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Effects of seasonal illumination and thermal environments on sleep in elderly men

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ABSTRACT

The purpose of this study was to investigate the effect of changes in the seasonal thermal environment and illuminance on sleep in older men by using actigraphy. Eight healthy male volunteers with a mean age of 64 ± 1 years served as subjects. The measurements were obtained in 4 consecutive seasons: spring, summer, autumn, and winter. The activity level and illuminance were monitored using a wrist actigraph system with illuminance meter for 5 consecutive days. Sleep parameters were determined using an actigraph-based, sleep-wake identification algorithm. The temperature and humidity in the bedroom of the subjects' homes were measured continuously for 5 days. During the actigraphic measurement, skin temperature and the temperature and humidity of the microclimate were measured continuously for 2 nights. Bedroom nocturnal Ta and humidity was significantly higher in the summer than in the other seasons. Sleep efficiency was worst in the summer due to the increased number and duration of nocturnal awakenings. However, a significant difference was not found in the subjective evaluation of sleep among the 4 seasons. The correlations between the sleep parameters and environmental factors such as temperature, humidity, and illuminance levels measured at the same time showed that increased lighting level before the sleep prolongs the bedtime and wake time after sleep onset, and became wake-up time earlier. Increased ta, humidity, and lighting level during the sleep period mount up the wake time after sleep onset and impaired the sleep efficiency index.

1. Introduction

Lighting plays an important role in the daily and seasonal rhythms of human life. Sleep is regulated by two systems: sleep/wake homeostasis and the circadian biological clock. Both circadian rhythm and sleep quality are influenced by light (the photoperiod) via neuroendocrine hormones. Sleep is also strongly linked to human thermoregulation, with the thermal environment being a key determinant of sleep.

Seasonal variations affect sleep quality, with decreased sleep stage 4 and increased rapid eye movement sleep (REM) occurring under the thermoneutral conditions present in winter compared to summer in Hokkaido (43° 39′N) [1]. Stage 4 sleep is the second stage of deep sleep, in which the brain is making the slow delta waves almost exclusively and REM sleep in which dreams generally occur. In subtropical climates, REM sleep lasts longer and REM latency is reduced in winter and spring, than in summer and fall [2]. The seasonality of REM sleep patterns was replicated, but not confirmed, in the same geographical area [3]. These direct effects on sleep quality are difficult to explain based on photoperiod time cues [1], and suggest that the effects of air temperature (Ta) cause seasonal variation [2].

Complaints about difficult initiation and maintenance of sleep increase with age due to increased numbers of brief awakenings and decreased slow wave sleep (SWS) [4–6]. Age-related decreases in melatonin secretion among healthy, elderly people are often associated with various types of sleep problems. Elderly nursing home residents who suffer from insufficient environmental illumination show diminished melatonin secretion [7]. Increased light exposure during the daytime improves nocturnal melatonin secretion in these elderly insomniacs; however, sleep duration and quality has not been confirmed to improve with increased light exposure in elderly nursing home residents (average age, >70 years). Many older persons live independently, for years, before entering nursing homes. However, few studies have examined the effect of illumination on the sleep patterns of these older adults,

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living independently in their homes. When light exposure data were recorded for a week in older and young subjects living at home on self-selected sleep-wake schedules, and matched for the time of year, the older subjects show higher levels of light exposure than young subjects throughout their waking day [8]. In a cross-sectional study, daylight exposure was reported to be positively associated with urinary melatonin excretion among the elderly [9]. In Japan, the duration of the photoperiod, levels of illumination, and the thermal environment change because of changing seasons. The effects of the seasonal lighting environment on the sleep of healthy, elderly individuals are unclear. When the effects of season on sleep and skin temperature (Tsk) in healthy, elderly people were compared over 3 seasons, sleep was found to be more often disturbed, due to heat in summer than in autumn or winter [10]. However, the influence of lighting was not investigated in that study.

The present study aimed to investigate the ambient illuminance level for healthy elderly adults. This was measured by a wrist actigraph which was equipped with an on-board miniature photodiode, during the 4 seasons. The effects of illumination and thermal conditions on sleep among elderly persons during the 4 seasons were determined using the actigraphic measurements.

2. Methods

2.1. Subjects

The study participants were recruited from a pool of volunteers in the local human resource center, aged over 60 years, in the Tsukuba area of Japan (36°, 1′N). Based on their responses to a questionnaire, volunteers were excluded if they had chronic disease or insomnia, snored, took regular naps, required regular medication(s), had recently been hospitalized, or slept for extremely long or short times. Eight volunteers were selected for this study. They engaged in some simple work, i.e., gardening, cleaning, or office work, for 2 or 3 days a week. The subjects worked on a regular schedule in all seasons. The following physical characteristics (mean ± standard deviation) of the volunteers were measured: age (64 ± 1 years), height (162 ± 6 cm), weight (67 ± 8 kg), and body surface area (1.7 ± 0.1 m^2). The subjects were requested to lead their lives as normally as possible and to maintain a sleep log.

