Calibrated Personal Light Exposures as They Might Affect Melatonin Suppression in Different Populations

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Background

In mammals, melatonin is synthesized by the pineal gland at night and in darkness. Studies with nocturnal rodents have shown that a reduction in melatonin can enhance tumor growth (Blask, Dauchy, & Sauer, 2005). Since light can suppress melatonin at night, concerns have been expressed in the literature about light at night (LAN) as a potential causative agent for breast cancer in humans (Stevens et al., 2007).

Optical radiation incident on the retina will suppress melatonin synthesis if the light levels are sufficiently high and the durations are sufficiently long (Figueiro, Lesniak, & Rea, 2011; Lewy, Wehr, Goodwin, Newsome, & Markey, 1980; Rea, Figueiro, Bierman, & Hamner, 2011; Rea, Figueiro, Bullough, & Bierman, 2005; Zeitzer, Dijk, Kronauer, Brown, & Czeisler, 2000). The amount and duration of light exposure necessary to suppress melatonin production is species specific. The circadian systems of nocturnal rodents are several orders of magnitude more sensitive to light than that of humans. The spectral sensitivities of species also differ. Rodents are, for example, highly sensitive to ultraviolet radiation while humans are not at all sensitive to radiation in this region of the electromagnetic spectrum (Amir & Robinson, 1995; Benshoff, Brainard, Rollag, & Lynch, 1987; Bullough, Rea, & Figueiro, 2006).

To properly consider LAN as a potential causative agent for breast cancer, it is necessary to, first, properly characterize light as a stimulus for the human circadian system and, second, to measure calibrated personal light exposures in populations that might be at risk for breast cancer (Figueiro, Rea, & Bullough, 2006; Rea, Brons, & Figueiro, 2011). The goal of the present study was to examine personal calibrated light exposures in different groups of participants and relate them to predictions of how they might impact melatonin production. All participants had worn the Daysimeter, a personal circadian light meter, for a period of five to seven days, depending on the experimental protocol (Bierman, Klein, & Rea, 2005).

Methods

Instrumentation

The Daysimeter measures and records a person's light exposures and activity levels during their normal daily routine (Bierman et al., 2005). Since light must reach the eye to be effective for the circadian system, the Daysimeter is designed to measure light in the plane of one cornea. The Daysimeter is calibrated in terms of photopic illuminance (lux), circadian illuminance (CL_A), and the absolute sensitivity of the human circadian system (CS). CL_A is a measure of circadian effective light, and it is based on the model of phototransduction by Rea et al. (2011, 2005). The values of CL_A are scaled so that 1000 lux of CIE Illuminant A (incandescent source at 2856 K) is equivalent to 1000 units of CL_A. CS values are transformed CL_A values, and correspond to relative melatonin suppression after one hour of light exposure for a 2.3 mm diameter pupil during the midpoint of melatonin production (Rea, Figueiro, Bierman, & Bullough, 2010). Since CS is defined in terms of the circadian system's input-output relationship, including threshold and saturation, it is considered a better measure of the circadian effectiveness of light than either lux or CL_A.

Participants

We reanalyzed data from four different studies in which participants wore the Daysimeter for at least five consecutive days: 24 young adults age 18-30 years (Sharkey, Carskadon, Figueiro, Zhu, & Rea, 2011), 22

school teachers (Rea, Brons, & Figueiro, 2011), 22 8th graders (Figueiro, Brons, Plitnick, Donlan, & Leslie, 2010), and 77 rotating- and day-shift nurses (Miller, Figueiro, Bierman, Schernhammer, & Rea, 2010). Participants had been instructed to keep their normal schedules while participating in the study.

Procedures

Participants in every study were instructed to wear the Daysimeter at all times except when sleeping or bathing, and to place it next to them when it was not being worn. All subjects were trained to use the device by a member of the research team, and written instructions were left with each subject. Subjects were also instructed to keep a sleep log and report when they wore the device as well as their wakeup and bedtimes.

