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Effects of natural light on the sleep- wake rhythm of healthy elderly people: a field study

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Abstract

Objective: A common problem among elderly people is sleep disturbance. Frequently nocturnal awaking is hereby the most common complain, other difficulties are falling asleep and early awakening. Daylight can activate the photoreceptors in the retina and have an impact on the human circadian rhythm by controlling the diurnal melatonin suppression. Since daylight is our natural source, it is expected that daily exposure to daylight has an influence on the circadian rhythm. The aim of this study is to determine whether there is a correlation between the exposure to natural light and the sleep-wake quality of healthy elderly people based on field measurements. *Methods:* 18 subjects participated in this field study. The subjects were asked to wear a light sensitive cell to collect their (day)light exposure as well as an actigraph on their non- dominant wrist to assess their sleep- wake rhythm and sleep quality. Additionally a sleep and activity logbook was kept which also incorporated relevant questions regarding subjective sleep parameters. The measurement period lasted for five consecutive days. *Results:* The Pittsburgh Sleep Quality Index (subjective sleep quality) and the sleep efficiency showed no significant correlations with exposure to natural light. High intensity light exposure was poorly correlated with sleep quality, but was significantly negatively correlated with daytime naps. In addition, a negative significant correlation was found between light exposure directly before sleeping and activity level the day after. However, subjects who reported watching TV before sleep had an increased activity level the following day. *Discussion:* The results did not meet the hypothesis that people who have a high natural light exposure are good sleepers and that the average nocturnal light exposure during sleep affects the sleep quality. However, the hypothesis that high intensity light exposure is negatively correlated with the amount of naps that same day was confirmed. Concluding, according to this study, natural light exposure during the day does not seem to influence the sleep quality among elderly people but it does has an influence on their sleep- wake pattern.

Keywords

Healthy elderly people; Daylight exposure; Sleep pattern; Naps; Activity; Actigraph; Light sensor

Introduction

A common problem among elderly people is sleep disturbance [1]. Van Someren mentioned in his review that different studies indicate that 40- 70% of the elderly suffer from chronic sleep disturbances. Hereby is frequently nocturnal awaking the most common complain, other difficulties are falling asleep at night and early awakening. These sleep disturbances in turn cause problems in physical and mental health [1]. Problems in physical health have been associated with cardiovascular related issues like hypertension and perturbation of endocrine function. Depression, daytime sleepiness, anxiety, poor concentration, and productivity are issues related to mental health. To reduce or avoid these sleep disturbances, many elderly use hypnotic prescriptions; 40% of all hypnotic prescription is used by elderly people. 10- 27% of this population is using sleeping pills on a daily basis [1].

The chronic sleep disturbances are frequently caused by a disruption in the circadian rhythm. With these individuals circadian rhythms in hormonal levels and sleep- wake patterns show a flatter amplitude, decreased stability, increased fragmentation and altered phase- relations [2]. One of the circadian rhythms is the sleep-wake rhythm [3, 4, 5]. This rhythm is driven by the, in the brain located, superchiasmatic nuclei (SCN). The SCN is influenced and stimulated by light signals (Zeitgebers) received by the retina. When light (daylight/ electrical light) reaches the typical light- sensitive cells (photoreceptors) in the retina, signals are sent to the SCN [6]. Light that activates the photoreceptors impacts the human circadian rhythm by controlling the diurnal melatonin suppression [6]. Melatonin is known as a sleep hormone and has a close relationship with sleep initiation and maintenance. A factor that influence the lack of stimulus of the photosensitive retinal cells, and therefore insufficient stimulus of the SCN, is the aging of the eyes. Throughout the years, the diameter and the flexibility of the pupil reduces. Also, the lens yellows and becomes less transparent [7, 8]. In addition, the yellow lens prevents blue light (450- 495 nm) from entering the retina. The yellowing of the lens will therefore result in a reduction of sleepiness because of the decreased secretion of melatonin [9]. Based on these biological processes a correlation is expected between the exposure to light on regular basis and a proper functioning SCN.

