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Original Article

Timing of light exposure and activity in adults with delayed sleep-wake phase disorder

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ABSTRACT

Objective: To characterize the patterns of light exposure and physical activity level and assess their relationship with sleep quality and depressive symptoms in adults with delayed sleep-wake phase disorder (DSWPD).

Methods: 42 DSWPD (22 female, mean age 34.5 y) and 26 (±4 years) age-and-sex-matched controls (12 female, mean age 33.4 y) underwent seven days of light and activity monitoring.

Results: Individuals with DSWPD had significantly delayed bed times and wake times, but similar sleep duration compared to controls. Subjective sleep quality (Pittsburgh Sleep Quality Index (PSQI)) was poorer in DSWPDs compared to controls. Those with DSWPD had significantly more activity and light exposure late at night (2:00–4:00) and significantly less activity and light exposure in the morning (8:00–11:00). Total 24 h levels of light and activity were not significantly different between DSWPD and controls. However, the DSWPD group had significantly more light exposure than controls 22 h after waking, during their sleep period. Later light exposure correlated with higher depression scores [Beck Depression Index (BDI)] and poorer sleep quality (PSQI).

Conclusions: The light exposure patterns observed in DSWPD likely contribute to and perpetuate the chronically delayed sleep and wake phase in these patients. In addition, increased light exposure during the sleep period may also contribute to the poor sleep quality and mood disorders that are common in these individuals.

1. Introduction

Sleep timing and duration are determined by a combination of homeostatic and circadian factors. The homeostatic drive for sleep builds up the longer one when awake, while the circadian system is thought to provide an alerting signal that serves to appropriately align periods of wakefulness and rest with the environment [1]. One of the key environmental signals that the circadian system relies on to maintain this alignment is the light-dark cycle. In humans, light exposure at night, (before the core body temperature minimum phase delays the clock or moves the clock later), early morning light exposure, after the core body temperature minimum phase, advances the clock (moves the clock earlier) [2,3]. In most individuals, this daily exposure to light helps to maintain appropriate alignment of behaviors (including the sleep-wake cycle) with the environment.

Delayed sleep-wake phase disorder (DSWPD) is a circadian rhythm sleep-wake disorder characterized by a delay in the habitual sleep period relative to the environment, resulting in insomnia and impaired daily functioning [4]. Misalignment between the endogenous sleep-wake cycle and the daily light – dark cycle or required social/professional activities can lead to sleep complaints of insomnia and/or excessive sleepiness. In addition to sleep complaints, there are higher levels of depression, anxiety and substance abuse disorders among individuals with DSWPD [5,6].

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The pathophysiology of DSWPD is poorly understood, but there are several proposed mechanisms that relate to the timing of and response to light.

One potential mechanism is that individuals with DSWPD are more sensitive to light exposure in the evening, during a period when light would be more likely to cause phase delays [3]. Melatonin secretion is suppressed by light, and individuals with DSWPD have been shown to have a greater degree of melatonin suppression at night when compared to controls [7], suggesting that individuals with DSWPD may also be more sensitive to the phase-delaying effects of light in the evening. It has also been hypothesized that those with DSWPD may have a reduced circadian sensitivity to photic entrainment during the phase advance window of the phase response curve [8,9]. Alternatively, it is possible that the duration and timing of environmental light and dark exposure may play a role in developing DSWPD [10,11]. Behavioral factors may contribute to this, with individuals with DSWPD staying up later and sleeping later, resulting in greater light exposure during the phase delay portion of the night and less light exposure during the phase advance portion of the morning, leading to an overall delay.

Although light is the most powerful synchronizing agent for the circadian clock, prior/past studies quantifying the timing and amount of light exposure in DSWPD or evening-types are limited [12–14]. A small study looking at light exposure in 10 evening-types and nine morning-types reported that morning-types (ages 19 to 34 y) were exposed to more light in the morning while evening-types were exposed to more light in the evening [12]. A subsequent study conducted in an older group (11 evening-types and 12 morning-types, ages 62 to 77 y) also found similar results [13]. However in both studies after analyzing light exposure with respect to circadian time (CT) rather than clock time, either using the time of dim light melatonin onset [12] or time since wake [13], there were no significant differences in the pattern of light exposure between morning types and evening types [12,13]. A case-controlled study looking at adolescents with DSWPD and controls (ages 10 to 18 y) showed that individuals with DSWPD were exposed to more evening and less morning light based on clock time; however when normalized for wake time there were no significant differences [14]. Adolescents often have increased social pressures to stay up later, regardless of chronotype [15], which may influence these results, making it important to evaluate light and activity in adults allowed to follow their habitual sleep schedule. Also, previous studies generally excluded light exposure during the sleep period, but it is possible that increased light during the rest period may also adversely affect sleep quality and timing [16].

