Assessing the impact of daylight exposure on sleep quality of people over 65 years old

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Abstract

Due to our social behaviours, people spend at least 80% of their time indoors, mostly under artificial light. In research and building design, daylight is considered a valuable asset because it is the primary source of free, good quality light and it is suggested that it has a positive influence on human performance, health and sleep quality. There is a tendency in the population for increasingly poor sleep quality with age, and this affects at least 50% of the elderly population. Research on sleep disruption has found that especially in the elderly population, interrupted sleep can affect alertness, cognitive performance and mood. This increases the risk of falls, increases fatigue and reduces some other mental functions. Exposure to daylight (indoors and outdoors) is expected to reduce sleep disruption. Physical activities and sleep quality were assessed using 32 participants living independently in the UK, aged between 65 and 95 years old. The study was divided into two seasons due to a considerable difference in daylight availability in summer and winter. In each season participants completed the Pittsburgh Sleep Quality Index (PSQI) questionnaire, Morningness–Eveningness Questionnaire (MEQ) and a seven-day sleep diary/log activity; where time spent outdoors was identified. It was expected that participants who reported less exposure to daylight during summer and winter would report worse sleep quality. However, this was not the case; subjective sleep quality did not differ greatly between summer and winter, even though exposure to daylight varies greatly between seasons. This study explores the relationship between exposure to daylight throughout two different seasons and people's chronotypes, physical activities and sleep quality (between and within participants). This information is essential to find means of supporting an ageing population.

Practical applications: In the built environment, daylight is an important feature to consider for the occupant's health and wellbeing. This research provides real-world insight into the amount of daylight that active aged people are exposed to during two seasons in London, and how this could impact their overall sleep quality. The findings suggest that exposure to daylight could benefit people over 65 years old with poor sleep quality by reducing the number of awakenings during the night. This research provides a step towards understanding how daylight exposure effects people, and can be used to inform housing design for the ageing population.

Keywords

Daylight, light, subjective sleep quality, elderly population, old people

Introduction

Over time, the human's body clock has adapted to solar time, when there is light we are supposed to be active and when it is dark our body prepares to rest and restore energy. The body clock, or circadian system, is a free running system with a length of 24 h.[1] It regulates many of our internal biological functions; controls the hormonal rhythms, body core temperature, sleep-wakefulness, mood and other behavioural cycles.[2]

The light–dark (L-D) pattern is one of the principal cues that helps to maintain our circadian system synchronized to our day-length environment.[3] The input of the L-D pattern is received by the human eye and depending on the light characteristics (wavelength, amount of light, duration of exposure) can affect either the visual system or the non-image forming (NIF)a system or both.

With age, the physiology of the human body changes; however, only when it begins to impair people's lifestyle, will people try to make the necessary adjustments to reduce them. Due to changes in the physiology of the eye and brain, both the visual system and non-image forming or NIF functions are diminished. The human eye changes with time; after people reach their mid-40s there is reduction of light reaching the retina, due to a combination of factors: the eye's lens starts yellowing, the size of the pupil decreases, absorbance of light increases and there is an increase in the occurrence of pathological conditions that lead to some type of vision loss.[4] In addition to these changes older people are more likely to suffer from visual loss, the most common causes are cataract, glaucoma, age-related macular degeneration, diabetic retinopathy and retinal detachment. Combining all these factors, simple visual activities can then be more demanding than before.

Because of these factors, degradation of in the circadian rhythm becomes more common in older people, the circadian amplitude diminishes, the circadian phase advances (it starts earlier than environment cues)[5] and the ability to adapt to phase shift is reduced. These modifications have an impact on physiological processes.[6] Distorted sleep/awake patterns are mostly associated with irregular circadian timing, which may contribute to more health problems.[7] There have been various approaches to reduce or control sleep disturbances; pills (sleeping or melatonin supplements), dieting or light therapy. Even though it has been documented that bright light therapy is a way to treat seasonal affective disorder (SAD), depression, sleep disorders and jet-lag,[8–10] to achieve the desired result, subjects have to look at very bright sources for specific periods of time which not suitable for all subjects due to particular sensitivity to light. Also, people experiencing these disorders might benefit from appropriate environmental lighting, either designed environments or just being exposed to daylight.

