Glycative Stress Research

Online edition : ISSN 2188-3610
Print edition : ISSN 2188-3602
Received : November 27, 2020
Accepted : April 5, 2020
Published online : June 30, 2020
doi:10.24659/gsr.7.2_123

Original article

Effect of the newly developed articulatory panels (Aural Sonic): A pilot clinical trial.

Manabu Fukushima [1)], Shiori Uenaka [2)], Masayuki Yagi [2)], Wakako Takabe [1)], Yoshikazu Yonei [1)],

1) Department of Media Technologies, School of Engineering, Nippon Bunri University, Oita, Japan
2) Anti-Aging Medical Research Center and Glycative Stress Research Center, Faculty of Life and Medical Sciences, Doshisha University, Kyoto, Japan

Abstract

***Purpose*:** Since the articulation panel (Aural Sonic^{R}) has a characteristic of absorbing unpleasant sound and leaving a comfortable sound, stress reduction and relaxation effects are expected. In this study, we examined the effect of the installation of the articulator panel (test product) in the bedroom on sleep quality using the melatonin metabolite 6-sulfatoxy-melatonin (SaMT) as an index.

***Methods*:** The first trial was an uncontrolled open pilot study of 10 male students (26.4 ± 8.7 years), in which a test panel was set up in the bedroom at home. The second trial was performed as a controlled shift comparison trial of 6 male and one female students (27.3 ± 11.6 years), in which SaMT was measured at a training camp facility with a constant sleep environment while monitoring illuminance and temperature with a sleep environment measurement device, then the effect between the control and test panel was compared.

***Results*:** In the first trial, the amount of urine discharged SaMT during the night was −13.4% lower when using the test panel ($p = 0.046$), which was determined to be due to the difference in illumination conditions. In the second test, it was confirmed that illuminance and temperature were constant, the 24-hour urinary SaMT concentration was significantly higher (+54.7%) when using the test panel (38.2 ± 5.6 ng/mL) than when using the control panel (24.7 ± 2.3 ng/mL, $p = 0.028$).

***Conclusion*:** It was suggested that the installation of the articulation panel in the bedroom could improve the sleep quality with increased melatonin excretion, due to the reduction of unpleasant noise, improving sleep environment. Since melatonin secretion is affected by the sleep environment, it is necessary to evaluate it under constant conditions such as room temperature and illuminance.

***KEY WORDS*:** articulation material, sleep quality, melatonin, 6-sulfatoxy-melatonin (SaMT)

Introduction

The drop of the quality of sleep is one of the age-related deteriorations. The Japanese have a tendency towards a chronic lack of sleep from children to adults [1-3)]. Indefinite complaints due to lack of sleep are common not only in middle-aged people but also in childhood and puberty, which is associated with various lifestyle-related diseases and mental health issues [4-8)]. Maintaining high sleep quality is very important from a viewpoint of preventive medicine.

There is a bidirectional link between sleep and glucose metabolism. Approximately 40% of patients with diabetes, a representative disease with high glycation stress, have some sleep disorders [9, 10)]. Obesity [11-13)] and diabetes [14-16)] are frequently associated with sleep apnea syndrome (SAS), a typical disorder with poor sleep quality. In order to reduce glycation stress, it is necessary to concurrently consider the prevention and treatment of abnormal glucose metabolism and sleep disorders.

A comfortable environment is important to keep our sleep quality high. In addition to temperature, humidity, and illuminance, it is desirable to use moderate load exercise [17)]

Corresponding to: Manabu Fukushima, PhD
Department of Media Technologies, School of Engineering, Nippon Bunri University
1727 Ichigi, Oita, 870-0397 Japan
TEL: +81-97-524-2748 FAX: +81-97-592-0911 e-mail: fukushima@nbu.ac.jp
Co-authors: Uenaka S, ctud2025@mail4.doshisha.ac.jp; Yagi M, myagi@mail.doshsisha.ac.jp;
Takabe W, wtakabe@mail.doshsisha.ac.jp; Yonei Y, yyonei@mail.doshsisha.ac.jp

and bedding suitable for individual conditions[18-20]. In addition, noise is one of the factors that hinder sleep. Noise reduces sleep quality, while a completely silent environment, sometimes worrying about heartbeat, may interfere with falling asleep.

