Scientific Research Publishing

Health, 2023, 15, 281-288
https://www.scirp.org/journal/health
ISSN Online: 1949-5005
ISSN Print: 1949-4998

Effect of False Windows on Light Exposure and Sleep Quality in Hospitalized Patients

Hiroki Onodera[1], Mitsuru Ida[2], Masahiko Kawaguchi[2]

[1]Department of Medical Technology Center, Nara Medical University Hospital, Kashihara, Japan
[2]Department of Anesthesiology, Nara Medical University, Kashihara, Japan
Email: nwnh0131@naramed-u.ac.jp

How to cite this paper: Onodera, H., Ida, M. and Kawaguch, M. (2023) Effect of False Windows on Light Exposure and Sleep Quality in Hospitalized Patients. *Health*, **15**, 281-288.
https://doi.org/10.4236/health.2023.154020

Received: February 26, 2023
Accepted: April 9, 2023
Published: April 12, 2023

Abstract

Purpose: We aimed to investigate the effects of installing false windows next to hospital beds without windows on the amount of light received by patients and their sleep quality. **Methods:** The study included patients admitted to the Department of Neurology at our hospital between September 2020 and August 2021. An Actigraph device was fitted to patients' wrist and their beds to measure the amount of light received and sleep quality. Patients were divided into three groups: bed with a window, aisle bed with a false window, and aisle bed without a window. Mean sleep efficiency (%), mean steps (per day), and the amount of light (lux) received by the patients and beds were measured. **Results:** Valid data were obtained for 48 participants (median age, 66.5 years). There were 23 patients in beds with a window, 13 patients in aisle beds without a false window, and 12 in aisle beds with a false window. No statistically significant differences were found in terms of mean sleep efficiency, number of steps taken, and the amount of light received by the patients ($P > 0.05$); however, difference in the mean amount of light received by the beds at the location of the bed was statistically significant ($P < 0.001$). **Conclusion:** The amount of light that the patient receives is not necessarily affected by the location of the bed or the presence of a false window.

Keywords

Actigraph, False Window, Sleep Efficiency

1. Introduction

Reduced natural light in windowless hospital beds disrupts circadian rhythms and causes sleep disturbances in patients [1]. Several studies have reported the effects of low levels of light exposure in patients in windowless hospital beds. For example, daylight hours have been reported to be reduced in windowless hospital beds [2]. Furthermore, patients staying in windowless rooms in the intensive care unit have been reported to be more prone to delirium than those in rooms with windows [3]. Reports indicate that environments with limited light exposure increase patients' risk of delirium, depression, heart disease, and diabetes due to sleep disturbance [4] [5] [6] [7]. Patients in beds closer (<1.0 m) to a window had better subjective sleep quality than those in beds further away (>3.0 m) from a window [8]. Furthermore, hospital rooms with windows are less stressful, patients are more satisfied [9], and postoperative recovery may be accelerated [10]. Thus, light through windows in hospital rooms is an important aspect for improving patients' satisfaction and recovery. False windows installed on walls can display various outdoor views in windowless hospital rooms and produce psychological effects comparable to those of real windows [11]. However, to the best of our knowledge, the effects of false windows on sleep and light have not yet been fully examined. In this study, false windows were installed next to windowless beds in the neurology department to examine patients' sleep quality and to measure the amount of light received by patients in beds with and without windows.

2. Methods

2.1. Ethical Approval and Informed Consent

This observational study was approved by the Institutional Review Board of Nara Medical University (Kashihara, Nara, Japan; Chairperson Prof. M. Yoshizumi, Approval No. 2520, August 8, 2020). Consent was obtained from all patients in writing and verbally. This study was registered with the UMIN Clinical Trial Registry (UMIN000041022).

2.2. Hospital Environment

Nara Medical University Hospital is located at 34˚30'14''N and 135˚47'32''E. Among the 914 beds in our academic medical center, 57 were available in the neurological ward. The 57 beds included 10 private rooms, one room shared by three patients, and 11 rooms shared by four patients. A false window (Atmoph Window, Atmoph Inc., Kyoto, Japan) was installed next to one of the aisle beds in a room shared by four patients (**Figure 1**, ③) [12]. The false window displayed scenery from a web camera installed on the roof of the hospital in real time from 7 am to 7 pm. The false window was turned on and off according to the patients' requests.

