0.7***	40.6 ± 0.9	**39.7 ± 0.8****	43.4 ± 1.2
% less than 20 h/wk[b]	7.0 ± 0.5	5.5 ± 0.5	**10.9 ± 2.2****	5.3 ± 1.8	**10.3 ± 1.8****	**14.3 ± 2.0***
Hours of sleep	6.82 ± 0.02	6.83 ± 0.02	6.98 ± 0.09	**6.25 ± 0.09***	6.85 ± 0.06	6.88 ± 0.06
% with zero caffeine intake[c]	10.7 ± 0.5	10.0 ± 0.6	**15.3 ± 2.5****	13.5 ± 1.7	**13.7 ± 1.6****	8.9 ± 1.6

[a]Mean ± *SE*. Bolded means for each nonday-shift population within a row are significantly different (*$p < .01$; **$p < .05$) from means for day-shift workers when compared by *t*-tests; PIR, poverty income ratio.
[b]After adjustment for covariates (age, age^2, gender, race/ethnicity, current smoking status, work hours, calories consumed, and alcohol intake), only the other work shift had a higher percentage of the group with <20 h/wk when compared with the day shift.
[c]After adjustment for covariates (age, age^2, gender, race/ethnicity, current smoking status, work hours, calories consumed, and alcohol intake), there were no differences in percentage of groups with zero caffeine intake when compared with the day shift.

Table 2. Caffeine Intake by Work Shift in NHANES 2005–2010

Work shifts	Mean 24-hour caffeine intake on all days (mg)	P-value (vs. day shift)	Mean 24-hour caffeine intake on weekdays (mg)	P-value (vs. day shift)
Day	198 ± 3[a]		203 ± 5	
Not day	197 ± 9	.9294	199 ± 10	.7033
Evening	211 ± 21	.5407	217 ± 23	.5538
Night	191 ± 15	.6327	184 ± 19	.3387
Rotating	199 ± 13	.9155	206 ± 15	.8314
Other	191 ± 16	.6495	188 ± 19	.4587

[a]Least square mean ± *SE*. Gender combined data adjusted for age, age^2, gender, race/ethnicity, current smoking status, work hours, calories consumed, and alcohol intake, and included individuals who did not consume any caffeine.

higher proportion of evening- and rotating-shift workers had zero caffeine intake. However, except for other-shift workers, these differences were not statistically significant after adjustment for covariates (age, age^2, gender, race/ethnicity, current smoking status, work hours, kcal consumed, and alcohol intake). Total mean sleep hours on weekdays or workdays for the evening-, rotating- or other-shift workers were not significantly different from day-shift workers, but total sleep for night-shift workers was 8.5% less than day-shift workers (6.25 ± 0.09 vs. 6.83 ± 0.02 hours, $p < .0001$) (Table 1).

Adjusted total 24-hour caffeine intake

Caffeine intake of the total adult population was 192 ± 5 mg/d on all days and 194 ± 6 mg on weekdays. The total mean 24-hour caffeine intake of employed adults (including individuals who did not consume any caffeine) was 196 ± 4 mg and was significantly higher ($p = .0051$) than that of unemployed adults (181 ± 5 mg) on all days and also on weekdays only (201 ± 5 mg for employed vs. 179 ± 5 mg for unemployed, $p = .0023$).

Adjusted total 24-hour caffeine intake by work shift

Total mean 24-hour caffeine intake on all days or on weekdays among day-shift workers was not different from the all nonday-shift workers after adjusting for demographic factors known to be associated with caffeine intake: age, age^2, gender, race/ethnicity, current smoking status, work hours, kcal consumed, and alcohol intake (Table 2) [2]. Mean 24-hour caffeine intake of evening- night-, and rotating-shift workers were also similar to that of day-shift workers on all days as well as on weekdays. The caffeine intake of evening-, night- and rotating-shift workers remained similar to day-shift workers when the data for male and female workers were analyzed separately (data not presented).

Distribution of 24-hour adjusted caffeine intake by work shift

All categories of shift and nonshift workers had peak caffeine intakes between 6:00 am and 10:00 am (Figure 1) similar to the general population [2]. Caffeine intake for day- and night-shift workers peaked at 6:00 am–8:00 am, and peak caffeine intake