It is expected that a soothing sound will provide a comfortable sleep, however, there are many unclear points about the sound, wavelength, sound pressure, and wavelength fluctuation. In recent years, low frequency noise generated from wind power generation, "eco cute", and the like has also become a problem, countermeasures against which are an issue. In the present study, we have used a panel with acoustic characteristics that absorbs unpleasant sounds and reflects comfortable sounds (Aural Sonic™: Tokyo Steel Industrial Co., Ltd., Kita-ku, Tokyo, Japan)[21], and the effect of the panel on sleep quality was examined.

Method

1. An open-label, uncontrolled pilot study (measured at home).

The test subjects were 10 healthy male students of Nippon Bunri University, and the effect of using the test panel[21] at home on sleep was verified. The test panels were provided by Tokyo Steel Industrial Co., Ltd. Subjects were 26.4 ± 8.7 years of age, 169.3 ± 6.9 cm of height, 63.8 ± 10.2 kg of body weight, and 22.2 ± 2.7 kg/m^2 of body mass index (BMI). Two test days were set during the test period from January to March in 2017, and the following items were compared with respect to the effects of sleep when the test panel was used and when it was not used. Examination items included a background survey, blood pressure, body composition (body weight, body fat percentage), 6-sulfatoxy-melatonin (SaMT)[22] as a melatonin metaboliteand creatinine (Cre) in the nocturnal urinary bladder storage specimen (early morning first urine), which were measured by LSI Medience (Chiyoda-ku, Tokyo, Japan). Regarding the early morning first urine, the urine volume and the time duration of urinary bladder storage (from the time of the last urine to time of the first urine in the next day) were recorded. The indicated parameters (degree of sleep / sleep time) by Sleep Cycle^R were also compared. Sleep Cycle^R (Sleep Cycle AB, Gothenburg, Sweden) was downloaded and used in a smart phone equipped with a 3 dimension acceleration sensor. There were no dropouts, and all cases were analyzed.

2. Control shift comparison test with illumination monitoring (measured at the camp facility).

The illuminance in the bedroom after the lights were turned off was set to a constant condition so that the illuminance during sleep did not affect melatonin secretion, and the test was conducted using control panels and test panels. The sleep environment (temperature, illuminance, floor vibration) was measured over time using a self-made sleep environment measurement device.

As a control panel, a panel similar in appearance to the test panel and having no articulation function was used. Subjects were 6 (5 males and 1 female), 27.3 ± 11.6 years of age, 170.5 ± 8.1 cm of height, 61.7 ± 11.5 kg of body weight, and 21.1 ± 2.9 kg/m^2 of BMI.

In September 2017, we had a three-night four-day training camp and the study was performed at the accommodation facility of the university (***Fig. 1***). Among the measurement items, SaMT was measured using first morning urine samples and 24-hour urine samples, the rest was the same as the previous study "**1. An open-label, uncontrolled pilot study**". There were no dropouts, and all cases were analyzed.