A preliminary literature study concluded that some studies did find a positive influence of natural light exposure on the sleep- wake rhythm [10]. One study concluded that longer exposure to high intensity light results in higher efficiency of sleep [11]. Another study mentioned that an increased lighting exposure delayed bedtime, while wakeup time became earlier when lighting exposure increased [12]. A third study found a 13% increase in urinary 6-sulfatoxymelatonin excretion due to an increase in the duration of daylight exposure of at least 1000 lux from 37- 124 minutes [13]. However, not all sleep parameters showed a correlation. Sleep latency had no correlation with any lighting exposure [12] and there was no evidence found that daytime activity is higher when exposure to high intensity light is longer [11]. In addition, one study reported to find no difference in sleep efficiency between summer and winter [11], while another study did find that the sleep efficiency index decreases significantly in summer compared to fall and winter [14]. Subjective evolution of sleep among the four seasons showed no significant difference [12]. All the studies mentioned used different methodologies causing difficulties in comparing the studies. Discrepancies between the references are, measurement device/ -questionnaire, time interval, season, parameter, setting, sample size, and latitude.

The present study is conducted based on an observation study by Aarts et al. and a field study by Tsuzuki et al. [12]. The aim of this study is to determine whether there is a correlation between the exposure to natural light and the sleep-wake rhythm of healthy elderly people based on field measurements. A field study reflects the real situation as it interferes with the normal daily life as little as possible. The advantages of natural light compared to artificial light are its every day freely available, its high illuminance value/ intensity even on overcast days and its wide spectral composition. The first hypothesis this study addresses is that a high PSQI (subjective sleep quality [15]) is correlated with low sleep efficiency. It also investigates that elderly people who have a high natural light exposure are good sleepers (hypothesis two). Thirdly, this study investigates that a high intensity light exposure increases the activity level. The fourth hypothesis is that blue light exposure before bedtime influences the sleep- wake pattern. Next, high intensity light exposure is correlated with the amount of naps that same day. Finally, this study investigates that the average light exposure during daytime affects the sleep quality and the correlation of average nocturnal light exposure during sleep on the sleep quality.

Methods

Subjects

18 subjects voluntary participated in this study (77.8% female, *n*= 14; 22.2% male, *n*= 4). The age of the participants ranged from 69 to 84 years (*mean*= 77.1; *SD*= 4.5 years). Inclusion criteria were an age of 65 or older, mobile, living independently in own dwelling, and no health problems which restrain them from going outdoors. Subjects were excluded if they used sleep medication or suffered from Alzheimer disease or other types of Dementia. This information was extracted from the subjects' responses to an initial questionnaire. All subjects were living in Parkstad, which is a region of the province of Limburg in The Netherlands. Based on the scores of the Pittsburgh Sleep Quality Index (PSQI) one half of the participants could be classified as 'good- sleepers' (*n*= 9) and the other half as 'bad- sleepers' (*n*= 9). The median PSQI was 5.0.

Instruments

Light sensor: The subjects were asked to wear a calibrated light sensitive cell (LightLogControl, Gary Martin, Edinburgh, Scotland [Figure 1]) continuously for the duration of the study to collect their daylight exposure. They were instructed to wear the light sensor at chest height attached to their clothing. During night time they had to place the sensor on their nightstand. The light sensor was not worn during showering/ bathing which lasted between 30 to 90 minutes per day. Only once a subject reported not to wear the sensor for a longer period, which involved 150 minutes due to a swim session. The data of that day was excluded from the analyses. The sampling interval was set at 60 seconds. This sample period results in output data every 60 seconds based on an average over a sample every ten seconds. Prior to this field study, the technical quality of the LightLogControl was determined based on CIE recommendations [16]. This reference provides a directive how to determine the technical quality of a light sensor on its relevant factors. The three indices f_2 (directional response index), f_3 (linearity index) and $f_{6,T}$ (temperature index) were determined. The LightLogControl was found to have index f_2 as well as index f_3 results in class D while index $f_{6,T}$ results in class A. This light sensor was chosen since it measures in the three wavelengths which most other light loggers are not capable of.

Figure 1: Picture of the LightLogControl.

Actigraphy: The subjects were asked to wear an Actiwatch Spectrum (1 pcs.) or Actiwatch Spectrum Plus (4 pcs.) (Philips/ Respironics, Murrysville, PA) on their non-dominant wrist to assess their sleep- wake rhythm. They were informed to wear this

Actiwatch continuously during the test period (daytime and night time). In general, the device was only removed for a shower, which lasted between 10 to 90 minutes per day. Again, one participant reported a 150- minute period not wearing the sensor. One participant did not wear the Actiwatch during one night and another participant ended the measurement session (4 hours) too early. These missing data points were excluded from the analyses. Epoch of the Actiwatch was set on 60- seconds. The sensitivity of the Actiwatch Spectrum is 96.5% whereas the specificity is 32.9% and the accuracy 86.3% [16].

