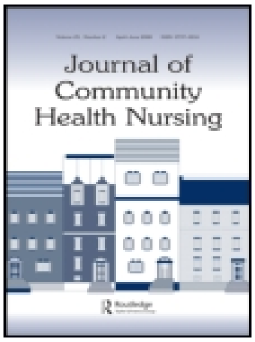

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Akie Ichimori, Keiko Tsukasaki & Emi Koyama

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Illuminance, Subjective Sleep Quality, and Psychosomatic Health in Elderly Individuals Requiring Care: A Survey of Japan's Hokuriku Region in Winter

Akie Ichimori
Division of Health Sciences, Graduate School of Medical Science, Kanazawa University, Japan, and Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University, Japan

Keiko Tsukasaki
Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University, Japan

Emi Koyama
Graduate School of Science and Technology, Kyoto Institute of Technology, Japan

We measured the illuminance exposure for 3 days in winter of a convenience sample of 44 elderly people certified as requiring support in Japan's Hokuriku region. We calculated the illuminance ratio per minute during activity and while in bed and analyzed the relationship between illuminance, subjective sleep quality, and psychosomatic health. There was a significant negative correlation between illuminance and 15-item Geriatric Depression Scale scores. Multiple regression analysis indicated that depression scores were significantly related to age, level of required support, and illuminance. The findings suggest that environments without light and dark cycles increase depression scores in frail elderly people.

Light is believed to affect sleep, mood, and mental health, and it acts on human biological rhythms to regulate the sleep–wake cycle (Honma, Honma, & Hiroshige, 1989). The duration of sunlight varies by season, and the resulting change in the light–dark cycle affects sleeping time (Honma et al., 1989), with later sleeping and waking times and higher rates of insomnia in winter compared with summer (Friborg, Bjorvatn, Amponsah, & Pallesen, 2012; Honma, Honma, Kohsaka, & Fukuda, 1992). Winter depression is also more prevalent in higher latitudes (Mersch, Middendorp, Bouhuys, Beersma, & van den Hoofdakker, 1999), and bright-light therapy has been shown to be effective against winter depression (Golden et al., 2005). Few studies have examined the effects of the amount of light on physical health, but there is evidence that fatigue is greater

Address correspondence to Akie Ichimori, Faculty of Health Sciences, Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University, 5-11-80 Kodatsuno, Kanazawa, Ishikawa 920-0942, Japan. E-mail: ichia@mhs.mp.kanazawa-u.ac.jp

in high latitudes and during winter (Friborg et al., 2012). This suggests that light might be related to physical fatigue.

Most studies on the amount of light, sleep, and physical and mental health have compared seasons and latitudes (Friborg et al., 2012; Mersch et al., 1999), or experimentally manipulated illuminance and the light environment (Kozaki, Miura, Takahashi, & Yasukouchi, 2012; Lack, Wright, & Paynter, 2007; Thorne, Hampton, Morgan, Skene, & Arendt, 2010; Zeitzer, Friedman, & Yesavage, 2011). Relatively few studies have measured illuminance in people's homes and its relationship with sleep and depression.

Research on natural light environments has focused on workers, university students (Hoaki et al., 2011; Smolders, de Kort, & van den Berg, 2013), older people living independently (Campbell, Kripke, Gillin, & Hrubovcak, 1988; Obayashi, Saeki, Iwamoto, Ikada, & Kurumatani, 2013), and those in care facilities (Ancoli-Israel et al., 1997; Mishima, Okawa, Shimizu, & Hishikawa, 2001; Shochat, Martin, Marler, & Ancoli-Israel, 2000). A relationship between the amount of light and mental health has been reported among home-dwelling, frail, older people (Ichimori, Tsukasaki, & Koyama, 2013; Obayashi et al., 2013), but the relationship between light and sleep remains unexamined. One previous study measured the light environment of home-dwelling older people using a stationary luminometer to determine the relationship between mental health and daytime illuminance (Obayashi et al., 2013). However, the relationship between sleep and illuminance in the participants' daily sleep–activity cycle remains unclear.

Japan's Hokuriku region is located on the western side of the middle-northern part of Japan, along the Sea of Japan. In winter, the region receives heavy snowfall and going outdoors can be difficult; sunlight hours are particularly short, compared to other parts of Japan. The daily duration of sunlight in Hokuriku from January to March is 2.9 ± 3.3 hr (Japan Meteorological Agency, 2011), shorter than the 5.9 ± 3.9 hr seen in other regions with the same latitude in eastern Japan.