Results

Table 1 shows the mean evening (four hours before bed) and the mean morning (four hours after rising) light exposures for the different groups. It should be emphasized that the evening and morning values can occur both early and late in the day for rotating nurses. From the Daysimeter data, we calculated mean lux, CL_A, and CS exposure levels. Log_{10} transforms of the photopic and CL_A values are included because of the highly skewed distributions of recorded light exposures; brief exposures to extremely bright light (e.g., sunlight) dominate the arithmetic mean values. The log_{10} transform of the values is probably more representative of the central tendency in light exposures than the arithmetic mean.

Discussion

Several studies have postulated that exposure to electric LAN poses health risks because it is sufficiently bright to suppress melatonin or to disrupt our circadian rhythms (Stevens, 2005; Stevens & Rea, 2001; Stevens et al., 2007). However, very few data have been reported concerning actual light exposures in living and working environments during night and day. Gooley et al. (2011) showed that an 8-hr exposure to < 200 lux at the cornea of a 4100 K light source resulted in significant suppression of evening melatonin in the laboratory. Although no real-life light measurements were presented by the authors and they did not utilize a photometric instrument calibrated in terms of the spectral sensitivity of the human circadian system, they postulated that 60 to 180 lux at the cornea (which was referred to as < 200 lux condition) is representative of room lighting that individuals are typically exposed to in their homes in the evening. Depending upon the spectral power distribution of the source, 200 lux at the cornea from a 4100 K source is associated with a CS value of between 0.15 and 0.19. The present data suggest, however, that average evening light exposures by various populations do not reach this level in any population, including rotating-shift nurses who, among the groups examined

Table 1: Mean and standard errors of the mean (±) morning and evening light exposures for different populations

	Lux morning	Lux evening	Loglux morning	Loglux evening	CL_A morning	CL_A evening	$LogCL_A$ morning	$LogCL_A$ evening	CS morning	CS evening
Young adults (24)	772 ±188	38.2 ±4.3	2.00 ±0.06	1.22 ±0.06	1650 ±438	34.3 ±3.6	2.02 ±0.06	1.17 ±0.05	0.193 ±0.015	0.046 ±0.005
Teachers (22)	373 ±80	40.4 ±9.9	1.94 ±0.05	1.07 ±0.06	478 ±105	44.1 ±14.5	1.88 ±0.06	0.97 ±0.07	0.172 ±0.013	0.036 ±0.006
8^{th} Graders (22)	268 ±25	63.0 ±19.6	2.04 ±0.04	1.19 ±0.08	305 ±54	78.4 ±30.7	1.96 ±0.03	1.13 ±0.08	0.184 ±0.006	0.046 ±0.008
Day-shift nurses (33)	296 ±50	73.9 ±16.9	1.49 ±0.04	0.94 ±0.05	408 ±173	35.8 ±11.1	1.30 ±0.06	0.79 ±0.04	0.109 ±0.011	0.029 ±0.004
Rotating-shift nurses (44)	277 ±56	104 .0 ±13.7	1.37 ±0.04	1.09 ±0.06	414 ±103	135 ±22.4	1.35 ±0.04	1.06 ±0.05	0.114 ±0.009	0.066 ±0.006