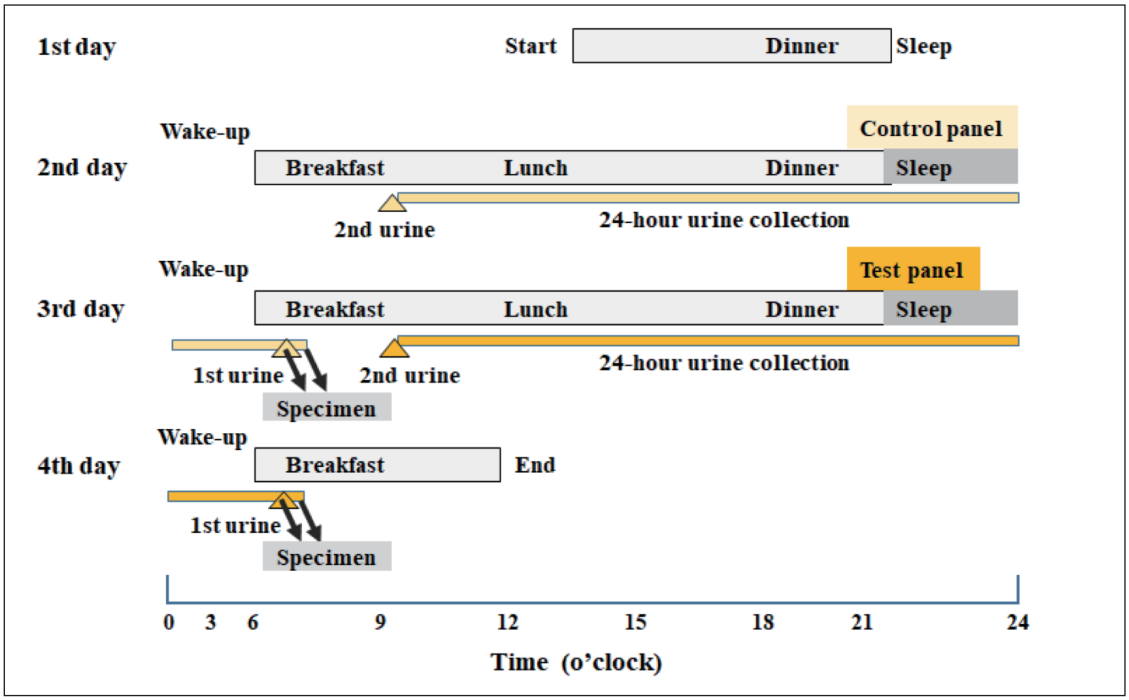

Fig. 1. **Test schedule: Second test**

Sleep environment measurement device

Figure 2 shows the configuration of the device. In the device, a temperature sensor, an illuminance sensor, and an acceleration sensor were connected to the main unit, measured information was transmitted to a remote monitor via WiFi, and recorded on a USB memory stick connected to the remote monitor. In order not to disturb the sleep environment, a sensor was attached to my RIO and housed in a wooden case (***Fig. 3***). The equipment was set at the bedside and the remote monitor was located in a separate room.

Ethical considerations

This study was conducted as an exercise-style course as part of a university education program. Participating students chose this subject voluntarily and participated in the practice of assembling the sleep environment measurement device and in the practical training of environment measurement. No invasive tests were performed. The participants were informed about the ethics of this research.