The time spent inside the home is greater for frail, older people, who require assistance to go outside when daylight is short. These people are likely to spend their time under insufficient light conditions. However, the extent of their illuminance exposure during their activity time is unknown. As the world's most rapidly aging population, Japan is promoting a national preventive health care policy for the elderly that certifies frail, elderly individuals requiring assistance under the nursing care insurance system as requiring level 1 or 2 support (Long-Term Care Insurance Act, 2007). One way to reduce the need for care among older people is to ensure they receive sufficient light in the daytime to maintain proper physical activity, sleep, and mood, even in winter. The aims of this study are to clarify the relationship between subjective sleep quality and psychosomatic health by studying illuminance during activity and while in bed, to demonstrate the effects of illuminance on sleep and health in elderly individuals requiring care, and to investigate ways to prevent the need for care through adjustments to illuminance levels.

MATERIALS AND METHODS

Subjects

We used a convenience sample comprising 49 elderly individuals referred by a comprehensive regional support center for the elderly and a home-care service provider located in Ishikawa

Prefecture in Japan's Hokuriku region. All subjects had been certified as requiring level 1 or 2 support and gave their consent to participate in the study.

This study was approved by the Kanazawa University Medical Ethics Committee (October 28, 2009, Archive number 227 and June 20, 2014, Archive number 227-2).

The survey periods were from February 6 to April 2, 2010; January 16 to March 23, 2011; and February 12 to March 19, 2012. The survey questionnaire was administered by visiting the subjects at their homes over a 3-day period in which they did not have any plans to go out. Each person completed the survey once in one of the aforementioned study periods.

Survey Questionnaire

We visited the subjects' homes and conducted the survey using a questionnaire form that gathered information on key attributes (age, sex, certified support level) and living conditions (lives alone or not; using outpatient service; type of dwelling and ownership status; separation of living room and bedroom; social visits to house by friends, relatives, others; outings other than for welfare/care purposes; and going out during the survey period).

Subjective Sleep Quality

Subjective sleep quality was assessed using the Japanese version of the Pittsburgh Sleep Quality Index (PSQI-J; Doi et al., 2000). The PSQI-J contains 18 questions on sleep disorder severity. The questions are divided into seven components that are scored from 0 to 3 points for a total of 21 points, with a higher score indicating a more severe level of sleep disorder. Doi et al. (2000) reported that a sleep disorder cutoff score of 5.5 provides optimal sensitivity and specificity; therefore, subjects in the present study who scored 6 points or higher were classified as the "poor sleep group" (p. 168). The use of oral sleep medications was determined based on PSQI-J responses.

Psychosomatic Health

Psychosomatic health was evaluated using version 2 of the Short Form 36-Item Health Survey, including physical component summary scores (PCS), and mental component summary scores (MCS; Fukuhara & Suzukamo, 2004). We also used the 15-item Geriatric Depression Scale (GDS15; Lawton, 1975), and classified subjects with a score of 6 or higher as the *poor mental health group*.

Illuminance

Measurement method. Illuminance per minute was measured over a 3-day period using a 3640 illuminance logger (Hioki E. E. Corporation, Nagano, Japan). The measurement accuracy of the logger's light sensor was ±3%, which satisfies the Japan Industrial Standard (JIS) ±5% criterion for general Class A light meters (Hioki E. E. Corporation, 2008). Relative spectral sensitivity in the visible range approached the spectral luminous efficiency of the International Commission on Illumination's standard photometric observer and satisfied the JIS criterion for relative spectral sensitivity in the visible range. The grazing incidence properties satisfied the JIS standard for general Class A light meters (Hioki E. E. Corporation, 2008). Based on this, we determined that the light meter was capable of providing reliable measurements for use in this study.

We selected two measurement points: the location where the subject typically sat in the living room and the pillow on which the subject slept. If the subject had a shared living room and bedroom where he/she both sat and slept, we selected one measurement point. Alternatively, if the subject spent time in a room other than the living room and bedroom, we selected three measurement points. The upper limit for indoor illuminance was set at 2,000 lx to fall within the measurement range of the light meter.

Outdoor illuminance was measured at one point on the roof of a research facility located in the same prefecture to determine illuminance when the subject left the house. Outdoor illuminance was measured during the periods February 26 to March 15, 2010; January 15 to February 7, 2011; February 19 to March 7, 2011; January 31 to February 22, 2012; and March 7 to 29, 2012. Local cloud cover, hours of sunlight, and other general weather conditions were taken into account when calculating outdoor illuminance. The upper measurement limit for outdoor illuminance was set at 20,000 lx.