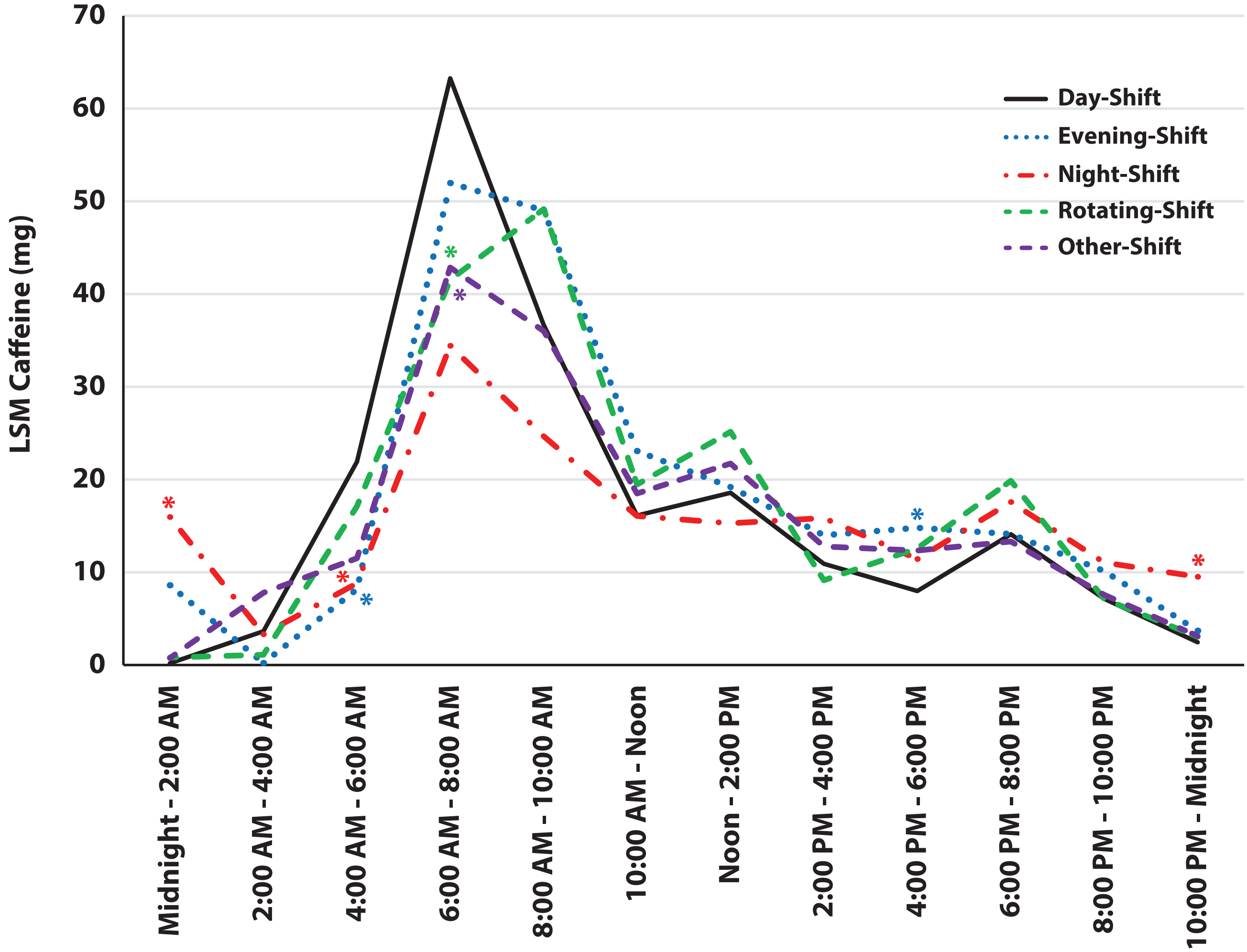

Figure 1. Time course of mean caffeine intakes in 2-hour blocks of time on weekday by work shift, NHANES 2005–2010. Gender combined data adjusted for age, age^2, gender, race/ethnicity, current smoking status, work hours, calories consumed, and alcohol intake, and included zero caffeine consumers. *Significantly different from day shift at $p < .05$.

for night-shift workers during this time period was about 54% of day-shift worker intake (34.4 ± 17.5 vs. 63.2 ± 3.5), but the difference was not significant ($p = .1055$). Evening-shift workers consumed the most caffeine between 6:00–8:00 am and 8:00–10:00 am (52.0 ± 13.2 and 49.0 ± 19.0 mg, respectively). Night-shift workers consumed significantly more caffeine during night hours (10:00 pm–midnight and midnight–2:00 am) than day-shift workers ($p < .02$). Rotating-shift workers' maximum caffeine intake was between 8:00 am and 10:00 am. The time of maximum caffeine intake of workers in the other-shift category was between 6:00 am and 8:00 am, which was 32% less (42.9 ± 7.1 vs. 63.2 ± 3.5, $p = .0133$) than that of day-shift workers (Figure 1).