Sleep- activity log: In addition, participants were asked to keep a sleep and activity logbook. The logbook and accompanying questions had to be filled in within one hour before going to bed and within one hour after waking up. The questions asked them how long it took them to fall asleep, how often they awaked during the night, which time they woke up in the morning, how often they had daytime naps, and when the devices were temporarily removed.

PSQI: The Pittsburgh Sleep Quality Index was used to assess subjective sleep quality. A global PSQI of five and higher means a poor sleeping quality while a score below five means a good sleeping quality. The subjective sleep quality index has a sensitivity of 89.6%, and a specificity of 86.5% (p= 0.001) in differentiating between good and poor sleepers [17].

Procedure

The participants were asked whether they wanted to volunteer in the study. In addition, they were informed about the aim and procedure of the experiment orally and they all signed an Informed Consent Form. The measurement period started with filling out two initial questionnaires: PSQI and a general questionnaire. The general questionnaire involved questions about their living situation, indoor lighting, and normal activity pattern. The measurement period lasted for five consecutive days (Sunday evening until Friday evening). During this period the participants had to wear their sensors (Actiwatch and LightLogControl) and to fill out the questions for the sleep- activity logbook (every morning and evening). Due to a limited amount of measurement devices the subjects were randomly assigned a week and divided into groups of five subjects. The protocol was repeated for four consecutive weeks. However, the last two weeks were postponed by one week due to the change in Daylight Saving Time (DST). The study was performed from March 2016 until April 2016 (March: average temperature= 5.4°C; total rainfall= 54mm; April: average temperature= 8.7°C; total rainfall= 62mm) [18].

Data analyses

The different parameters were estimated using PSQI, LightLogControl, Actiwatch, and sleep- activity logbook. The parameters are defined in Table 1.

Table 1: Parameters

Name	Definition	Measurement device
Activity	Activity accounts in the interval of ≥150 mobile counts	Actiwatch
Average blue light exposure during 30 minutes before sleep	Average blue light exposure during the last 30 minutes before going to sleep	LightLogControl
Average light exposure during 4-h before sleep	Average light exposure during the last four hours before going to sleep	LightLogControl
Average light exposure during 30 minutes before sleep	Average light exposure during the last 30 minutes before going to sleep	LightLogControl
Average light exposure during daytime	Average light exposure during the hours awake	LightLogControl
Average light exposure during sleep	Average light exposure during the hours asleep	LightLogControl
Average sleep efficiency	Sleep efficiency of five consecutive nights	Actiwatch
Bedtime (BT)	Moment falling asleep	Actiwatch
High intensity light exposure	Duration of light exposure (≥1000 lux or ≥3000 lux) in minutes	LightLogControl
Minimum sleep efficiency	Lowest sleep efficiency of five consecutive nights	Actiwatch
Naps	Any sleep that occurred outside the subjects' bedtime period	Logbook
PSQI	Subjective sleep quality	PSQI
Sleep duration (SDU)	Total time between falling asleep and waking up	Actiwatch
Sleep efficiency (SE)	Percentage of time in bed actually spent sleeping	Actiwatch
Sleep latency (SL)	Time elapsed between bedtime and falling asleep	Logbook
Standard deviation of sleep efficiency	Standard deviation of sleep efficiency of five consecutive nights	Actiwatch
Wakeup time (WT	Moment waking up	Actiwatch
Watched TV during 30 minutes before sleep	Subjects reported watching TV 30 minutes before going to sleep	Logbook

In advance, the raw data of the light sensor was corrected by a Hagner E4-X reference cell (B. Hagner AB, Solna, Sweden) based on the linearity index. All the measurements are analysed with the software program IBM SPSS Statistics 22. In advance, the data of the Actiwatch was processed by the software package Philips Actiware 6.0.8. The data of the LightLogControl was processed by the software package LightLogControl Version 1.0. Pearson's correlations and Independent Samples t- test were performed to test the hypotheses (*n* range from 72- 89). All the tests were performed two- tailed with the critical p-value set at 0.05. Only the correlations between subjects are included in the analyses.