2.3. Patient Selection

This observational study was conducted at Nara Medical University between September 2020 and August 2021 in patients aged > 20 years who were admitted to four-bedded rooms with a false window in the neurology ward of the hospital. Exclusion criteria were patients who could not understand Japanese, patients

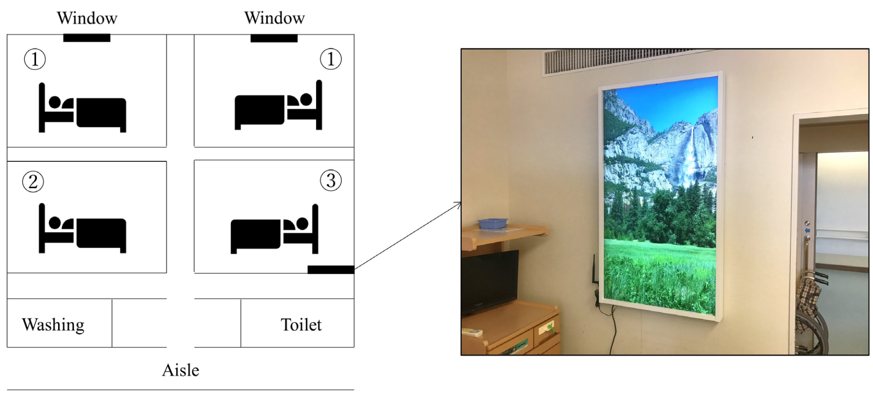


Figure 1. Rooms were shared by four patients and the beds were assigned numbers according to their location as follows: ①: Window side. The distance between window and bed is 80 cm. ②: Aisle side without false window. The distance between window and bed is 330 cm. ③: Aisle side with false window. The distance between false window and bed is 70 cm. The spaces between beds were separated using a curtain and bed three had a false window.

who did not provide written informed consent, patients with a Mini-Mental State Examination score < 20 [13], and patients who spent all day in bed and needed assistance with toileting, eating, and dressing (C1 and C2 level of independence) [14]. The flow of participants is shown in **Figure 2**.

2.4. Actigraph

Polysomnography (PSG) is the gold standard for sleep assessment; however, this requires the individual to sleep in a monitoring room, which may be distressing. The Actigraph is worn mainly on the wrist, and it does not measure sleep per se, but rather it records levels of physical activity, which is highly correlated with sleep [15]. Compared with PSG, the Actigraph can record activity, amount of light, and sleep quality for a longer period, allowing the evaluation of natural sleep, and can differentiate between sleep and wakefulness with an accuracy of >80% [16]. An Actigraph device was attached to the patient's non-dominant arm and bed on admission for testing (**Figure 3**), and the data were collected at the time of discharge. Actigraph data were collected using an Actigraph wGT3X-BT device (ActiGraph™; ActiGraph, Pensacola, FL, USA). The collected data were analyzed using ActiLife6 software (Version 6.13.4, ActiGraph), and Cole-Kripke was used as the analysis algorithm [17]. The Actigraph was configured to collect activity in 60 s epochs. Mean sleep efficiency (SE; %) steps taken during the measurement period, and amount of light received by the device and beds (lux) from 7 am to 7 pm were measured using the Actigraph device. SE was measured as the ratio of the total sleep time from bedtime to waking to the time determined to be sleep by the algorithm.