The volunteers were informed about the study protocol and each provided a written consent to participate. This study was approved by the ethics committee of Institute of Advanced Industrial Science and Technology (AIST). The subjects' physical and mental health was confirmed by their answers to a questionnaire regarding their physical and mental condition and sleep patterns, and whether each was a “morning (M) person” or an “evening (E) person” [11], prior to the start of the study. Seven of eight subjects were M type, and one was neither M type nor E type.

2.2. Procedure

The study was performed in the subjects' homes during four consecutive seasons: spring (from late April to early May), summer (from late July to early August), autumn (from late October to early November) and winter (from late January to early February); each subject participated in each seasonal measurement period.

The subjects were requested to wear two wrist actigraphy (Micro-mini motionlogger actigraph; Ambulatory Monitoring Inc., NY, USA and Actiwatch-L; Mini Mitter) on the nondominant hand for 5 consecutive days from Monday to Friday, except while bathing. Moreover, they kept a written sleep diary, to track bedtime, waking time, meal times, bathing time, and times when the actigraph was temporarily removed. Actigraphy is a physical activity monitor, typically worn on the wrist, to record activity movement level and intensity over time. An accelerometer generates a variable voltage that is digitally processed and sampled and a value expressed as activity counts is recorded in its board memory. The activity counts correlate with sleep/wake patterns. Actigraphic recordings were analyzed with commercial software (Action-W, 2.4.20, Ambulatory Monitoring Inc.) using the Cole-Kripke algorithm for scoring sleeping and waking [12]. Over the time course of the recordings, time in bed (TIB; defined as the primary sleep period during which subjects were trying to sleep in bed) was determined nightly according to the participants' sleep diary. Sleep latency (SL: time from bedtime to sleep onset), sleep period time (SPT: time from sleep onset to the end of last sleep episode in the morning), wake after sleep onset (WASO: total waking time scored in SPT), and sleep efficiency index (SEI: percentage of sleeping time in SPT) were calculated by the software. Another actiwatch-L was equipped with an on-board miniature photodiode for measurement of the amount and duration of illuminance. We used the actiwatch-L as a photometer, to measure the light intensity from 1 to 150,000 lux in an interval of 1 min. The subjects were asked to expose the actiwatch-L to the ambient environment, without covering it with their clothing.

During the activity-monitoring period, the outside temperature and the temperature and relative humidity (RH) of the bedroom in their own houses were measured continuously at 1-min intervals. During the nocturnal activity-monitoring period on Monday and Thursday, the Tsk of the forehead, chest, upper-arm, thigh, calf, and foot were continuously measured, also at 1-min intervals, using a thermistor and data logger (LT8A, Gram Corporation). The mean weighted Tsk was calculated according to the method of Ramanathan [13]. The microclimate temperature and humidity between the chest skin and pajamas were continuously measured, also at 1-min intervals, using a thermistor, hygrometer, and data logger (LA8B, Gram Corporation). A thermistor and a hygrometer probe were attached to a 5-mm-thick, 10 mm × 10 mm heatproof board, which was directly placed on the skin at the flat part of the upper chest area, under the pajama.

The bedding insulation was estimated by the investigators using the insulation values from a checklist, where the subjects answered about the number or kind of their bedding or covering used in the present study, because each insulation used by the subjects was hard to directly measure by a thermal manikin. The checklist included the insulation of many typical beddings or coverings that had been measured by a thermal manikin.

Thermal comfort questionnaire had to be filled out before and after sleep. Subjective evaluations for sleep were done using a questionnaire after sleep and responses to the questionnaire were obtained from each subject as follows: do you fall asleep easily? (1. well, 2. rather well, 3. neutral, 4. rather difficultly, 5. difficultly); How do you feel when you wake up in the morning? (1. refreshed, 2. rather refreshed, 3. neutral, 4. rather sleepy, 5. sleepy); Do you have enough time to sleep? (1. enough, 2. rather enough, 3. neutral, 4. rather deficient, 5. deficient); Do you sleep deeply? (1. deeply, 2. rather deeply, 3. neutral, 4. rather lightly, 5. lightly); Did you sleep well compared to the last week? (1. well, 2. rather well, 3. neutral, 4. rather badly, 5. badly).

Similarly, responses to a questionnaire regarding their bedding, clothing, and air conditioning were also recorded. A whole-body thermal sensation scale and the evaluation of thermal environment, a 9-point scale similar to that used by the Society of Heating, Air-conditioning, and Sanitary Engineers of Japan, was used − 9, very hot; 8, hot; 7, warm; 6, slightly warm; 5, neutral; 4, slightly cool; 3, cool; 2, cold; 1, very cold. A 7-point comfort sensation scale, similar to that used by the Japan Society of Refrigeration and Air-