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A week in the life of full-time office workers: Work day and weekend light exposure in summer and winter

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ABSTRACT

Little is known about the light exposure in full-time office workers, who spend much of their workdays indoors. We examined the 24-h light exposure patterns of 14 full-time office workers during a week in summer, and assessed their dim light melatonin onset (DLMO, a marker of circadian timing) at the end of the working week. Six workers repeated the study in winter. Season had little impact on the workers' schedules, as the timing of sleep, commute, and work did not vary by more than 30 min in the summer and winter. In both seasons, workers received significantly more morning light on workdays than weekends, due to earlier wake times and the morning commute. Evening light in the two hours before bedtime was consistently dim. The timing of the DLMO did not vary between season, and by the end of the working week, the workers slept at a normal circadian phase.

1. Introduction

The circadian system regulates many physiological and behavioral rhythms over the course of about one day. The daily timing of sleep and wake, for example, is largely influenced by the circadian system, though voluntary human behavior can override this internal time-keeping system. On average, the central circadian clock in humans has an endogenous period of ~24.2 h (Burgess and Eastman, 2008; Czeisler et al., 1999) and therefore requires daily phase advances (shifts earlier in time) to remain synchronized to the external 24-h day. Light in the evening causes the clock to shift rhythms later (phase delay) and light in the morning causes the clock to shift rhythms earlier (phase advance) (Czeisler et al., 1989; Khalsa et al., 2003). Thus, morning light is essential for the daily corrective phase advances, while evening light can exacerbate the clock's endogenous tendency to drift later and promotes circadian misalignment. Many people chronically experience such circadian misalignment when their circadian clock promotes later sleep, but they are required to wake prematurely to an alarm clock to meet their social obligations, such as work (Roenneberg et al., 2012; Wittmann et al., 2006). This "social jetlag" is associated with reduced alertness and performance (Burgess et al., 2012; Taylor et al., 2008; Yang and Spielman, 2001; Yang et al., 2001), greater use of alcohol, nicotine and caffeine, and an increased risk for depression and obesity (Levandovski et al., 2011; Roenneberg et al., 2012; Wittmann et al., 2006).

Full-time office workers are at high risk for social jetlag given their need to get up early in the morning to get to work, and their reduced exposure to the external light–dark cycle while they work ~8 h indoors during the workday. Several previous studies have measured 24-hour light exposure in healthy adults but the samples were of mixed (e.g., students, unemployed, part-time workers, full-time workers, retired) or unreported employment status (Cole et al., 1995; Hebert et al., 1998; Jean-Louis et al., 2000; Kawinska et al., 2005; Thorne et al., 2009). Others measured 24-hour light exposure in participants who slept according to fixed sleep times (Emens et al., 2009; Goulet et al., 2007; Scheuermaier et al., 2010). One study measured light exposure during a work week in daytime hospital workers, and reported lower light exposure at work (<500 lux) (Heil and Mathis, 2002). Unfortunately, however, they did not examine light levels by time of day, and their photosensor saturated at a relatively low 2500 lux. Thus, little is known about the 24-hour light exposure patterns of full-time office workers during a typical week when they are free to sleep and wake as they choose. The only opportunities for being outside and exposed to sunlight may be the commute to and from work, and perhaps during a lunch break. Limited exposure to the external light–dark cycle may be further exacerbated in winter when day length is

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shorter (Cole et al., 1995; Hebert et al., 1998; Jean-Louis et al., 2000; Thorne et al., 2009), and colder temperatures lead people to spend more time inside (Cole et al., 1995).

Thus, the aim of the current study was to describe the 24-hour light exposure patterns of full-time office workers over the course of a typical week during the summer months, when outdoor light exposure is expected to be optimal due to a long day length and warm climate in Chicago IL. A second aim was to compare 24-hour light exposure patterns of a subset of these full-time office workers again in the winter. Sleep/wake behavior, morning commute time, and evening activities were also examined, as a means to determine potential causes of alterations in light exposure.

2. Material and methods

2.1. Participants

Fourteen full-time office workers (4 males) ages 20–39 years (mean ± SD = 28 ± 5 years) completed the study between August 1 and September 12, 2012 (summer) in Chicago, USA at 41° 88’ N latitude. Participants self-reported their race as White/Caucasian ($n = 10$), Black/African American ($n = 2$), or multiracial ($n = 1$), one was unknown, and most identified as non-Hispanic ($n = 13$). Six of the 14 workers (2 males, 4 females; 4 Caucasian, 2 African American; mean ± SD age = 30 ± 7 years) repeated the study between January 30 and March 13, 2013 (winter).

Participants were non-smokers, and consumed moderate caffeine (<300 mg/day) and alcohol (<2 standard drinks/day) doses. All participants passed urine drug screens, reported no medical, psychiatric, or sleep disorders, and were medication free except for 4 women who were taking oral contraceptives. Body mass indices ranged from 20.9 to 34.2 kg/m^2 (mean ± SD = 26.6 ± 4.4 kg/m^2). Participants did not use corrective lenses (glasses or contact lenses), were not color blind according to the Ishihara test for color blindness, and reported no corrective eye surgery (e.g., LASIK).