Results

The basic characteristics of the 18 subject are included in Table 2. The results are categorized by parameter. First, the correlation between the PSQI and the sleep efficiency is shown. Secondly, the exposure to light and sleep quality is provided, followed by, the correlation between light exposure and naps. Finally, the results of testing the relationship between exposure to light and daytime activity are given.

Table 2: Characteristics of the 18 participants expressed in mean (standard deviation)

Characteristic	Result	Unit
Age, mean (SD)	77.1 (4.5)	Years
Gender, female	77.8	%
Daytime naps, yes	35.6	%
Watched TV during 30 minutes before sleep, yes	66.7	%
PSQI, mean (SD)	6.4 (4.1)	Score
Time outdoors, mean (SD)	1:42 (1:28)	HH:MM
Bedtime, mean (SD)	23:04 (1:50)	HH:MM
Wakeup time, mean (SD)	7:21 (0:51)	HH:MM
Duration of light exposure ≥1000 lux, mean (SD)	1:18 (1:07)	HH:MM
Duration of light exposure ≥3000 lux, mean (SD)	0:33 (0:35)	HH:MM
Blue light exposure during 30 minutes before sleep, mean (SD)	55.4 (336.2)	lx
Light exposure during 4-h before sleep, mean (SD)	731.1 (2118.9)	lx
Light exposure during 30 minutes before sleep, mean (SD)	258.3 (442.7)	lx
Light exposure during daytime, mean (SD)	1042.9 (1025.1)	lx
Light exposure during sleep, mean (SD)	97.5 (133.0)	lx

PSQI and sleep efficiency

A comparison is made between the PSQI and the sleep efficiency: no significant correlations were found [Table 3]. However, the results did show a correlation. The PSQI has a negative correlation with the average sleep efficiency. The same correlation was found between the PSQI and the minimum sleep efficiency. The standard deviation of the sleep efficiency, on the other hand, was positively correlated with the PSQI.

Table 3: Correlation matrix of PSQI and sleep efficiency

	PSQI		
	r	*p*	R^2
Average sleep efficiency	-0.355	0.148 [a]	0.126
Minimum sleep efficiency	-0.334	0.175 [a]	0.112
Standard deviation of the sleep efficiency	0.318	0.199 [a]	0.101

Correlation coefficients: ****< *0.01*, *< 0.05;** [a] Pearson's product- moment correlation coefficient (2- tailed)

Exposure to light and sleep quality

Table 4 shows all correlations between the sleep parameters and the different high intensity light exposure levels. The wakeup time and the average light exposure during four hours before sleep were significantly correlated. However, no other correlations were found between the light exposure and the sleep quality.

Table 4: Correlation matrix of light exposure and sleep parameters

	BT		WT		SL		SE		SDU	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Duration of light exposure ≥1000 lux in minutes	0.116[a]	0.333	0.002	0.989 [a]	0.164	0.169 [a]	0.050	0.679 [a]	0.130	0.275 [a]
Duration of light exposure ≥3000 lux in minutes	-0.015	0.901 [a]	0.071	0.551 [a]	0.070	0.561 [a]	0.108	0.365 [a]	0.019	0.873 [a]
Average light exposure during daytime	-0.10	0.933 [a]	0.179	0.133 [a]	-0.032	0.792 [a]	0.095	0.409 [a]	0.176	0.140 [a]
Average light exposure during sleep	-0.034	0.779 [a]	0.178	0.134 [a]	-0.072	0.545 [a]	-0.114	0.340 [a]	0.181	0.127 [a]
Average light exposure during 4-h before sleep	0.033	0.762 [a]	**0.231**	**0.029*[a]**	-0.022	0.853 [a]	-0.010	0.936 [a]	0.185	0.119 [a]
Average light exposure during 30 minutes before sleep	0.134	0.260 [a]	0.015	0.899 [a]	0.000	0.997 [a]	0.086	0.475 [a]	0.079	0.508 [a]
Average blue light exposure during 30 minutes before sleep	0.084	0.481 [a]	-0.044	0.711[a]	-0.05	0.668 [a]	0.117	0.329 [a]	-0.007	0.952 [a]
Watched TV during 30 minutes before sleep	*df*= 70, *t*= -0.615	0.541 [b]	*df*= 70, *t*= -1.211	0.230[b]	*df*= 67, *t*= 0.721	0.474[b]	*df*= 70, *t*= 0.153	0.870 [b]	*df*= 70, *t*= 0.108	0.914[b]

