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Original Article

Altered sleep–wake patterns in blindness: a combined actigraphy and psychometric study

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ABSTRACT

Objective: Light plays an important role in the synchronization of the internal biological clock and the environmental day/night pattern. Thus, absence of vision is often associated with both increases in reported sleep disturbances and incidence of free-running circadian rhythms. In this study we discuss variability in the sleep–wake pattern between blind and normal-sighted individuals.
Methods: Thirty-day actigraphy recordings were collected from 11 blind individuals without residual light perception and 11 age- and sex-matched normal-sighted controls. From these recordings, we extracted parameters of sleep and wake, including episodes of rest, day-time and night-time sleep periods, and the number of awakenings throughout sleep. A measure of sleep efficiency was derived from these measures for each night-time sleep episode. We also examined complementary measures of sleep quality, using the Pittsburgh Sleep Quality Index, and chronotype, using the Morningness-Eveningness Questionnaire.
Results: Although no group differences were found when averaging over the entire recording period, we found a greater variability throughout the 30-days in both sleep efficiency and timing of the night-time sleep episode in blind participants as compared to sighted control participants. We also confirm previous reports of reduced sleep quality in blind individuals. Notably, the variability in sleep efficiency and in the timing of sleep correlated with the severity of sleep disturbances.
Conclusion: The timing and physiology of sleep are strongly dependent on the endogenous circadian phase; therefore, observed findings support the hypothesis of free-running circadian rhythms as a dominant factor for the sleep disturbances experienced in blindness.

1. Introduction

Circadian control over sleep–wake patterns is a frequently studied phenomenon. Particularly, the use of a forced desynchrony protocol (originally defined by Kleitman [1]) has shown that, when sleep is attempted at an irregular phase of the circadian rhythm, sleep latency and awakenings are increased, and overall sleep time is decreased [2–4]. Additionally, the underlying sleep structure, such as rapid-eye movement (REM) sleep, and its microstructure, eg, sleep spindles, are also dependent on the circadian phase [5–7].

The master biological clock, located in the suprachiasmatic nucleus (SCN) [8], and associated circadian rhythms are kept synchronized to the environmental 24-hour day/night cycle through various zeitgebers, or time cues. In humans, as with most mammalian species, light is the primary zeitgeber for circadian entrainment through the direct projections of the melanopsin-containing retinal ganglion cells to the SCN via the retinohypothalamic tract [9,10]. In the absence of light, endogenous circadian rhythms become free-running, resulting in a temporal deregulation of the biological clock from the 24-hour environmental and social day-night schedule.

Therefore, it comes with no surprise that blind individuals report more sleep disturbances than their normal-sighted counterparts, particularly regarding symptoms of insomnia [11,12]. Moreover, the presence and intensity of sleep disturbances are dependent on the presence of residual vision; totally blind individuals, without residual light perception, report greater sleep disturbances than those with residual vision [13]. In addition, blind individuals also show

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a higher proportion of free-running circadian rhythms [14], as measured by changes in melatonin concentration and core body temperature. It is estimated that approximately half of the totally blind population has free-running circadian rhythms, while the remaining displays either normally or abnormally (advanced or delayed) entrained rhythms [15]. Similar to overall sleep disturbances, free-running circadian rhythms are more prevalent in blind individuals with no light perception [2,16,17]. Blind individuals in whom the non-photic retinohypothalamic tract is absent – as is the case of enucleated people – have a higher prevalence of free-running rhythms compared to non-enucleated blind individuals [18]. As most peripheral retinal diseases cause a degeneration of the optic nerve, including the optic chiasm (ie, [19,20]), these may also be associated with an atrophy of the retinohypothalamic tract, with the exception of a few rare cases where this 'non-visual' tract is fully preserved [21]. Consequently, blindness from central origin, or lesions occurring posterior to the lateral geniculate nucleus, should have only limited influences on circadian rhythms.

These studies, both in blind and normal-sighted individuals, highlight the intrinsic relation between light input, sleep quality, and sleep–wake patterns. However, it is important to underscore some discrepancies between free-running circadian rhythms and reported sleep disturbances. Although persons with free-running circadian rhythms also tend to report more sleep disturbances, some do not express any complaints regarding their sleep quality [18,22]. On the other hand, the presence of sleep complaints in the blind population does not necessarily imply that they have free-running circadian rhythms [12].