Calculation of illuminance variables. Data on illuminance per minute were categorized according to the subject's rest–activity cycle. Rest and activity were determined based on the following data: lights on/lights off data, 3-day lifestyle questionnaire, per-minute waveform data from an activity meter attached to the subject's waist (Actimarker; Panasonic Inc., Osaka, Japan), and per-minute waveform data from a wrist watch-type actigraph (AMI Inc., New York, United States).

Average illuminance during activity time and while in bed were calculated. Because we needed to consider the effect of illuminance within the subject's 24-hr circadian cycle as a whole, rather than as individual events, we used the following formula to calculate the rest and activity cycle illuminance ratio. Drawing on the Weber–Fechner law that sensation is proportional to the logarithm of the stimulus intensity, we developed the following logarithm for illuminance:

The ratio index of the mean illuminance during activity time/while in bed (the illuminance ratio) = Log_{10} the mean illuminance during activity time − Log_{10} the mean illuminance while in bed.

Methods of Analysis

We calculated the mean, median, and range of average illuminance during activity time and while in bed during a 3-day period. To analyze the correlation between key attributes—living conditions, the variables of illuminance, subjective sleep quality, and psychosomatic health—we used Student's *t*-test, Welch's *t*-test, the Mann–Whitney *U* test, Pearson's correlation coefficient, and Spearman's rank correlation coefficient.

We also used stepwise multiple regression to analyze variables that exhibited a significant single correlation with illuminance, including their correlation with other variables. Analyses were conducted using JMP® Version 9.0 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Of the 49 elderly individuals who were initially selected to participate in the study, five were excluded because of incomplete data. Analyses were therefore performed using data from the remaining 44 subjects (36 women, 8 men, M age = 82.8 ± 5.3 years, age range = 64–90 years). Nineteen subjects (43.1%) required level 1 support, and 25 required level 2 support (56.9%). Table 1 shows the living conditions of the participants. The mean time spent outdoors (if any) during the measurement period was 269.7 ± 274.0 min (approx. 4 hr 30 min), the median was 175 min (approx. 3 hr), and the range was 42–1,131 min.

TABLE 1
Living Conditions of the Participants (n = 44)

	n *(%)*
Lives alone	
Yes	30 (68.2)
No	14 (31.8)
Using outpatient service	
Yes	26 (59.1)
No	18 (40.9)
Type of dwelling	
Private	36 (81.8)
Communal	8 (18.2)
Type of ownership	
Own home	36 (81.8)
Rent home	8 (18.2)
Separation of living room and bedroom	
Separate rooms	35 (79.5)
Same room	9 (20.5)
Social visit from others	
Yes	33 (75.0)
No	11 (25.0)
Outings other than welfare/care purpose	
Yes	40 (90.0)
No	4 (9.1)
Going out during the survey period	
Yes	31 (70.5)
No	13 (29.5)

TABLE 2
Subjective Sleep and Psychosomatic Health ($n = 44$)

	Mean ± SD	*Median*	*Range*	n	%
PSQI-J (points)	4.9 ± 3.0	4.5	0–13		
SF-36v2PCS (points)	39.2 ± 10.0	39.4	22.2–61.7		
SF-36v2MCS (points)	58.3 ± 7.1	57.8	45.6–78.0		
GDS15 (points)	4.5 ± 2.7	3	0–11		
Use of sleep medication					
Yes				17	38.6
No				27	61.4

Subjective Sleep Quality and Psychosomatic Health

The survey results for subjective sleep quality and psychosomatic health are shown in Table 2. Mean PSQI-J score was 4.9 points, which was lower than the 6-point cutoff indicating poor sleep. In total, 29 subjects (65.9%) were classed as belonging to the good sleep group and the remaining 15 subjects (34.1%) were considered part of the poor sleep group. In response to the PSQI-J question on the use of sleep medication, 17 subjects (38.6%) answered in the affirmative; 27 subjects (61.4%) reported not taking any sleep medications.

The mean score for the PCS physical health index was 39.2 points and the mean score for the MCS mental health index was 58.3 points. The mean GDS15 score was 4.5 points, which was below the 6-point cutoff indicating a tendency toward depression.

Illuminance

Illuminance during activity time and while in bed in elderly individuals certified as requiring care is shown in Table 3. Mean illuminance during activity time exhibited a substantial standard deviation at 988 ± 1005 lx. This was because the subject with the lowest mean score spent all activity time in a very dark indoor environment equivalent to just 15 lx. Subtracting the time spent outdoors from the activity time, mean illuminance solely for time spent indoors was 201 ± 149 lx; the median was 151 lx and the range was 15–618 lx.