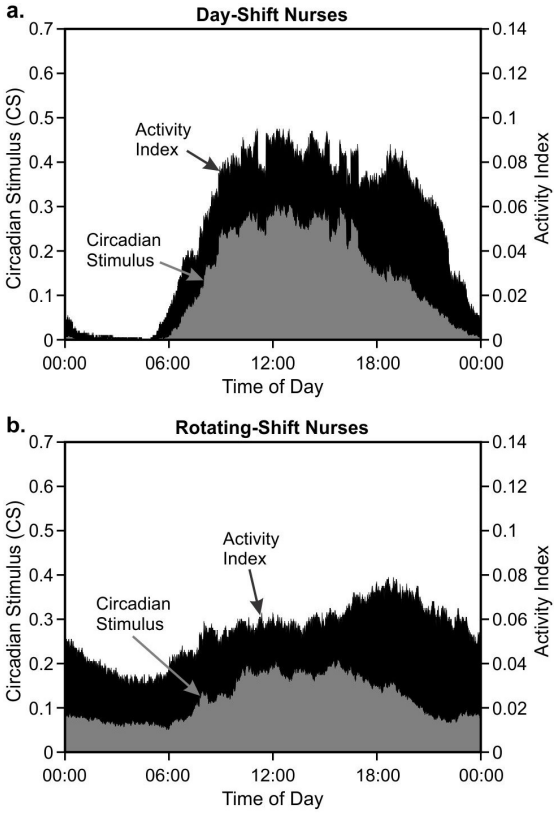

Fig. 1: Day-shift and Rotating-shift 24-hr CS and activity profiles. The data for every rotating-shift and every day-shift subject were averaged in one hour periods to create a 24-hr profile representing the average 24-hr light/dark and rest/activity patterns for each of the groups. CS levels were set to zero and activity levels were set to the minimum activity level recorded by the device during sleep periods. Any periods of inactivity exceeding 30 minutes that occurred outside of sleep periods were removed since those represent probable non-compliance.

here, are known to be at higher risk for breast cancer. The mean CS values ranged from 0.03 to 0.07, suggesting that their evening light exposures would result in suppression values that were below 7%. Figure 1 shows the average light and activity profiles of day-shift and rotating-shift nurses from Table 1. What is most apparent in this pair of plots is the lack of consistency in the light/dark and activity/rest patterns for rotating-shift nurses as compared to the day-shift nurses. Clearly too, Figure 1 shows that rotating-shift nurses, unlike day-shift nurses, are exposed to circadian-effective light throughout their biological night that could potentially suppress nocturnal melatonin.

The significance of these light exposures for health outcomes is not known, but recent studies suggest that LAN *as actually experienced at night on rotating-shift workers* may not be the root (or the only) cause of low melatonin levels and, by extension, poor health outcomes in this population. Dumont, Lanctôt, Cadieux-Viau, and Paquet (2012) measured ambulatory light exposure and 24-hr melatonin excretion [6-sulfatoxymelatonin (aMT6s)] in 13 full time rotating-shift workers working both night- and day/evening-shift periods. The authors found no difference in total 24-hr aMT6s excretion between the two working periods. Moreover, light exposures were not correlated with aMT6s levels excreted during the night of work. The authors did find, however, that the measured light exposures were negatively correlated with total 24-hr aMT6s excretion when they were working the night-time period. As the authors suggest, circadian desynchrony may have attenuated melatonin production and thereby induced the overall lower levels of melatonin excretion. In another study, Peplonska et al. (2012) examined aMT6s in 354 nurses and midwives and found no significant differences in aMT6s concentrations between women working rotating shifts and those working day-shifts. However, women who reported working, on average, eight or more rotating night-shifts per month did have significantly lower aMT6s concentrations than those who worked fewer nights per month.

The measured light exposures (CS) presented in Table 1 and Figure 1 appear to be consistent with the results of Dumont et al. and Peplonska et al. Namely, the circadian-effective light exposure levels are relatively low during the working nights for rotating-shift nurses, but because rotating-shifts create an inconsistency in the light/dark exposure (and activity/rest) pattern over many days and weeks, circadian dysynchrony can occur, resulting in lower total melatonin concentration levels.

The data presented here further help our understanding of light exposures in different populations. These data are very rich and offer many opportunities for further analyses that are just beginning to be pursued,

including an investigation of the level of circadian disruption experienced by these various populations. In general, tools like the Daysimeter now make it possible to measure real-world circadian light exposures and to determine levels of circadian entrainment in the field. These measurements can also help provide insights into possible improvements in the environmental lighting conditions that could minimize maladies associated with disruption of the circadian system.

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