BT= Bedtime [HH:MM]; WT= Wakeup time [HH:MM]; SL= Sleep latency [minutes]; SE= Sleep efficiency [%]; SDU= Sleep duration [minutes]; Correlation coefficients: **< *0.01*, *< 0.05;** [a] Pearson's product- moment correlation coefficient (2- tailed), [b] Independent Samples t- test (2- tailed)

Exposure to light and naps

Table 5 shows the correlations between the different levels of high intensity light exposure and naps. A significant negative correlation was found between high intensity light exposure (≥ 1000 lx and ≥ 3000 lx) and naps during the same day. In addition, the average light exposure four hours before sleep and naps the following day correlated significantly. However, no correlation was found between the average blue light exposure before sleep and naps the following day. When participants watched TV before bedtime this did not correlate to their naps. A significant negative correlation was found between the average light exposure during daytime and naps. However, the average light exposure during night time did not influence significantly.

Table 5: Correlation matrix of light exposure and naps

	Naps same day as light exposure			Naps day after light exposure		
	df	*t*	*p*	*df*	*t*	*p*
Duration of light exposure ≥1000 lux in minutes	***81***	***-3.276***	***0.02**[b]***	X	X	X
Duration of light exposure ≥3000 lux in minutes	***86***	***-3.725***	***0.00**[b]***	X	X	X
Average light exposure during daytime	***68***	***-2.778***	***0.07**[b]***	X	X	X
Average light exposure during sleep	X	X	X	68	-0.176	0.861 [b]
Average light exposure during 4-h before sleep	X	X	X	**58**	**2.024**	**0.043*[b]**
Average blue light exposure during 30 minutes before sleep	X	X	X	87	-0.902	0.370 [b]
Watched TV during 30 minutes before sleep	X	X	X	88	1.085	0.281 [b]

Correlation coefficients: **< *0.01*, *< 0.05;** [b] Independent Samples t- test (2- tailed)

Exposure to light and activity

Besides the effects of light exposure on sleep, its effects on daytime activity were calculated [Table 6]. No correlation was found between high intensity light exposure and activity the same day or the day after. A negative significant correlation was found between the average light exposure during four hours before sleep and activity the day after. Exposure to blue light before sleep did not correlate significantly with activity. Watching TV before bedtime, however, had a positive significant influence on the activity level the next day.

Table 6: Correlation matrix light exposure and activity

	Activity same day as light exposure		Activity day after light exposure	
	r	*p*	*r*	*p*
Duration of light exposure ≥1000 lux in minutes	-0.075	0.485 [a]	-0.088	0.464 [a]
Duration of light exposure ≥3000 lux in minutes	0.100	0.347 [a]	0.111	0.352 [a]
Average light exposure during daytime	-0.145	0.173 [a]	-0.135	0.259 [a]
Average light exposure during sleep	X	X	-0.077	0.520 [a]
Average light exposure during 4-h before sleep	X	X	**-0.294**	**0.012*** [a]
Average blue light exposure during 30 minutes before sleep	X	X	0.071	0.555 [a]
Watched TV during 30 minutes before sleep	X	X	**df** **56** / **t** **2.369**	**0.021*** [b]

X= not available; Correlation coefficients: **< *0.01*, *< 0.05; [a] Pearson's product- moment correlation coefficient (2-tailed); [b] Independent Samples t- test (2- tailed)

Discussion

This study started by investigating the correlation between the PSQI and the sleep efficiency. The results support that a high PSQI is related to poor sleep efficiency; however, the correlations were not significant. The results could suggest that the parameter sleep efficiency is not a correlated assessment for the PSQI. In addition, the subjects were only asked to assess the subjective sleep rating prior to the measurements; assessing their sleep quality every day would provide a better measure [19].