In 2005, an intervention study carried out by Aarts and Westerlaken[11] was focused on the improvement of health and wellbeing in older adults (65 to 90 years old). Measures of the daytime and evening light conditions, questionnaires and visual acuity tests were taken in the elderly's living environments (mostly living rooms). They found, as other studies have already reported, that the elderly's homes tend to be poorly lit,[12] that lighting levels are not enough to influence their biological rhythm and that daylight might help achieve positive effects on their sleep rhythm or improvement on their SAD-symptoms. Similarly, Karami et al.[13] measured the effect that sunlight has on melatonin suppression and sleepiness from the elderly living in a nursing home in Iran. They reported that exposure to morning daylight could correct the circadian rhythm of people living there. However, the reported results showed that exposure to sunlight increases the melatonin concentration in the morning and it reduces at night. Meanwhile results from the questionnaires measuring subjective sleepiness reported an increase in sleepiness during the night and an increase in alertness from 8:00 to 20:00 h. Although this may be true, these results are contradictory because, if melatonin increases then people should feel sleepier. Likewise at night, if melatonin decreases an increment in alertness would be expected.

The preliminary results of this research[14] were consistent with the observation that daylight can help on synchronise sleep patterns. Consequently, it has been hypothesized that if people are exposed to enough daylight sleep quality might be improved significantly. Because people are often not exposed to the right light at the right time due to daily patterns, designed environments[15] and physiological limitations that increase with age; it is hypothesized that increased exposure to daylight could benefit the sleep quality of people over 65 years old. The aim of the present field study was to analyse whether exposure to daylight in London in the 65+ years old population has a relationship to their sleep quality. The study was carried out in peoples' homes to reduce disturbance of their daily activities.

Method

A field study was completed to examine whether there is a relationship between daylight exposure, circadian chronotype and subjective sleep quality in people over 65 years old. Surveys collected information about subjective sleep quality, chronotype, exposure to daylight and daily activities of each subject. The study was carried out at various locations across London during summer (2018) and winter (2019).

Participants

The original sample size of 38 was reduced to 32 because 2 people died and 4 choose not to continue with the study in winter. Thirty-two participants, 25 females and 7 males, over 65 years (mean age = 75.3 SD 5.9 years) took part of the study in their homes. All participants were recruited trough advertisement placed on organisations' working with people over 55 years newsletters, libraries, community centres and public spaces (around London). The criteria needed to take part in the study was to be above 65 years, being able to do simple activities (grocery shopping, household activities, cleaning, etc.), willingness to complete a sleep diary for a week and complete the questionnaires in their homes. Sixty percent of the participants mentioned they had good sleep quality and the rest stated to had some sleep difficulties. Participants were compensated with £16.00 for the time invested during the study (£8.00 per season). Participants were presented with an information sheet and consent form to be signed, when they agreed questionnaires were provided to them. This study was registered and approved by UCL Ethics Committee, project registration number: 10645/001. Data were collected between May 2018 and February 2019.

Data collection

Participants were visited in their home; on the first day, they were asked to complete the Pittsburgh Sleep Quality Index (PSQI)[16] and the Morningness–Eveningness Questionnaire (MEQ)[17] (in that order) and they were given a sleep diary to complete during the following week. After completion a sleep diary and activity log was provided and explained by the researcher. They were asked to keep it and fill-in for following seven days. This procedure was repeated twice: in summer (2018) and winter (2018–2019).

Subjective sleep quality

Subjective sleep quality was assessed using two different tools: PSQI and the sleep diary (post-sleep). The PSQI is a self-reported questionnaire developed to discriminate between "good" and "poor" sleep quality. It assesses sleep quality during the majority of days and nights in the previous month. The PSQI consists of 19 questions related to sleep duration, latency, habitual sleep efficiency, sleep disturbances, use of sleeping medications, daytime dysfunction and sleep quality.[16] For the purpose of this study the last question was removed (questions rated by the partner/flatmate) because 68.75% of participants were living alone and these answers do not affect the PSQI global score. The sleep diary consisted of two parts, participants were asked to fill in the first part in the morning (after waking up) and the second part at night (before going to sleep). These questions were similar to the PSQI questions, and were related to their sleep quality ("how well rested you feel"), sleep duration, latency and sleep disturbances were asked along with time spent outdoorsb during the morning (6:00–11:59), afternoon

(12:00–17:59) and evening (18:00–23:59). The sleep diary template can be found in supplementary Appendix 1.