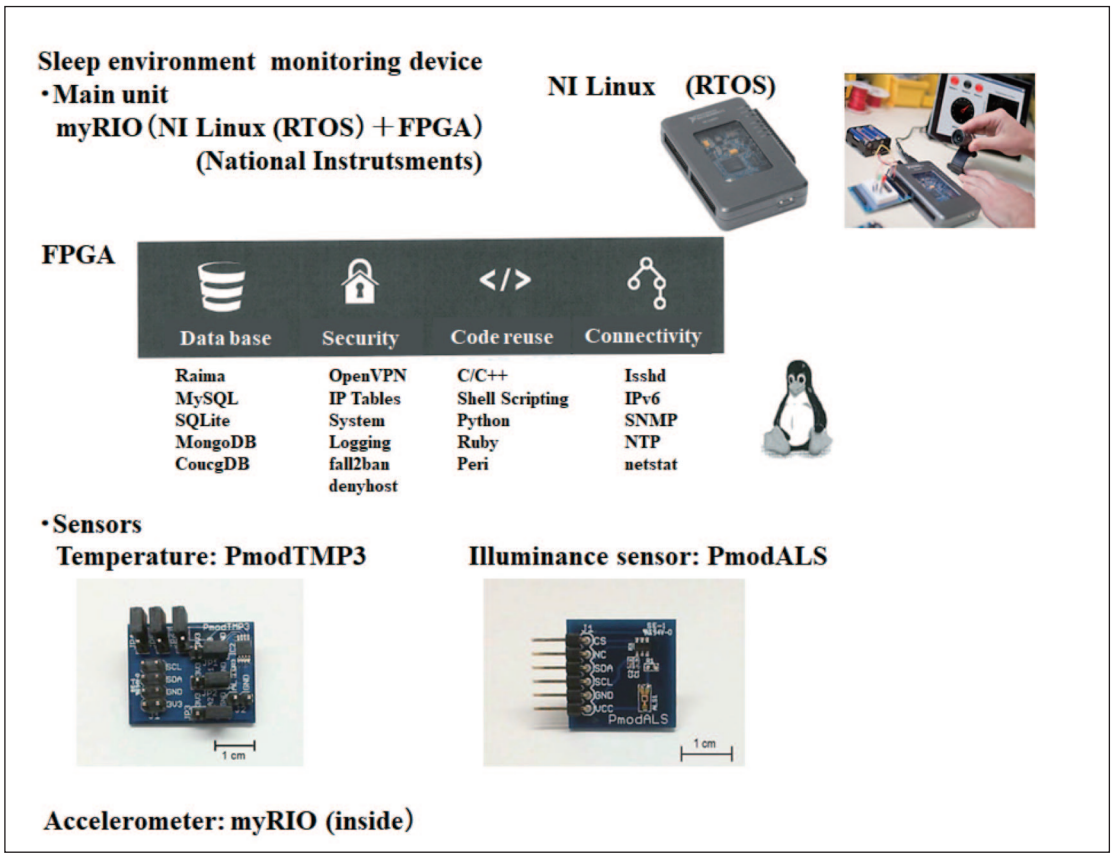

Fig. 2. **The configuration of the sleep environment monitering device**

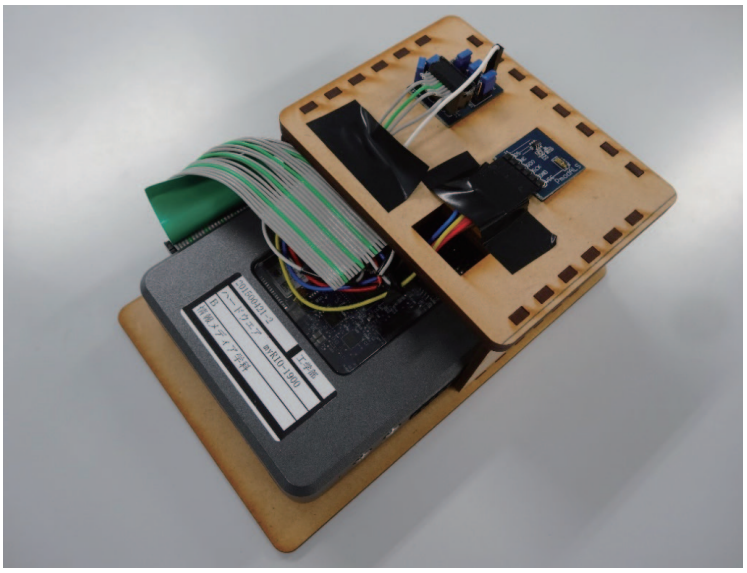

Fig. 3. **A picture of the sleep environment monitering device**

Statistical analysis

A paired t-test when the number was 10 or more, and a Wilcoxon signed rank test when the number was less than 10, were used for comparative analysis, which was performed by using SPSS Statics25 (IBM Japan, Minato-ku, Tokyo, Japan).

Results

1. An open-label, uncontrolled pilot study (measured at home).

Figure 4 shows the results of urine SaMT concentration corrected by Cre (ng/mg Cre), urinary discharged SaMT (urine SaMT [ng/mL] × the volume of the first urine[mL] / storage time [h]) and sleep duration with and without using the test panel. Urine dischaged SaMT with the test panel (1,905 ± 172 ng/hr) was siginificantly lower (–13.4%) than that without the panel (2,199 ± 150 ng/hr, p = 0.046). There were no significant difference in SaMT concentration or sleep duration.

Comparison analysis was also performed on the parameter indicated by Sleep Cycle^{R} (***Fig. 5***). There were no significant differences in pleasant sleep index or sleep duration.

2. Control shift comparison test with illumination monitoring (measured at the camp facility).

Figures 6 & 7 show the result image of "Sleep Cycle^{R}" and monitored data of room temperature and illumination of each subject. Temperature changes were similar in all bedrooms. The illuminance in the bedroom was kept below 2 lux while the lights were off. The sleep environment on the second and third days was almost the same.

Figure 8 shows results of the urine SaMT concentration corrected by Cre, SaMT in 24-hour urine samples, urinary discharged SaMT (urine SaMT [ng/mL] × the volume of the first urine [mL] / storage time [h]), and sleep duration using the control panel and the test panel. SaMT in 24-hour urine samples using the test panel (38.2 ± 5.6 ng/mL) was significantly higher (+54.7%) than that using the control panel (24.7 ± 2.3 ng/mL, p = 0.028).

There were no significant differences in pleasant sleep index or sleep duration indicated by Sleep Cycle^{R} between the conditions using the test panel and the control panel (***Fig. 9***).