Work hours and nonwork hours adjusted caffeine intake by shift work

Day-shift workers consumed 68% more caffeine during work hours than during nonwork hours ($p < .0001$). There were no significant differences in caffeine intake during work hour and nonwork hours for evening-shift workers ($p = .0841$) and night-shift workers ($p = .5505$). Additionally, compared with day-shift workers, both evening- and night-shift workers consumed less caffeine (46% and 36% less, respectively, $p < .01$) during work hours and more caffeine (169% and 72% more, respectively, $p < .01$) during nonwork hours (Table 3).

Discussion

The NHANES 2005–2010 data indicate about 25% of employed adults are nonday-shift workers, consistent with other reports, which suggest that somewhere between 20% and 29% of all US workers work nondaytime/alternative shift schedules [18, 45]. Given the problems associated with shift work, it has been suggested nonday-shift personnel seek to counter their on-the-job sleepiness with various fatigue countermeasures including use of more caffeine than day workers [40]. However, our data indicate this may not be the case. Although it is reported more caffeine is frequently consumed by shift workers [24, 46], our cross-sectional study using representative population data from NHANES found there were no significant differences in the 24-hour caffeine intake of nonday-shift workers (evening, night, rotating, or other) compared with day-shift workers after controlling for covariates including age, race, ethnicity, current smoking status, work hours, kcal consumed, and alcohol intake

Table 3. Adjusted means of 24-hour caffeine intake during work time and nonwork time on weekdays by work shift in NHANES 2005–2010

	Work hours caffeine intake (mg)	*P*-value (vs. day shift)	Nonwork hours caffeine intake (mg)	*P*-value (vs. day shift)
Day shift	156 ± 4[a]		49.5 ± 3.4	
Evening shift	**84.0 ± 9.1**	<.0001	**133 ± 24**	.0014
Night shift	**99.2 ± 18.7**	.0053	**85.1 ± 9.5**	.0029

[a]Least square mean ± *SE*. Gender combined data adjusted for age, age^2, gender, race/ethnicity, current smoking status, work hours, calories consumed, and alcohol intake, and included individuals who did not consume any caffeine. Bolded means for each evening- or night-shift population within a column are significantly different from day shift. For rotating- and other-shift workers, working time frame was unknown, so the work and nonwork hours caffeine intake could not be determined.

known to affect caffeine intake [2]. Furthermore, evening- and night-shift workers consumed significantly less caffeine during their work hours than day-shift workers and more caffeine during nonwork hours after adjustment for covariates.

Although caffeine, a stimulant consumed by more than 80% of the US population, has known beneficial effects on fatigue, alertness, and cognitive performance, its benefits and risks when used by shift workers have not been established in controlled investigations of such workers [1, 3–5, 8, 24]. A few observational studies reporting shift workers consume more caffeine than day workers have been conducted [35, 37, 38]. However, the sample sizes of these studies were small and various factors could have biased the results such as differences in demographics, lifestyle, and occupational classifications, all known to effect caffeine intake [2]. To the best of our knowledge, no previous investigations have compared caffeine intake among different shift workers using a large representative population and adjusted for known confounders such as age, ethnicity, and current smoking status.

Since day-shift workers prepare for work and begin their work in the morning, the fact they consume most of their caffeine early in the day (before or when they are at work) is in agreement with our previous observation that US adults generally consume most of their caffeine in the morning [2]. However, our findings with shift workers appear contrary to expectation since one would anticipate that, in comparison to day workers, evening and night workers would consume more caffeine during their work hours (to promote alertness) and less caffeine during nonwork hours (to promote daytime sleep). This unexpected observation could be accounted for, at least in part, by the fact shift workers generally do not fully adapt to their nontraditional work-rest cycle [47]. For example, a survey of nurses working the night shift reported they preferred to sleep at night during their off-shift days and were not well adapted to night-shift work [48]. A comprehensive literature review concluded only a very small minority (<3%) of night workers fully adapt to their work schedules [49]. The inability of shift workers to fully adapt to their nontraditional schedules may help to explain their use of caffeine in a pattern that is similar to day workers and is consistent with the fact the activities of daily life in modern society generally require daytime work and nighttime sleep. It is also possible shift workers use caffeine for purposes other than promoting alertness.