Circadian typology/chronotype

The MEQ17 was used to score participant's chronotype. The MEQ consist of 19 questions related to participants' preferred time to perform certain types of activities during a free day. MEQ assess whether a person is "Definitely Morning Type" (score 70–86), "Moderately Morning Type" (score 59–69), "Neither" (score 42–58), "Moderately Evening Type" (score 31–41) or "Definitely an Evening Type" (score 16–30). For this study, the internal consistency coefficient of the scale was (Cronbach's alpha) .85 for summer and .83 for winter.

Exposure to daylight

Exposure to daylight was calculated using reported times people spent outdoors and daylight availability during those times. London's daylight availability between 2018 and 2019 was obtained from Public Health England dataset, data were reported as mean photopic illuminance every 5 min in kilolux.

Analysis

Analyses were performed with non-parametric statistical methods because the data are not normally distributed. Tests were chosen on the basis that the data met all the relevant criteria to validate their use. Mann–Whitney U test was used to observe if there were any statistical differences between "good" and "poor" sleepers. Kendall's tau-b was used to observe if there were any associations between exposure to daylight, circadian typology, PSQI score and the reported well rested from the sleep diary. Data analysis was carried out using SPSS 25.0 for Windows. All tests were run for both summer and winter using all data points (per participant, per day; see Table 1).

Table 1. Median scores results from sleep quality groups in summer and winter. Statistical test (p-values) of Mann-Whitney U test and Kendall's tau-b.

	Statistical Tests					
	Mann-Whitney U Test					
	Summer			Winter		
	Good	Poor	*ρ*-value	Good	Poor	*ρ*-value
	n=105	n=117		n= 98	n= 126	
Well rested score	4	4	*ρ*=.182	5	4	*ρ*<.05
Reported Sleep Hours	07:08 hrs	06:50 hrs	*ρ*=.063	07:25 hrs	06:52 hrs	*ρ* =0.020
No. of awakenings at night	1	1	*ρ*=.137	1	2	*ρ* =0.025
Exposure to daylight	107.7 KluxHrs	142.05 KluxHrs	*ρ*=.004	6.9 KluxHrs	7.03 KluxHrs	*ρ* =0.558
	Kendall's tau-b					
	n= 222			n= 224		
Exposure to daylight	τb = .144		*ρ* = 0.004	τb = -.072		*ρ* = 0.146
Circadian Typology	τb = -.237*		*ρ*<.05	τb = -.239*		*ρ*<.05
	n=32			*n=32*		
PSQI Score	τb = -.285		*ρ* = 0.029	τb = -.485*		*ρ*<0.05

* Correlation is significant at *ρ* <0.01

Results

The raw data obtained from the sleep diary were averaged per participant (over the week) and these results were compared to the obtained score in PSQI for each season. A negative correlation between PSQI and reported well-rested variables in both seasons, summer $\tau b = -.285$, $p = .029$ and winter $\tau b = -.485$, $p < 0.05$ was found. The sample size was divided into "poor" (PSQI>5) and "good" (PSQI≤5) sleep quality depending on their PSQI score, both summer and winter results were considered separately to determine the type of sleep quality in each season. "Poor" and "good" differed between participants over seasons, for example one participant had "good" sleep quality score during summer but in winter the score increased so this person was considered as having "poor" sleep quality in winter, see Table 2.

Table 2. Participants' Sleep quality over two seasons

Type	Summer		Winter	
Good Sleep Quality	n= 14	%43.75	n= 14	%43.75
Poor Sleep Quality	n= 18	%56.26	n= 18	%56.26
Total	n = 32	% 100	n = 32	% 100

The amount of daylight exposure was calculated per individual using the daylight availability dataset. People reported the total time they spent outdoors separated in three periods (morning, afternoon and evening). Thus to calculate the illuminance they were exposed to, it was necessary to estimate the exact time they were out (HO) and the hours they were indoors. To calculate the start time (STc) for the morning period, mean time was calculated from the reported "waking up" time to the end time of the defined "morning" period (12:00 h). From the calculated mean time, half of the total reported time spent outdoors during this period was subtracted. Therefore, the end time (ETd) for the morning period is the start time added to the reported time spent outdoors during morning. For the afternoon period, a similar calculation was carried out, however instead of using the reported "waking up" time, the start and end time defined for "afternoon" hours (12:00–18:00 h) were used. For the evening period the ST was set at 18:00 h. Knowing the start times and end times we were able to calculate the average daylight exposure to those specific hours.