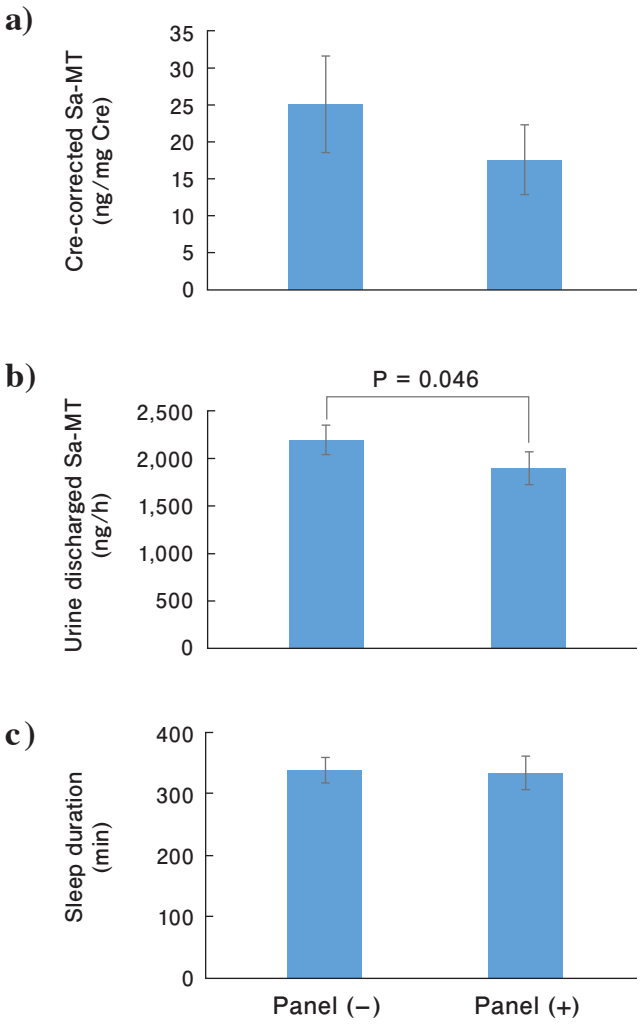

Fig. 4. **Urine SaMT: First test**

a) Urine SaMT consentration corrected by Cre. **b)** Urine discharged SaMT. **c)** Sleep duration. Results are expresses as mean ± SEM, n = 10, paired t test. SaMT, 6-sulfatoxymelatonin, one of melatonin metabolites; Cre, creatinine; SEM, standard error mean.

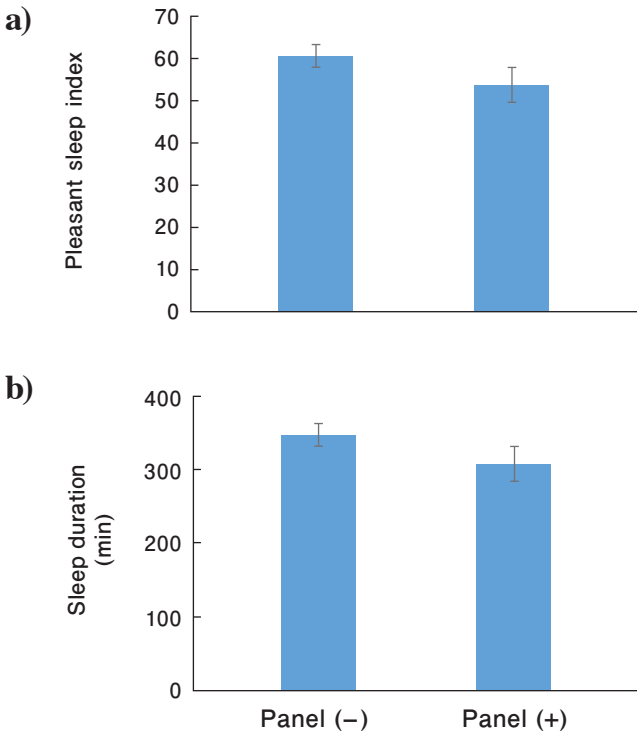

Fig. 5. **"Pleasant sleep index" and "Sleep duration" by "Sleep Cycle^{R}": First test**

a) "Pleasant sleep index". **b)** "Sleep duration". Parameters are analyzed by "Sleep Cycle^{R}". Results are expresses as mean ± SEM, n = 8. Two cases excluded due to the unclear image data from Sleep Cycle^{R}. SEM, standard error mean.