2.5. Outcomes

The primary outcomes were the patients' sleep efficiency and amount of light

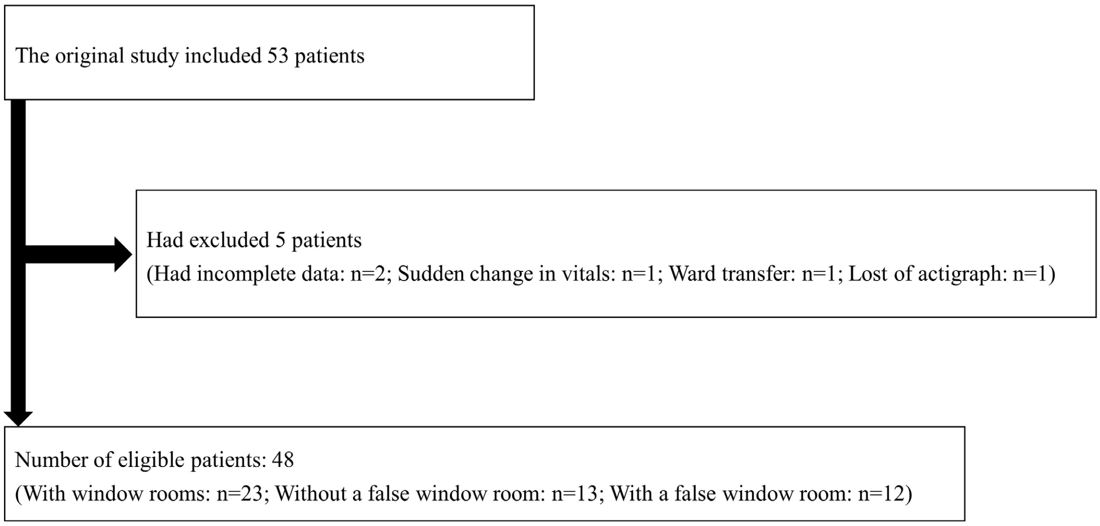
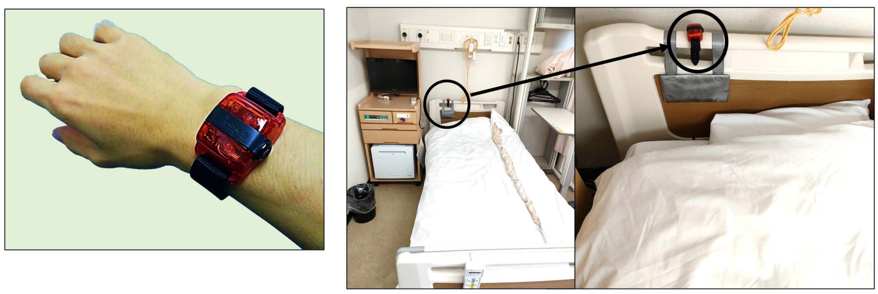


Figure 2. Flow of participants included in the study.



(a) (b)

Figure 3. Actigraph. (a) Patient wearing an Actigraph on the wrist of their non-dominant arm. (b) The Actigraph was located at the head end of the bed.

received. The secondary outcomes were the number of steps and amount of light received by the bed.

2.6. Statistical Analysis

Continuous data are presented as mean [standard deviation (SD)] and categorical variables are presented as numbers. The participants were divided according to the room and window into three groups (**Figure 1**): bed with a window; aisle bed with a false window, and aisle bed without a window. The mean sleep efficiency (%), mean steps (/day), and mean amount of light (lux) received by the patients and beds were determined using one-way analysis of variance (ANOVA) using EZR (version 1.54). All P values < 0.05 were considered statistically significant.

3. Results

Among 53 eligible patients, 48 (31 males and 17 females) were analyzed and valid data were obtained. Among the included patients included, 23 were in beds with windows, 13 in aisle beds without a false window, and 12 in aisle beds with a false window (**Figure 3**). Five patients were excluded, including two with incomplete data, one with a sudden change in condition, one transferred to a hospital room, and one with lost equipment.

The patient data are presented in **Table 1**. The 48 patients had a mean age of 64.4 ± 12.8 years, mean body mass index 22.5 ± 4.4 kg/m^2, and were predominantly male (64.6%). The mean length of the hospital stay was 17.3 ± 9.4 days. None of the patients had a Mini-Mental State Examination score of <20 and C1 or C2 levels of independence.

The Actilife analysis data are presented in **Table 2**. The mean sleep efficiency was 87.1% ± 5.5% for patients in beds with a window, 86% ± 4.6% for patients is aisle beds without a false window, and 84.4% ± 5.3% for patients in aisle beds with a false window ($P = 0.33$). The mean amount of light received by the patient was 58.6 ± 45.0 lux in beds with a window, 30.9 ± 51.1 lux in aisle beds without a

Table 1. Patient data at hospital admission and discharge.