Factors Related to Subjective Sleep Quality and Psychosomatic Health

Significant relationships with PSQI-J scores were seen in *lives alone or not* ($p = 0.012$) and *outings other than welfare/care purpose* ($p = 0.032$). Significant relationships with PCS scores were observed for *separation of living room and bedroom* ($p = 0.006$) and *use of sleep medication* ($p = 0.012$). MCS score was not significantly related to any variables. There was also no significant relationship between average illuminance during activity time and while in bed and the variables of sleep quality and psychosomatic health. A significant negative correlation was identified between the illuminance ratio and GDS15 score (Table 4).

Multiple Regression Analysis of Depression Scores

Stepwise multiple regression was performed to identify any relationships between GDS15 score and the following 14 explanatory variables: age, sex, certified support level, number of household members, type of dwelling, dwelling ownership status, separation of living room and bedroom, role within the household, outings other than for welfare/care purposes, going out during the survey period, PSQI-J score, use of sleep medication, PCS score, and the illuminance ratio. For the stepwise method, we selected three explanatory variables: age, certified support level, and the illuminance ratio. The results showed that GDS score was significantly and independently related to the illuminance ratio and age ($R^2 = 0.245$, $p = 0.010$; Table 5).

DISCUSSION

This study demonstrated, for the first time, illuminance levels during activity time and while in bed for elderly individuals requiring support living in the home. Average illuminance during activity time was close to the 1000 lx mark (988 lx). Shochat et al. (2000) reported that average illuminance between 7:00 a.m. and 7:00 p.m. among nursing home residents in the United States was 485 lx; our finding is approximately twice this level. Shochat et al.'s study did not mention the percentage of home residents who went outdoors; in our present study, 70.5% of subjects went outdoors for an average of approximately 4.5 hr. We consider that the high level of average illuminance was influenced by the percentage of individuals who went outdoors and the duration of time they spent outdoors. However, mean illuminance while indoors was just 201 lx, suggesting that prolonged inability to leave the home may have significantly reduced subjects' illuminance exposure.

Obayashi et al. (2013) reported that the median waking illuminance of typical elderly individuals residing at home in the Kansai region of Japan was 349 lx. Median activity time illuminance in our study was higher (538 lx). Our study only targeted frail elderly individuals; therefore, we expected their illuminance exposure to be lower than that of living-independently elderly persons. When measuring outdoor illuminance, we used a light logger that was fixed in a stationary position on the roof of a local research facility and made allowances for weather conditions and other relevant factors, whereas Obayashi et al. used a wrist-watch-type light meter. The disparate

TABLE 3
Illuminance Situations ($n = 44$)

	Mean ± *SD*	*Median*	*Range*
The mean illuminance during activity time (lx)	988 ± 1005	538	15−4101
The mean illuminance while in bed (lx)	5 ± 11	3	1−68
Log_{10} the mean illuminance during activity time	2.7 ± 0.5	2.7	1.2−3.6
Log_{10} the mean illuminance while in bed	0.5 ± 0.3	0.5	0.01−1.8
The ratio index of the mean illuminance during activity time/while in bed	2.2 ± 0.6	2.2	0.7−3.4

TABLE 4
Factors Related to Subjective Sleep and Psychosomatic Health ($n = 44$)

	n	*PSQI Median (mini-max)*	*p-value*	*SF-PCS Mean (SD)*	*p-value*†	*SF-MCS Mean (SD)*	*p-value*†	*GDS15 Median (mini-max)*	*p-value*
Certified support level									
Level 1	19	4 (1–13)	0.756	39.7 (10.3)	0.773	57.4 (6.1)	0.481	5 (1–10)	0.405
Level 2	25	5 (0–12)		38.8 (9.9)		59.0 (7.9)		3 (0–11)	
Lives alone									
Yes	30	5 (0–13)	0.012*	38.5 (10.0)	0.511	57.6 (6.1)	0.379‡	3 (0–11)	0.949
No	14	3 (1–7)		40.7 (10.1)		60.0 (9.0)		4 (1–10)	
Separation of living room and bedroom									
Separate rooms	35	4 (0–13)	0.341	41.3 (9.3)	0.006**	57.8 (6.7)	0.356	3 (1–10)	0.976
Same room	9	5 (2–10)		31.2 (8.9)		60.3 (8.7)		4 (0–11)	
Outings other than welfare/care purpose									
Yes	40	4 (0–12)	0.032*	39.8 (10.2)	0.228	58.5 (7.4)	0.618	3 (0–11)	0.211
No	4	7.5 (5–13)		33.4 (4.7)		56.6 (4.5)		6 (3–7)	
Use of sleep medication									
Users	17	7 (4–13)	< 0.001***	34.5 (9.7)	0.012*	57.9 (8.4)	0.739	4 (1–9)	0.539
Non-users	27	3 (0–8)		42.2 (9.1)		58.6 (6.3)		3 (0–11)	
Age		−0.226§		0.203§		0.238§		−0.182§	
Log_{10} the mean illuminance during activity time		0.074§		0.242¶		−0.020¶		−0.224§	
Log_{10} the mean illuminance while in bed		−0.086§		0.151§		0.187§		0.091§	
The ratio index of the mean illuminance during activity time/while in bed		0.159§		0.224§		−0.146§		−0.302§*	