Participants were working full-time in the same office for at least one month before beginning the study. Participants worked on weekdays (Monday through Friday), and did not work on weekends. Reported work start times ranged from 7:30 to 9:30 (mean ± SD = 8:28 ± 00:34) and end times from 16:30 to 18:00 (mean ± SD = 17:06 ± 00:28). Participants reported no night shift work in the month before the study start and no travel across time zones in the month before the study start. The Rush University Medical Center Institutional Review Board approved the study protocol, and therefore, the study was performed in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki. Each participant provided written informed consent before study participation, and received monetary compensation for participation.

2.2. Protocol

Throughout a 10-day protocol, participants were instructed to keep their usual sleep schedule and daytime work schedule during the summer. On day 2 (Thursday) of the study, participants visited the laboratory so that we could review their data and provide any feedback or corrections. After this visit, participants did not come back to the laboratory for the next 7 days (5 workdays and 2 weekend days) so as not to disturb their normal weekly routine. On day 10 (Friday), participants completed a circadian phase assessment in the laboratory. Two to 3 participants completed the study at the same time. A subset of participants repeated the same 10-day protocol during the winter. One female participant changed jobs between summer and winter assessments; however, her typical work schedule was similar between seasons (summer: 8:30–17:00; winter: 8:45–17:00).

2.3. Behavioral sleep/wake and ambient light exposure

Participants wore two actigraphs throughout the study. One actigraph was worn on their non-dominant wrist (Actiwatch-L, Philips Respironics, Inc. Bend OR) to monitor sleep/wake behavior. Data were collected in 30-second epochs. Participants documented their bedtime and wake times, and their activities during the 4 h before bedtime each day, which guided actigraphic analysis of sleep and wake. Wrist activity data were analyzed using Actiware 5.7 (Philips Respironics, Bend OR) using the immobile minutes sleep interval detection algorithm (10 mins of immobile minutes defined sleep onset and sleep end) and a medium wake threshold. Each sleep episode (including any reported naps) was scored beginning at participant-reported bedtime until reported wake-up time. If discrepancies between reported sleep times and the actogram emerged, the authors inspected these data together to determine the scoring interval. The following variables were extracted: sleep onset time, sleep end time, and total sleep time. The wrist actigraph failed on a total of 17 nights (10.6% of total number of nights analyzed). Reported sleep onset and wake-up time from daily logs were used instead of actigraphic sleep estimates in these cases when it was not available.

A second actigraph with photosensor (Actiwatch Spectrum, Philips Respironics, Inc. Bend OR) was worn around the neck (closer to the eye than the wrist) like a medallion to measure 24-hour ambient light exposure (Burgess and Eastman, 2004, 2006). Data were collected in 30-second epochs. Participants were instructed to remove the photosensor around the neck for showers or baths and while sleeping, but to keep the photosensor facing outward in the same room. Times at which participants removed the photosensor were documented daily. Activity on the photosensor around the neck was inspected using Actiware 5.7 to ensure participants wore the photosensor, and that they accurately documented when the photosensor was not being worn. Ambient light measured during times when the photosensor was not being worn during waking hours was omitted from the dataset. The percent of epochs removed for each participant ranged from 1.9% to 11.7% (mean ± SD = 5.5% ± 3.2%) in the summer and 1.8%–11.7% (mean ± SD = 5.8% ± 3.6%) in the winter.

White (broad spectrum) light data collected after the laboratory visit on day 2 until the start of the circadian phase assessment on day 10 were included in the analysis. Illuminance was measured in lux (SI unit for illuminance). Ambient light from sleep onset to sleep end (measured from wrist actigraphy) was recoded as 0 lux. If participants wore sunglasses, they recorded sunglasses on and off times on a daily log, and pressed an event marker on the photosensor when the sunglasses were put on and taken off. The percent of light transmitted through each participant's personal sunglasses was measured in the laboratory, and then used to correct the light data. The light data were averaged into 30-minute bins according to 24-hour clock time separately for workdays and weekend days. Data were also averaged into 30-minute bins relative to actigraphically estimated sleep times. The minimum daily wake duration in the current sample was 11 h 29 minutes; therefore, we examined light in the 5.5 h after wake time and the 5.5 h before sleep start time separately for weekends and weekdays. Data were base 10 log-transformed (Log_{10} (white light lux +1)) (Burgess and Eastman, 2006; Burgess and Molina, in press; Emens et al., 2009).

Some context is necessary to interpret light level findings in this study. The light level at twilight is about 3 lux and at sunrise/sunset is about 400 lux under a clear sky. Outdoor light levels during the daytime are greater than 1000 lux, and can reach more than 100,000 lux on a bright sunny day. By contrast, indoor lighting is not as bright as the outdoors; light levels in the home are typically less than 50 lux (Burgess and Eastman, 2004) and light levels in