The aim of the present study was to further examine how the sleep–wake pattern is altered in a well-characterized group of blind individuals without residual light perception. We focused on the variability in the sleep–wake pattern over an extended sampling period. Actigraphy and sleep diaries have been suggested as complementary measures to medical interviews; polysomnographic recordings are also suggested as complementary measures for the assessment of sleep disorders, particularly for the diagnosis of sleep–wake circadian rhythm disorders. Yet, this method has seldom been utilized in sleep studies of blind individuals. In our study we used continuous actigraphy (30 days) to isolate particularities of the sleep–wake pattern in blind individuals. More specifically, we examined both the average and the variability across the recording period. Actigraphy was complemented by measures of general sleep quality and chronotype to better understand and explain the sleep–wake patterns in blindness. To the best of our knowledge, this is the first study using actigraphy data collected over an extended period of time to investigate variability in sleep–wake patterns of blind individuals.

2. Methods

2.1. Participants

Data were collected from 11 blind individuals with no self-reported conscious light perception (M_{age}: 44.5 ± 14.9; three males; all right-handed). In all cases, blindness was of peripheral origin (retina or optic tract). Approximately half of the group was born blind (5/11) while the remaining (6/11) became blind throughout life. Eleven age- and sex-matched individuals (normally sighted; M_{age}: 43.4 ± 14.2; four males; two left-handed) with normal or corrected to normal vision were also recruited. Table S1 (Supplementary file) reports the demographic information of the participants. Each participant provided written informed consent for participation. The Regional Capital Research Ethics Committee of Denmark (De Videnskabsetiske Komiteer, Region Hovedstaden, Denmark) approved the study (H-2-2014-081). None of the participants reported having neurological or psychiatric disorders. Purported presence of depression and anxiety was tested using the Beck Depression Index and the Hospital Anxiety and Depression Scale. Participant screening also included a structured medical interview and one night of cardiac, respiratory, and movement monitoring (CRM; similar to Level III sleep studies) in order to rule out severe sleep apnea (apnea–hypopnea index, AHI > 15) or excessive limb movements that may interfere with sleep–wake patterns. Additionally, we screened for the presence of REM-Sleep Behavior Disorder (RBD) and excessive daytime sleepiness using the RBD screening questionnaire (RBD-SQ) and the Epworth Sleepiness Scale, respectively. Participants also reported having regular sleep–wake schedules (ie, no shift work), and had not been traveling across time zones in the month prior to the experimental trial. The participants taking sleep medication ($n = 4$) were asked to refrain from doing so, starting one week prior to the start of the trial until the end of the study period. This was done to ensure that the natural endogenous rhythm would be expressed throughout the trial. All participants were compliant with this constraint, except for one who resumed taking sleep medication during the last week of the trial. These days were excluded from the analysis for this participant. In addition to age and sex, additional factors of interest included work status and child care, because they contribute to the regularity and stability of sleep–wake patterns.

2.2. Actigraphy

In order to measure shifts in the sleep–wake cycle over time, participants wore an actigraph (Actiwatch Spectrum, Philips Respironics, Murrysville, PA, USA) for a period of 30 days. Watches were worn continuously throughout this period but were removed if there was a risk of getting the watch wet (eg, taking a shower) or if it caused interference with daily activities (eg, playing a sport). Actigraphy recordings were complemented by daily sleep and activity logs in which participants reported pertinent information about their sleep (such as the time they went to bed, the number and duration of night-time awakenings, etc.) and daily activities (eg, napping and irregular activities, such as parties).

Activity and photic light recordings were sampled in one-minute epochs, for a total of 1440 samples per day. From these recordings, activity states (active, rest, and sleep) were automatically detected using the validated default settings of Respironics Actiware (version 5.70.1, Actiwatch Communication and Sleep Analysis Software, Philips Respironics). Default settings included an activity threshold-crossing zone method (40 activity counts) which was used to determine active epochs (for definition and comparison of activity count measures, we refer to Reference [23]). Sleep onset was marked following ten minutes of inactivity and sleep offset was marked when at least ten minutes of activity was detected within the non-active, rest period. Two investigators (SA and CG) crosschecked recordings for artifacts and correspondence with the daily sleep logs. Manual adjustments of the sleep–wake activity were based on event markers, activity patterns, photopic measures, and sleep diaries. Nights with missing data, or that were marked as irregular by the participant (travel, festivities, etc.) were excluded from analysis. The two nights spent at the sleep center during the experimental period were also excluded from the analysis. Recording malfunction occurred for one of the blind participants, resulting in only 12 days of recordings for this participant. In total, an average of 25.2 days was kept for blind participants and 26.3 days for sighted controls.

The various parameters that were extracted from the actigraphy data to assess sleep efficiency and sleep–wake patterns are listed in Table 1. We limited the parameters of interest to the timing of sleep (onset and offset), the occurrence of day-time naps, and the measure of night-time sleep efficiency, as well as its associated sub-measures: time in bed (TIB), total sleep time (TST), and awakenings throughout the sleep period (wake after sleep onset; WASO). Sleep