For example, if a person reported waking up at 7:30 h and be out for 2:30 h in the morning on 25 May, then the formula would be as follows:

$$ST = (\overline{7:30, 12:00}) - (2{:}30/2)$$

$$ST = 9{:}45 - 1{:}15$$

$$ST = 8{:}30$$

then ET for being outdoors in the morning would be

$$ET = ST + 2{:}30$$

$$ET = 8{:}30 + 2{:}30$$

$$ET = 11{:}00$$

Then the average exposure to daylight was calculated from 8:30 to 11:00 h using the provided data for 25 May.

Subjective sleep quality: Summer and winter

To observe which variables (amount of daylight, hours slept during the night, type of chronotype) could have an influence on subjective sleep quality on the sample size, statistical analyses were conducted splitting the data into “good”–“poor” sleep quality and summer-winter.

Good and poor sleep quality

Mann–Whitney U test showed no significance difference in the reported “well-rested” score in summer ($U=5.521$, $z=-1.334$, $p=.182$) between two groups of participants with different sleep quality: “poor” ($n=117$) and “good” ($n=105$), both groups had a median score of 4 (score from the sleep diary 1=“barely rested” 6 =“well rested”). However, there was a significance difference in winter ($U=3.816$, $z=-5.078$, $p < .05$) between both groups. The median score for “poor” ($n=126$) was 4 and for “good” ($n=98$) was 5. See Figure 1 which shows the number instances of a given score on the well-rested scale broken down by season and reported sleep quality.

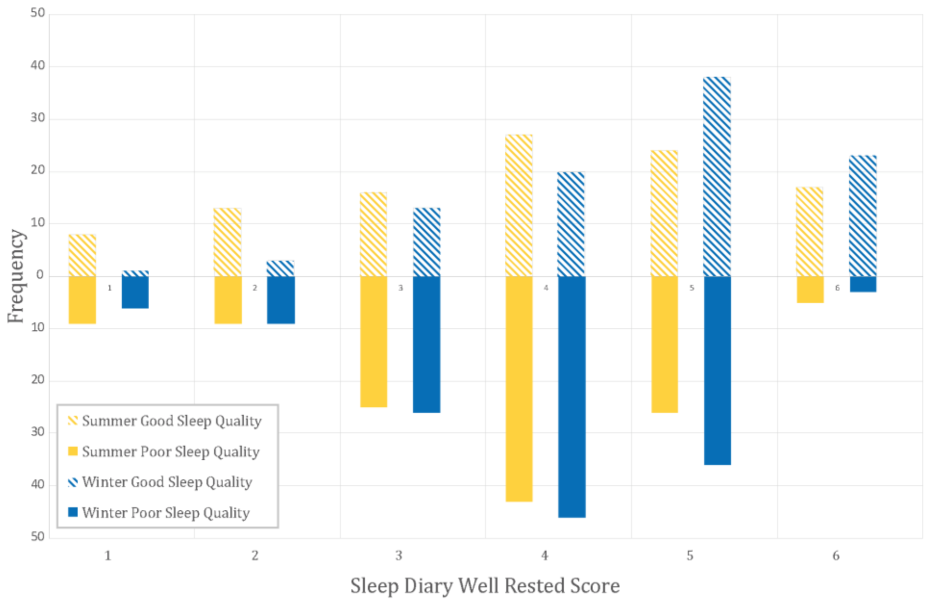

Figure 1. Distribution of “well-rested” score between the two groups of sleep quality in summer and winter. The categorization of “poor” (solid colours) and “good” (pattern colours) sleep quality was based on PSQI results for each season.

Circadian typology

Kendall’s tau-b showed a relationship between sleep quality (using the “how well rested” variable) and the score of participant’s circadian typology for both summer and winter. There was a strong negative association between summer MEQ and summer how well-rested people felt, which was statistically significant, $\tau b=-.237$, $p < .05$. In winter, there also was a strong negative association between the MEQ and how well rested, which was statistical significant, $\tau b=-.239$, $p < .05$. The negative correlation coefficient for both groups indicates that people reporting a high score in “well rested” are people ranked with low ordinal scores for MEQ (1=Definitely morning person, 2=Moderately Morning person, 3=Neither, 4 =“Moderately Evening Person” and 5=“Definitely Evening person”) and vice versa. These results indicate that people reporting with a high score of well rested are more likely to be a morning person. These results support previous findings on research suggesting that circadian typology is dependent on age. As people get older, they tend to shift to morning chronotype.[18]

Reported sleep hours

For reported slept hours during the night the statistical test showed no significant difference between sleep quality (well-rested score) groups in summer ($U=5.253$, $z=-1.861$, $p=.063$). Sleep hours at night increase from poor sleep quality (6:50 h) to good sleep quality (7:08 h). In winter, there was a significance difference between groups ($U=5.058$, $z=-2.319$, $p=.020$). Sleep hours at night increase from poor sleep quality (6:52 h) to good sleep quality (7:25 h). Well-rested variables were similarly distributed for both groups in both seasons.