The aim of this study was to investigate the timing of light exposure and activity in adults with DSWPD compared to intermediate chronotype controls. We hypothesize that the timing of light exposure in relation to sleep-wake timing will differ between adults with DSWPD and controls, and that these differences may contribute to the delay in behavior, reduction in sleep quality and increase in depressive symptoms observed in individuals with DSWPD.

2. Methods

2.1. Participants

Forty-two DSWPD (34.5 ± 10.8 y, 27 females) and 26 age-and-sex-matched controls (33.4 ± 13.1 y, 12 females) participated in this study. Participants were considered to have DSWPD if they met the International Classification of Sleep Disorders criteria for DSWPD [4], determined by a board-certified sleep physician during a clinical interview. The control group was defined as individuals having an intermediate-type diurnal preference on the Horne–Ostberg questionnaire [17] and no dissatisfaction with their sleep/wake times. Controls were matched by age (±four years) and sex.

2.2. Procedures

Participants were recruited between January 2004 and November 2007 using printed and online advertisements. Advertisements solicited participants who had normal sleep times and those that had an ‘extreme evening preference’ or who considered themselves a ‘night owl.’ There were no exclusion criteria for this study. All participants gave written informed consent and were compensated for their participation. All procedures were approved by the Institutional Review Board at Northwestern University. After written consent was obtained, each subject completed the Horne-Ostberg Self-Assessment Questionnaire, the Pittsburgh Sleep Quality Index, the Epworth Sleepiness Scale and the Functional Outcomes of Sleep Questionnaire. After completing the questionnaires, each subject wore an activity monitoring device and kept a sleep log for four weeks. The participants then underwent a clinical interview with a board-certified sleep medicine physician to determine DSWPD status. From the individuals recruited, only those with an intermediate preference (controls) or evening-type preference on the Horne–Ostberg Self- Assessment Questionnaire and a clinical diagnosis of DSWPD were included in this analysis.

2.3. Measures

2.3.1. Horne-Ostberg questionnaire

The Horne-Ostberg Self-Assessment Questionnaire is an assessment of ‘morningness– eveningness,’ consisting of 19 items that measure a subject's preference for the timing of daily activities [17]. Each question has four answer choices that indicate a scale of ‘morningness’ to ‘eveningness.’ The lower scores indicate ‘eveningness’(16–30 Definitely Evening-Type, 31–41 Moderate Evening-Type), the higher scores indicate ‘morningness’ (59–69 Moderately Morning-Type, 70–86 Definitely Morning-Type) and a score of 42–58 indicates an intermediate-Type.

2.3.2. Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) is a self-rated 21-item questionnaire to assess individual sleep habits (bedtime, morning rising time, sleep-onset latency and night sleep duration), insomnia and hypnotic use over a one-month time interval [18].

2.3.3. Beck Depression Index

The Beck Depression Index (BDI) consists of twenty-one questions about the subject's mood during the past week. Each question has a set of at least four possible answer choices, ranging in intensity from zero to three [19]. Higher total scores indicate more severe depressive symptoms [20].

2.3.4. Epworth Sleepiness Scale

The Epworth Sleepiness Scale (ESS) asks subjects to estimate the likelihood of dozing off or falling asleep in eight different sedentary situations, estimating the subject's general level of daytime sleep propensity [21].

2.3.5. Functional Outcomes of Sleep Questionnaire

The Functional Outcomes of Sleep Questionnaire (FOSQ) assesses how sleepiness impacts activities of daily living [22]. Participant rate the 30 items from ‘no difficulty’ to ‘extreme difficulty’. The questions are grouped into five factors: activity level, vigilance, intimacy, sexual relationships, general productivity and social outcomes. In addition to the total score obtained