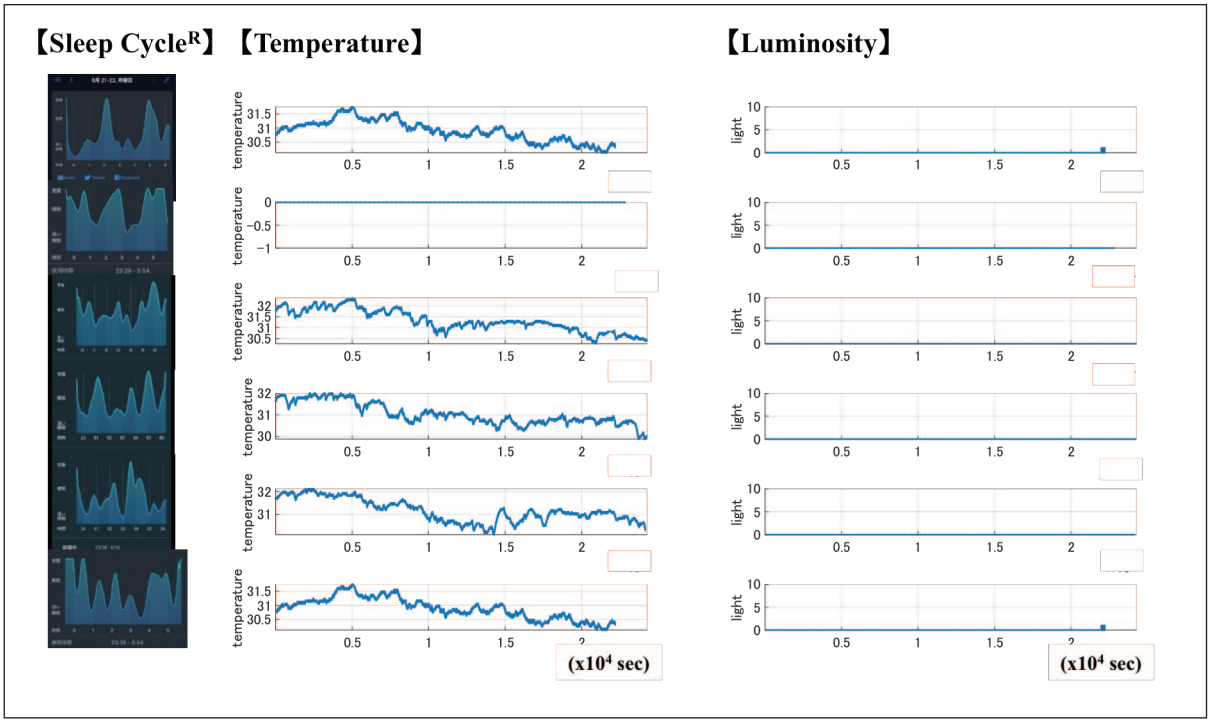

Fig. 6. **The sleep environment data in the 2nd day monitering with control panels: Second test**

a) "Sleep Cycle[R]" image graph. **b)** Temperature. **c)** Luminosity. Temperature and luminosity measured by the sleep environment monitering device.