Secondly, this study investigated the effects of natural light on the sleep- wake rhythm of healthy elderly people in the field. There was positive significant correlation found between the average light exposure during four hours before sleep and the wakeup time. We expected to find a negative correlation based on previous findings [12]. The discrepancy could be explained by including thermal variables. In addition, no effect of blue light exposure before bedtime on the sleep quality was found, which could be explained by the low exposure to blue light before sleep compared to the average blue light exposure throughout the day or due to the aging of the eye like the yellowing of the lens which prevents blue light from entering the retina. Also, we expected that people who experienced much natural light are good sleepers; however, no evidence was found. Earlier studies did find a correlation between high intensity light exposure and the nocturnal sleep quality [11, 12, 13]. These contradictory results could be explained by the variety in methodologies; some studies used wrist worn light sensors, others measured urinary 6-sulfatoxymelatonin excretion, some used a controlled setting, and again other studies were performed had a different latitude.

The most important findings from this study were the correlations between daylight exposure and naps. The significant results indicate that a higher light exposure during the day decreases the amount of daytime naps. Also, a higher light exposure before bedtime decreased the amount of daytime naps the following day.

The study by Aarts et al. found no significant correlations between the data on light exposure and activity [15]. The present study; however, shows that high intensity light exposure before bedtime decreased participants' activity level of the next day. The inconsistent results could be explained by the difference in parameter. In the present study is the light exposure four hours before bedtime related to the activity level, while the reference defines high intensity light exposure as the average light exposure per day. Subjects who reported that they watched TV before going to sleep had an increased activity level and therefore tend to be more active the next day. This could be explained due to the low amount of blue light exposure while watching TV.

One reference found a positive correlation between a short time falling asleep and the sleep efficiency [11]; however, this correlation is not supported by the results of the present study. On the other hand, a positive correlation between sleep duration and sleep efficiency was found; a long sleep duration thus is accompanied by a high sleep efficiency (r= 0.214, p= 0.05, n= 90). This suggests that when people sleep efficient they prefer to sleep longer.

A significant positive correlation is found between the sleep efficiency during the night and the daily light exposure the following day (≥2000 lux: r= 0.251, p= 0.05, n= 90; ≥3000 lux: r= 0.271, p= 0.01). The results suggest that proper sleep during the night enhances the activity level and the time spent outdoors the following day. The opposite relationship was also found significant, meaning that a high daytime activity increases the sleep efficiency (r= 0.238, p= 0.05). However, sleep duration was negatively correlated with daytime activity, which indicates that a high actively level decreases the sleep duration (r= -0.249, p= 0.05).

In the present study is no distinction made between male and female. A previous study on gender difference in sleep- wake rhythm reported that females had slight reduced sleep duration, increased number of awakenings, while showing no difference in nap length with males [20].

There are several limitations to this field study. First, the obligation to get up early was not considered, which can, for example, be due to a (bed)partner or early activities. Besides, some people might set an alarm clock deliberately because they like to get up early. These obligations influence the wakeup time and sleep duration and disturb the uncontrolled setting. Secondly, this study had a limited amount of participants (n= 18). Therefore, outliers could have influenced the results largely. In addition, it limits the representation of the findings. Thirdly, the measurement period lasted for five consecutive days which is also limited. Besides, no information was collected about daytime social events, which prevent daytime naps from occurring, although preferred. Finally, in this study is the illuminance level [lux] used to determine the light exposure. However, lux is a photopic unit and differs from the circadian spectrum in wavelength. By measuring the circadian irradiance, the circadian responses will be taken into account. Further research is needed to understand the relation between the circadian spectrum and the sleep- wake rhythm. Hence, the responses of circadian irradiance on the circadian rhythm could be determined. It is recommended to include the parameters duration and timing of the light exposure because they impact the sleep- wake rhythm.

Conclusions

In conclusion, some hypotheses had to be rejected. Our results required rejection of hypotheses that PSQI is correlated with sleep efficiency, that people who have a high natural light exposure are good sleepers, that blue light exposure before bedtime influences the sleep- wake rhythm, and that the average nocturnal light exposure during sleep affects the sleep quality. However, the hypotheses that high intensity light exposure is correlated with the amount of naps that same day and that high intensity light exposure affects the activity level were confirmed. Thus, it seems that natural light exposure during the day does not seem to influence sleep quality among elderly people, but does have a positive influence on their sleep- wake pattern. The contradictory results between different references and the present study could be explained by the variety in methodologies. Using a controlled or uncontrolled setting could affect the variables because of different boundary conditions and therefore affect the results. Finally, other variables like fresh air and social events affect the sleep- wake rhythm; however, these variables were not included in the present study.

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