Day- and night-shift workers may differ with regard to the nature of their duties or their work environments, and as a result, there may be substantial differences in the availability of coffee and other caffeinated beverages in the workplace. Administrative and clerical desk workers may be more likely to be day-shift workers and therefore have frequent access to caffeine, whereas nonday-shift workers may be in manufacturing occupations without continuous access to such beverages. In addition, it is possible night workers are consuming additional caffeine in the mornings (at the end of their night shifts) to increase their alertness if driving from work, and/or to assist them managing daytime family responsibilities, work a second job, or attend school during the day. Because caffeine effectively reduces daytime driving incidents after prolonged periods of wakefulness [50], workers may be ingesting it before driving after they work the night shift. Following such a commute home, they may continue to rely on caffeine to sustain their alertness during the day. Sixteen percent of night workers choose the night shift to facilitate better arrangements for family or child care [51], and as a result, they probably have domestic responsibilities after work. Furthermore, 23% of night workers hold secondary jobs, which they likely perform during the daytime [52], and a substantial number of working employees also attend school in addition to working their jobs [53]. Whether for family, economic, or educational reasons, these individuals may be consuming their morning caffeine to avoid falling asleep during the day. Nearly half of individuals who work more than one job use caffeine to help them cope with sleepiness at work [54], and more than three quarters of college students who consume caffeine do so to feel more awake at school [55].

Chronic sleep restriction results in on-the-job sleepiness, as well as sleepiness when off-duty, and decrements in attention and other cognitive functions and increases in accidents [6]. Regular night-shift workers have been reported to have shorter sleep times than day-shift workers, who themselves do not get sufficient sleep [24, 56], consistent with our findings that: (1) both daytime workers and nighttime workers are failing to obtain the minimum of 7 hours of sleep per night recommended by experts [57]; and (2) night-shift workers are sleeping about 8% less every day than day-shift workers. We did not observe significant differences in sleep duration between day-shift workers and evening-shift workers. Around-the-clock operations are essential for many occupations in the industrialized world. Unfortunately, such 24/7 schedules conflict with normal human diurnal circadian rhythms of behavioral and physiological processes, which evolved to ensure wakefulness during the day and sleep at night. When these rhythms are disturbed, the probability of fatigue-related incidents and accidents, as well as risks for the development of chronic health problems including sleep disorders increase [23, 24, 58]. Folkard and Tucker [25] observed workplace incidents on afternoon shifts in various industries increase by 18% compared with day shift, and on night shifts, they increase by about 30%. The undesirable consequences of shift work are exacerbated by the fact nearly 20% of shift workers develop circadian rhythm sleep disorders or shift work disorders, which are both characterized by insomnia and excessive sleepiness, which impair day-to-day functioning [23].

In an additional analysis with covariate adjusted data, we found a small but significant linear inverse relationship (−6.56 mg/d caffeine per hour sleep; p = .0247) of sleep hours with caffeine intake on all days but not with weekdays only (−4.71 mg/d caffeine per hour sleep; p = .2007). Unfortunately, this finding does not allow us to ascertain whether reduced sleep hours influenced caffeine intake or whether reduced caffeine intake influenced sleep hours, but given the largest difference in sleep across the work shifts was only about 0.75 hours, the difference in sleep hours equates to only about 5-mg caffeine intake (0.75*6.56) on all days (including weekends) and no impact on intake on weekdays. Such a small difference in caffeine intake is unlikely to have biological effects.

Limitations of this study include the inability to infer causation, as with any observational study. Also, as with any study based on self-reported data, under- or over-reporting cannot be ruled out. Additionally, the most recent NHANES data on shift work were only available for 2005–2010, and thus increases in use of energy drinks or other caffeine-containing food and beverages in the past few years are not captured. A major strength of our study is the use of a large, nationally representative, population-based sample of employed adults and controlling for factors known to influence caffeine intake.

In conclusion, the results of the present investigation on caffeine intake in shift workers unexpectedly indicate the adjusted 24-hour daily caffeine intake of day-shift workers is virtually identical to that of evening- and night-shift workers after adjusting form demographic and lifestyle factors. Also, surprisingly, evening and night workers consume less caffeine during their regular work hours than day workers and more caffeine during nonwork hours than day workers. We also found most caffeine is consumed in the morning hours regardless of work shift. Considerable research is required to determine the optimal pattern and extent of caffeine consumption for shift workers. Undoubtedly, the optimal intake will vary depending on many factors including the nature of work, length and timing of the shift, and demographic characteristics of the consumers. Another issue that could have accounted for the unexpected caffeine consumption pattern observed in the present investigation is the lack of information available to shift workers regarding "best practices" of caffeine use. A Google search to find shift-work-relevant advice on caffeine use found only very general guidance which, given the many patterns of shift work, is to be expected. Official government web sites such as the US Occupational Safety and Health Administration (OSHA) and the Canadian Centre for Occupational Health and Safety (CCOHS) also provide little specific guidance (www.osha.com; www.ccohs.ca).

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