Exposure to daylight

For exposure to daylight two non-parametric tests were run for both summer and winter. Mann–Whitney U test was run to observe differences among the Pittsburgh Index sleep quality groups and Kendall’s tau-b test was run to find out if there was a correlation between exposure to daylight and participants’ well-rested score (see Figure 2).

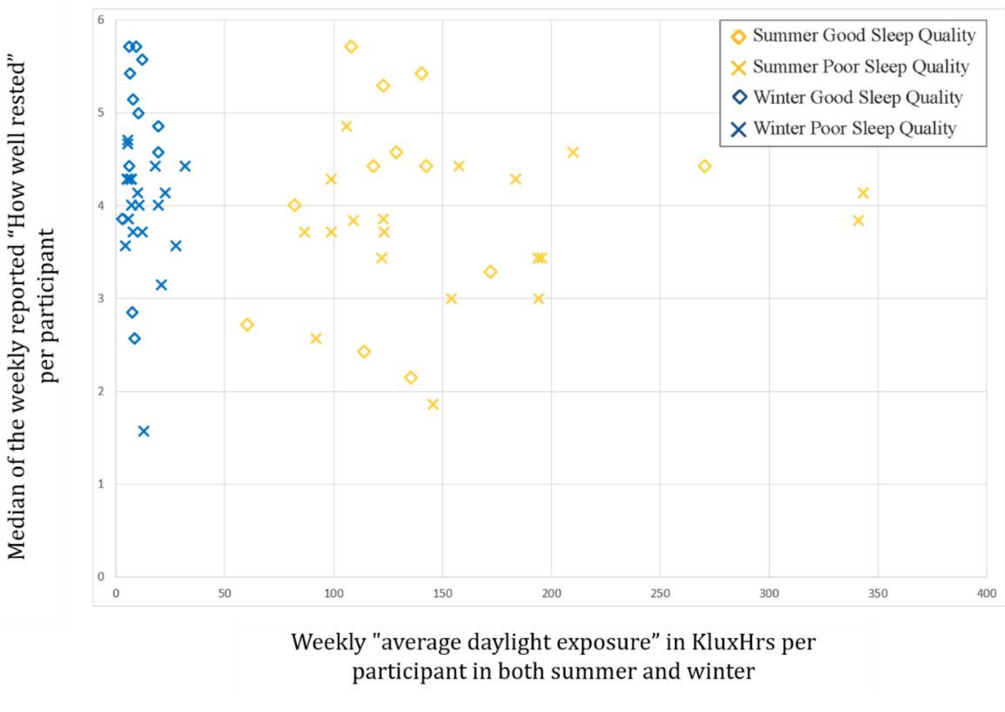

Figure 2. Relationship between weekly average exposure to daylight and weekly average of “How well rested” for winter and summer per participant. Yellow markers represent summer season and blue markers winter. Diamond markers are participants categorise as “good sleepers” and X markers are “bad sleepers”. Each participant is denoted by one winter and one summer marker, and does not necessarily fall in the same category of “good” and “poor” for each season. The categorization of “poor” and “good” sleep quality was based on PSQI results for each season.

The first test showed significant difference between sleep quality groups and exposure to daylight for summer ($U=7.533$, $z=2.911$, $p=.004$). In summer, the median value of daylight exposure was lower for the good sleep quality (107.71 klux hours) as compared to the poor sleep quality (142.048 klux hours). However, for winter there was no statistical significance between groups ($U=6.456$, $z=.586$, $p=.558$). Although non-significant, there was a marginal increase in daylight exposure between those who categorized as poor (7.025 klux hours) and good (6.954 klux hours) sleep quality.

For summer, the correlation test showed a strong, positive association between the amount of daylight exposure and self-reported well-rested score, which was statistically significant, $\tau b = .144$, $p = .004$. On the other hand, the Kendall's tau-b correlation result for winter was a weak, negative association between the amount of daylight exposure and the report of how well-rested people felt in winter, which was not statistically significant, $\tau b = -.072$, $p = .146$.