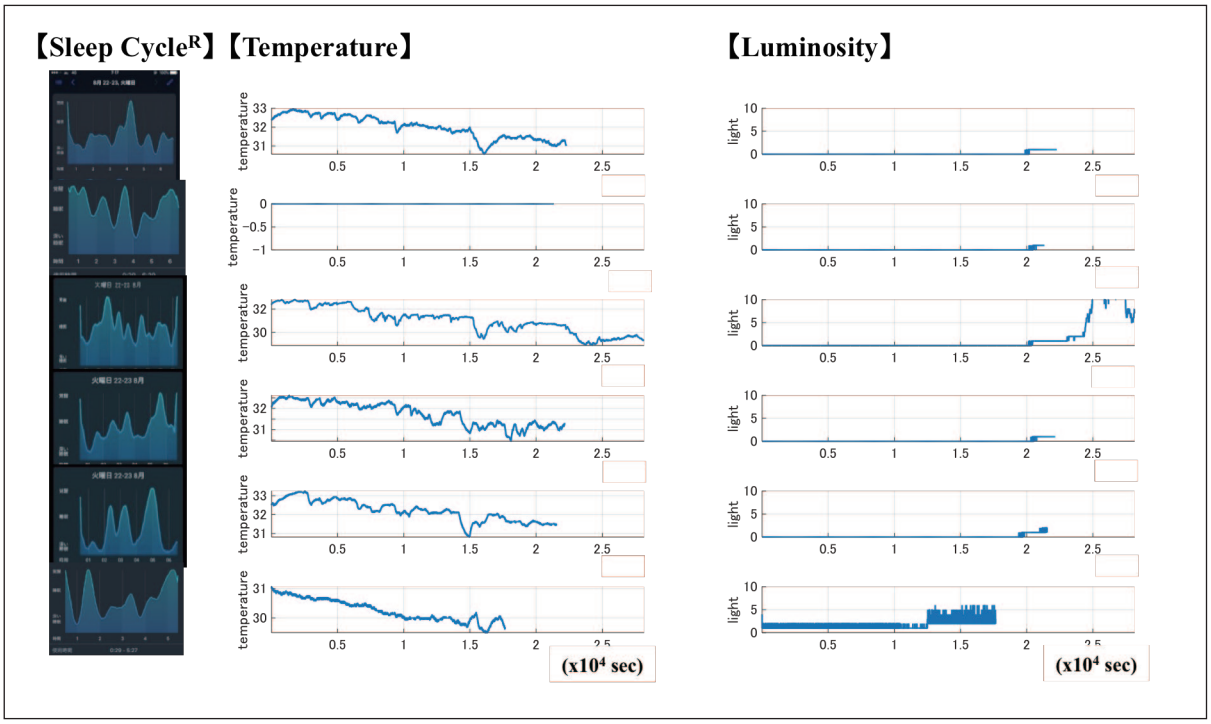

Fig. 7. **The sleep environment data in the 3rd day monitering with test panels: Second test**

a) "Sleep Cycle[R]" image graph. **b)** Temperature. **c)** Luminosity. Temperature and luminosity measured by the sleep environment monitering device.

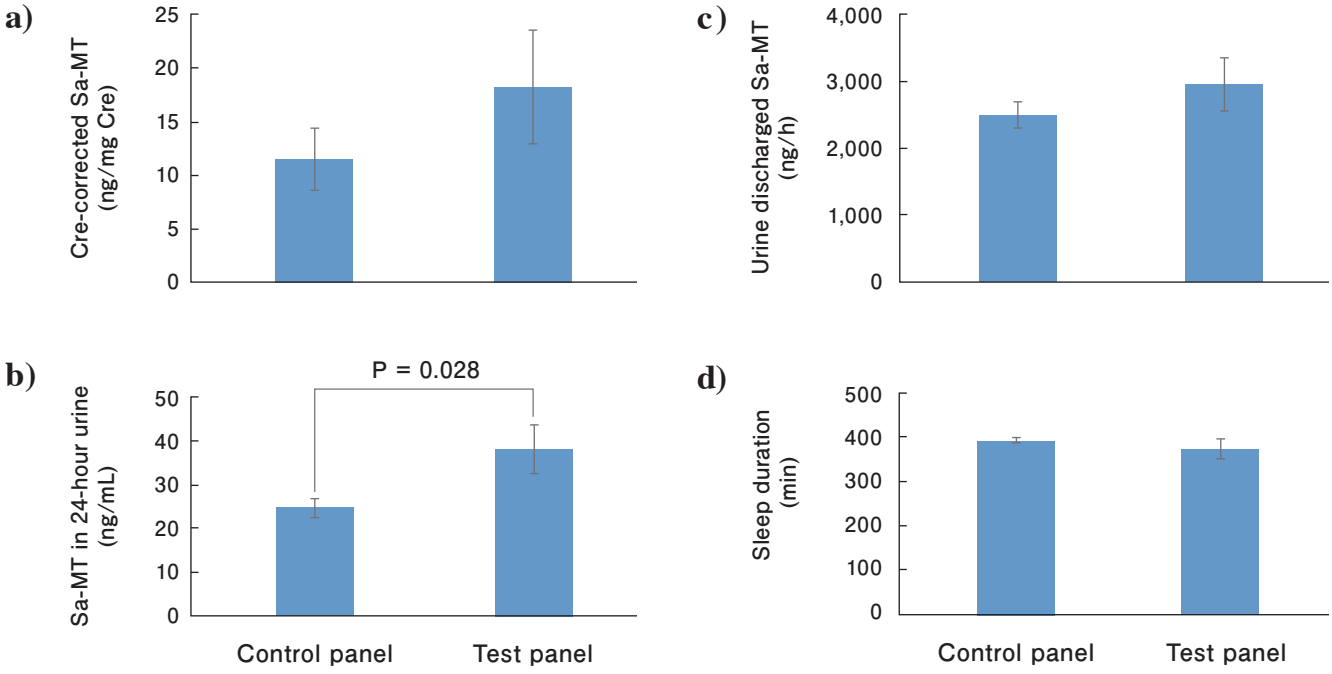

Fig. 8. **Urine SaMT: Second test**

a) Urine SaMT consentration corrected by Cre. **b)** SaMT concentration in 24-hour urine. **c)** Urine discharged SaMT. **d)** Sleep duration. Results are expresses as mean ± SEM, n = 6, Wilcoxon signed-rank test. SaMT, 6-sulfatoxymelatonin, one of melatonin metabolites; Cre, creatinine; SEM, standard error mean.