Mean (SD)	**Window side (n = 23)**	**Aisle side without false window (n = 13)**	**Aisle side with false window (n = 12)**
Sex (male/female), n	7/16	8/5	7/5
Age (years), mean (SD)	63.4 (14.9)	68.2 (13.8)	61.5 (9.7)
BMI (kg/m^2), mean (SD)	22.9 (5.6)	21.2 (4.8)	23.4 (2.7)
Length of hospital stay (days), mean (SD)	14 (5.4)	18 (9.4)	20 (13.5)
Level of independence	J1/J2 = 6/5 A1/A2 = 4/4 B1/B2 = 3/1	J1/J2 = 5/4 A1/A2 = 0/3 B1/B2 = 0/0	J1/J2 = 3/2 A1/A2 = 2/3 B1/B2 = 1/2
Mini-Mental State Examination, mean (SD)	26.8 (2.9)	26.4 (3.1)	27.8 (2.2)

BMI, Body Mass Index; SD, Standard Deviation. J1: The patient can go out by using public transportation, J2: The patient can go out in the neighborhood, A1: The patient goes out with assistance and is mostly out of bed during the day, A2: The patient goes out infrequently and alternates between sleeping and being out of bed during the day, B1: The patient can transfer to the wheelchair, as well as eat and excrete away from the bed, B2: The patient transfers to the wheelchair with assistance, C1: The patient can roll over, C2: The patient cannot roll over.

Table 2. Actilife analysis data.

Mean (SD)	Window side (n = 23)	Aisle side without false window (n = 13)	Aisle side with false window (n = 12)	*P*-value
Sleep efficiency (%), mean (SD)	87.1 (5.5)	86 (4.6)	84.4 (5.3)	0.33
Steps (/day), mean (SD)	5711 (3506)	5144 (2762)	5896 (1267)	0.78
Patient light exposure (lux), mean (SD)	58.6 (45.0)	30.9 (51.1)	32.0 (23.0)	0.10
Light exposure of hospital beds (lux), mean (SD)	15 (8.9)	6.3 (10.8)	2.3 (2.2)	<0.001

SD, Standard Deviation. Window side, the distance between window and bed is 80 cm; Aisle side without false window, the distance between window and bed is 330 cm; Aisle side with false window, the distance between false window and bed is 70 cm.

false window, and 32.0 ± 23.0 lux in aisle beds with a false window ($P = 0.10$). Mean steps (per day) were 5583.7 ± 2511.7 ($P = 0.78$). The mean amount of light at the hospital beds was 7.9 ± 21.9 lux ($P < 0.001$).

4. Discussion

In this study, there were no statistically significant differences in the amount of light received by patients or sleep efficiency among the three different bed groups. Previous studies reported that the mean amount of light received by hospital patients was 61.8 - 104.8 lux [18] [19]. In the present study, the amount of light received by all the hospital beds (window and aisle with or without a false window) was lower than previously reported. While the reason for this is unclear, it may be associated with the coronavirus disease pandemic, which limited patients' number of steps in hospitals. We hypothesized that greater amounts of light would enhance sleep efficiency; however, there was no significant difference among the three groups, with similar amounts of light and high sleep efficiency in all the groups. Other factors contributing to this high sleep efficiency could be explained by all groups having 5000 - 6000 steps. Typical daily activity is around 5000 - 7499 steps/day [20], and a higher number of steps is associated with greater sleep quality [21] [22]. The amount of light and steps did not differ among the three groups, which may be because these were influenced by activities that were not assessed in this study, including going to the examination room. The patients were able to switch the false window on and off, and it is possible that the amount of light was significantly lower because of the length of time it was turned off. In this study, Atmoph was used as the false window, but it has also been suggested that artificial skylight rooms (CoeLux ST and CoeLux S.r.L), which are close to natural light, may be better suited for controlling circadian rhythm [23]. This study has some limitations. First, this was a single-center study and caution should be exercised when generalizing these results. Second, the conditions for measuring the amount of light received were not standardized, and the amount of light received varied depending on the season and weather conditions [24]. Third, we did not measure the patient's lifestyle before admission, and lifestyle and medications taken prior to hospitalization may have influenced the results of the sleep and function assessments [25] [26].