These results showed some contractions between data from the sleep diary (reported well rested) and the PSQI result. In the first test the results suggest that people with more daylight exposure have a higher PSQI score indicating poor sleep quality for both summer and winter. However, in the correlation test a significant relation between exposure to daylight and reported well restedness in summer was found. This result suggests that in summer people with more daylight exposure reported a higher score of well rested (where 1 indicates "barely rested" and 6 "well rested"). The inconsistency of these data could be due the time period measured as the PSQI referred to the month prior to it being filled in and the sleep diary was regarding the following week.

Discussion

The present study investigates if subjective sleep quality could be affected by the variation in exposure to daylight and the circadian typology among people over 65 years old living in London. The findings presented in this paper are preliminary and complete analysis of the data will be available elsewhere later.

The results showed that more than half of the participants have poor sleep quality, and there is a significance difference between the PSQI score of independent groups of poor and good sleepers in both winter and summer. This supports previous findings that half of the older population have poor sleep quality.[19] In order to discuss sleep quality, it is important to consider all factors influencing it. One of them is the quantity of sleep (sleep length). The results suggested that subjective sleep quality was not related to the total hours people reported to sleep at night during summer: median hours of sleep for "poor" was 6:50 and for "good" 7:08; however, for winter it was found that people reporting having a good sleep quality (7:25) were having 30 min more than participants with poor sleep quality (6:52). Additionally, there were differences on awakenings during the night, in summer both groups had the same median of one awakening, meanwhile in winter "poor" sleepers reported to wake up at least twice during the night, while "good" sleepers only once.

Although in summer there was a relationship between reported well-rested score and amount of daylight exposure ($p = .004$), there was little difference between participants having "good" and "poor" sleep quality ($p = .182$). Both groups had higher exposure to daylight, moreover, "poor" sleep quality participants had more exposure to daylight (median exposure to daylight was 142 klux hours), which could be the reason for having no differences between groups in the reported well-rested score and less awakenings during the night in summer. On the contrary for winter, the results showed no relationship between exposure to daylight and subjective sleep quality ($p = .146$), and the reason for this could be that the exposure to daylight was similar for both groups, there was no difference in exposure to daylight between "poor" (6.95 klux hours) and "good" (7.09 klux hours) sleep quality ($p < 0.558$). These results, however, support what has been reported in a field study conducted in the Netherlands, that high intensity of light has a relationship with higher sleep efficiency.[20] This could be the reason that participants report better sleep during summer or simply because there is greater daylight availability in summer than in winter. The current results indicate that exposure to daylight, in this group of people, does not make a difference in their subjective sleep quality; however, it could be observed that in winter waking up at night increases which could be related to not be exposed to enough light that could help the internal clock synchronization, helping with the ability to sleep throughout the night.

Limitations of the study

Because of the nature of the field study which relied on committed volunteers, the small sample size limits the generalisability of the results of the study. The results obtained from the survey and the sleep diary/log are self-reported, and there was no other objective measure to validate these responses. The lack of objective measures was due to not using invasive equipment to collect this type of data. Additionally, responses from people spending time outdoors was an estimation as participants did not record exact times; therefore, daylight exposure could not be measured exactly, however the method described was the best approximation possible. Limitations of the survey method are evident in the contradiction between PSQI and "well-rested" scores. People who reported themselves to be well rested did not necessarily have a higher PSQI score. This could be due to the fact that the sample was self-selecting and may had a more positive outlook (hence a higher well-rested score) compared to those who declined to participate. Or it could indicate inherent flaws in the PSQI and/or survey responses.

Conclusion

Daylight plays an important role in people's overall wellbeing. It has been studied for decades in order to have scientific validation of its potential benefits to people.[21,22] Part of the results of this study showed a weak association in winter between daylight exposure and the reported well rested, while in summer there was a strong association between the same variables; however, it is not known whether this is due to the effect of daylight or their increased outdoor activities during summer. This could suggest that exposure to daylight has an impact on overall subjective sleep quality on this population (people over 65 years old, living by themselves, being moderately active or active). Moreover, exposure to daylight might affect the number of people's awakenings during the night. This could be useful for people with "poor" sleep quality, who could benefit from increasing their daylight exposure in order to have less awakenings during the night. Participants in this study were mainly active people with several social activities during the week, which might help them to have better sleep quality. It is also possible that the effect of daylight exposure could be more significant with people who are less active and unable to easily go out of their indoor environments however further research will be needed to see if this is true. Another possible implication of this study is that people only need to go out briefly to synchronise their circadian system; however, further analysis of people who do not go out is needed to draw this conclusion.

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