Note. Mann–Whitney U test, †Student t-test, ‡ Welch's test, § Spearman's rank correlation coefficient, ¶ Pearson's correlation coefficient.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

TABLE 5
The Multiple Regression Analysis of GDS15 ($n = 44$)

	Standard β	*95% Confidence Interval*	p	*VIF*	R^2
The illuminance ratio	−0.364	−0.311 to –0.281	0.02*	1.20	
Age	−0.342	−0.304 to –0.012	0.04*	1.02	0.245
Certified support level [Support level 1]	0.286	−0.054 to 1.625	0.07	1.21	

$^*p < 0.05$.

findings of these two studies could be attributed to differences in factors such as the measurement device, method, and timing, and the duration of time spent outside.

Our study also demonstrated, for the first time, a significant relationship between GDS15 scores and the illuminance ratio. The study by Obayashi et al. (2013) revealed a relationship between nocturnal illuminance and depression risk among typical elderly persons. In addition to insomnia, high blood pressure, habitual sleeping hours, and habitual physical activity, nocturnal illuminance is believed to be a significant risk factor for depression, with individuals who receive $\geq$ 5 lx at night 1.92 times more prone to depression than those who receive $<$ 5 lx. Additionally, individuals exposed to $\geq$ 10 lx for at least 30 min per night are 1.77 times more likely to develop depression than those exposed for less than 30 min (Obayashi et al., 2013). The mean illuminance while in bed in our study was 5 lx. In nocturnal environments where illuminance is less than 200 lx, suppression of melatonin secretion, which contributes to sleep quality, starts to occur (Zeitzer, Dijk, Kronauer, Brown, & Czeisler, 2000). Accordingly, the illuminance level while in bed of subjects in our study was deemed a suitable sleeping environment.

Riemersma-van der Lek et al. (2008) reported that elderly dementia patients in nursing care facilities who received 1000 lx of bright illuminance between the hours of 10:00 a.m. and 6:00 p.m. exhibited a significant improvement in depression scores after 1.5 and 3.5 years. These findings suggest that providing an environment with a light–dark cycle that allows bright illuminance after waking and dark illuminance during sleep may help to maintain mental health in frail, elderly individuals. Our results show a significant relationship between GDS15 scores and the illuminance ratio, and indicate that mean illuminance while indoors was low (201 lx). Our findings indicate the importance of helping frail elderly people living in the community to adjust their illuminance environment properly. We suggest that community health nurses could achieve this by encouraging frail elderly people to spend more time in a bright environment after waking (e.g., to put room lighting on, to spend time outside if the weather is nice) and to sleep in a dark illuminance environment at night. Such interventions may help to maintain the mental health of frail elderly people.

The findings also showed that younger subjects tended to have significantly high GDS15 scores. There was a 26-year age range among subjects in this study; therefore, although the level of required care may be the same across subjects, this substantial age variation may have affected the study results. Further longitudinal research is needed to clarify the effects of the illuminance environment on depression in elderly individuals requiring care.

Our study findings failed to uncover any significant relationship between illuminance and sleep quality assessed by a questionnaire survey. Our study included elderly persons who resided alone or with other elderly individuals; we were unable to use EEG measurements because of the time required to explain the measurement technique and the considerable burden it would have placed on the subjects. The lack of objective EEG sleep quality data was a limitation of this study, and was probably one of the reasons that we were unable to demonstrate a relationship between illuminance and sleep quality. Additionally, because we used a small convenience sample, these results are not generalizable. However, as many previous studies have only examined the relationship between illuminance and sleep in an experimental environment (e.g., Lack et al., 2007; Thorne et al., 2010; Zeitzer et al., 2011), our study was unique in attempting to confirm the relationship between sleep quality and illuminance in the home environment.

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