5. Conclusion

There were no statistically significant differences in the amount of light received by the patients or the mean sleep efficiency between the bed groups, as defined by the presence of a window or the presence or absence of a false window. We believe that the amount of exposure to light while active without lying down leads to good sleep quality, even in patients in beds with windows.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Küller, R. (2002) The Influence of Light on Circarhythms in Humans. *Journal of Physiological Anthropology and Applied Human Science*, **21**, 87-91. https://doi.org/10.2114/jpa.21.87

[2] Iwamoto, J., Obayashi, K., Kobayashi, M., Kotsuji, T., Matsui, R., Ito, K., *et al.* (2018) Decreased Daytime Light Intensity at Nonwindow Hospital Beds: Comparisons with Light Intensity at Window Hospital Beds and Light Exposure in Nonhospitalized Elderly Individuals. *Chronobiology International*, **35**, 719-723. https://doi.org/10.1080/07420528.2018.1430036

[3] Lee, H.J., Bae, E., Lee, H.Y., Lee, S.M. and Lee, J. (2021) Association of Natural Light Exposure and Delirium According to the Presence or Absence of Windows in the Intensive Care Unit. *Acute and Critical Care*, **36**, 332-341. https://doi.org/10.4266/acc.2021.00556

[4] Fadayomi, A.B., Ibala, R., Bilotta, F., Westover, M.B. and Akeju O. (2018) A Systematic Review and Meta-Analysis Examining the Impact of Sleep Disturbance on Postoperative Delirium. *Critical Care Medicine*, **46**, e1204-e1212. https://doi.org/10.1097/CCM.0000000000003400

[5] Baglioni, C., Battagliese, G., Feige, B., Spiegelhalder, K., Nissen, C., Voderholzer, U., *et al.* (2011) Insomnia as a Predictor of Depression: A Meta-Analytic Evaluation of Longitudinal Epidemiological Studies. *Journal of Affective Disorders*, **135**, 10-19. https://doi.org/10.1016/j.jad.2011.01.011

[6] Morris, C.J., Purvis, T.E., Hu, K. and Scheer, F.A. (2016) Circadian Misalignment Increases Cardiovascular Disease Risk Factors in Humans. *Proceedings of the National Academy of Sciences of the United States of America*, **113**, E1402-E1411. https://doi.org/10.1073/pnas.1516953113

[7] Schipper, S.B.J., Van Veen, M.M., Elders, P.J.M., van Straten, A., Van Der Werf, Y.D., Knutson, K.L., *et al.* (2021) Sleep Disorders in People with Type 2 Diabetes and Associated Health Outcomes: A Review of the Literature. *Diabetologia*, **64**, 2367-2377. https://doi.org/10.1007/s00125-021-05541-0

[8] Bano, M., Chiaromanni, F., Corrias, M., Turco, M., De Rui, M., Amodio, P., *et al.* (2014) The Influence of Environmental Factors on Sleep Quality in Hospitalized Medical Patients. *Frontiers in Neurology*, **5**, Article 267. https://doi.org/10.3389/fneur.2014.00267

[9] Mihandoust, S., Joseph, A., Kennedy, S., MacNaughton, P. and Woo, M. (2021) Exploring the Relationship between Window View Quantity, Quality, and Ratings of Care in the Hospital. *International Journal of Environmental Research and Public Health*, **18**, Article 10677. https://doi.org/10.3390/ijerph182010677

[10] Ulrich, R.S. (1984) View through a Window May Influence Recovery from Surgery. *Science*, **224**, 420-421. https://doi.org/10.1126/science.6143402

[11] Inoue, S., Takezawa, E. and Kawaguchi, M. (2020) Effective Medical Creation (EMC)—A New Approach to Improvement of Patient Management in the Standpoint of Hospital Room Environment. *Open Journal of Anesthesiology*, **10**, 409-421. https://doi.org/10.4236/ojanes.2020.1012036

[12] Miki, M. and Sato, K. (2012) A Research for the Effectiveness of False Windows in the Office. *The 35th Symposium for Information*, *System*, *Utility*, *Technology*, Tokyo, 13 December 2012, H34, 1-40.

[13] Folstein, M.F., Folstein, S.E. and McHugh, P.R. (1975) "Mini-Mental State". A Practical Method for Grading the Cognitive State of Patients for the Clinician. *Journal of Psychiatric Research*, **12**, 189-198. https://doi.org/10.1016/0022-3956(75)90026-6

[14] Tsuboi, A., Murakami Tsuneji, K.H., Shimizu, J. and Fujiwara, N. (2002) Relationship between Criteria for Evaluating the Degree of Independence of Disabled Elderly Persons in Performing Activities of Daily Living. *Journal of the Japanese Occupational Therapy Association*, **21**, 455-462.

[15] Fekedulegn, D., Andrew, M.E., Shi, M., Violanti, J.M., Knox, S. and Innes, K.E. (2020) Actigraphy-Based Assessment of Sleep Parameters. *Annals of Work Exposures and Health*, **64**, 350-367. https://doi.org/10.1093/annweh/wxaa007

[16] Marino, M., Li, Y., Rueschman, M.N., Winkelman, J.W., Ellenbogen, J.M., Solet, J.M., *et al.* (2013) Measuring Sleep: Accuracy, Sensitivity, and Specificity of Wrist Actigraphy Compared to Polysomnography. *Sleep*, **36**, 1747-1755. https://doi.org/10.5665/sleep.3142

[17] Cole, R.J., Kripke, D.F., Gruen, W., Mullaney, D.J. and Gillin, J.C. (1992) Automatic Sleep/Wake Identification from Wrist Activity. *Sleep*, **15**, 461-469. https://doi.org/10.1093/sleep/15.5.461

[18] Bernhofer, E.I., Higgins, P.A., Daly, B.J., Burant, C.J. and Hornick T.R. (2014) Hospital Lighting and Its Association with Sleep, Mood and Pain in Medical Inpatients. *Journal of Advanced Nursing*, **70**, 1164-1173. https://doi.org/10.1111/jan.12282

[19] Kopp, B.T., Hayes Jr, D., Ratkiewicz, M., Baron, N. and Splaingard, M. (2013) Light Exposure and Depression in Hospitalized Adult Patients with Cystic Fibrosis. *Journal of Affective Disorders*, **150**, 585-589. https://doi.org/10.1016/j.jad.2013.02.014

[20] Tudor-Locke, C. and Bassett, D.R. (2004) How Many Steps/Day Are Enough? Preliminary Pedometer Indices for Public Health. *Sports Medicine*, **34**, 1-8. https://doi.org/10.2165/00007256-200434010-00001

[21] Kimura, N., Aso, Y., Yabuuchi, K. and Matsubara, E. (2020) Association between Objectively Measured Walking Steps and Sleep in Community-Dwelling Older Adults: A Prospective Cohort Study. *PLOS ONE*, **15**, e0243910. https://doi.org/10.1371/journal.pone.0243910

[22] Greysen, S.R., Waddell, K.J. and Patel, M.S. (2022) Exploring Wearables to Focus on the "Sweet Spot" of Physical Activity and Sleep after Hospitalization: Secondary Analysis. *JMIR mHealth and uHealth*, **10**, e30089. https://doi.org/10.2196/30089

[23] Yasukouchi, A., Maeda, T., Hara, K. and Furuune, H. (2019) Non-Visual Effects of Diurnal Exposure to an Artificial Skylight, Including Nocturnal Melatonin Suppression. *Journal of Physiological Anthropology*, **38**, Article No. 10. https://doi.org/10.1186/s40101-019-0203-4

[24] Nioi, A., Roe, J., Gow, A., McNair, D. and Aspinall, P. (2017) Seasonal Differences in Light Exposure and the Associations with Health and Well-Being in Older Adults: An Exploratory Study. *HERD*, **10**, 64-79. https://doi.org/10.1177/1937586717697650

[25] Altman, M.T., Knauert, M.P. and Pisani, M.A. (2017) Sleep Disturbance after Hospitalization and Critical Illness: A Systematic Review. *Annals of the American Thoracic Society*, **14**, 1457-1468. https://doi.org/10.1513/AnnalsATS.201702-148SR

[26] Admi, H., Shadmi, E., Baruch, H. and Zisberg, A. (2015) From Research to Reality: Minimizing the Effects of Hospitalization on Older Adults. *Rambam Maimonides Medical Journal*, **6**, e0017. https://doi.org/10.5041/RMMJ.10201