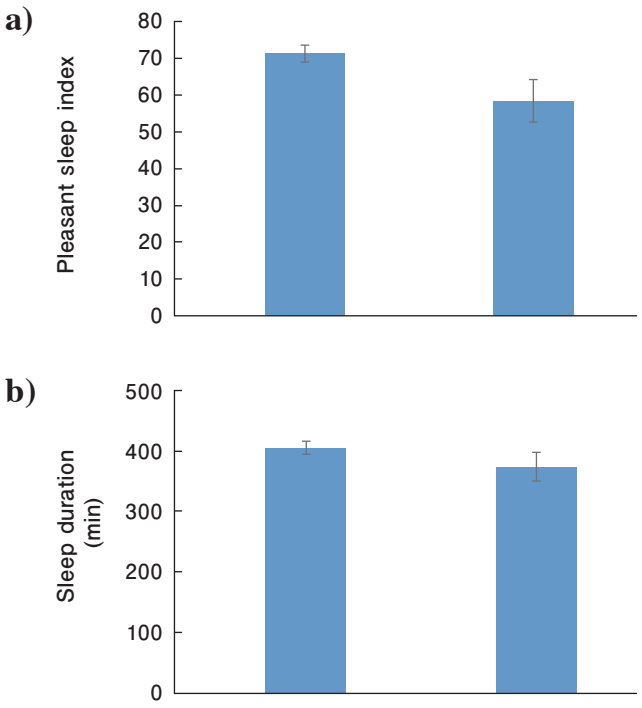

Fig. 9. **"Pleasant sleep index" and "Sleep duration" by "Sleep Cycle^{R}": Second test**

a) "Pleasant sleep index". **b)** "Sleep duration". Parameters are analyzed by "Sleep Cycle^{R}". Results are expresses as mean ± SEM, n = 6. SEM, standard error mean.

Discussion

In the present study, we examined the effects of the environment using the articulation panel, a test product, on sleep quality using students as subjects and melatonin metabolites as indicators. Articulating panels, which were developed for homes and offices, absorb sounds that are unpleasant for humans and leave comfortable sounds, thus increasing alpha waves by electroencephalography and is expected to reduce stress and increase relaxation [21]. There are several ways to assess sleep quality, and as one of them, urine SaMT, a melatonin metabolite, was used as an index. Sleep quality is sensitive to room temperature and illuminance, especially in light environments, which suppresses melatonin secretion, therefore we made our own sleep environment measurement device and used it for experiments.

The result of the first experiment (**An open-label, uncontrolled pilot study**) that urine discharged SaMT is lower when using the test panel (–13.4%) was different than expected. Previous studies have reported that the excretion of SaMT in urine varies with changes in room temperature during sleep [23]. Illuminance strongly affects melatonin secretion, which is suppressed in bright conditions [24]. Since, in the first test, measurements were taken in each home bedroom, we speculated that the cause was that the sleep environment, such as illuminance, temperature, and bedding was different for each subject.

The second test (**Control shift comparison test with illumination monitoring**) was conducted in a training camp, and SaMT measurement was performed under the

condition that the subject's sleep environment (illuminance, temperature, and bedding) was fixed. Using a continuous monitoring device, it was confirmed that the illuminance and humidity were almost the same, and that the illuminance was kept below 2 lux when the lights were turned off. The studies performed under these conditions showed that SaMT in 24-hour urine samples increased by more than 50% with the use of test panels. These results suggest that the use of articulatory panels may have increased melatonin secretion.

SaMT

The amount of urinary SaMT excretion is known to reflect the amount of melatonin secretion [22, 23]. SaMT is reduced in patients with diabetes [25] or growth hormone deficiency [26], and in workers who work night shifts [27].

Evaluation of melatonin secretion and sleep quality using SaMT as an index has not yet been widely conducted in Japan.

According to reports in Japan, the urinary SaMT production of 6 female nurses (average age 29.7 years) was, during the day shift, 660 ng/hr (07:00–23:00) and 2,580 ng/hr (23:00–07:00), while, during night shifts, were 640 ng/hr (07:00–23:00) and 1,420 ng/hr (23:00–07:00) [28]. The time in parentheses indicates the time from the start to the end of urine collection. Urinary SaMT production was reduced by about 45% during the night shift. Since a large amount of SaMT is generated from late night to morning, even during the night shift, it can be seen that melatonin secretion is secreted according to the biological clock rather than the lifestyle of sleeping.

In a study measuring urinary SaMT production in elderly living independently, serum cortisol was lower, insulin-like growth factor-I (IGF-I) was higher, and urine discharged SaMT was higher with higher physical activity [17].

The amount of urine discharged SaMT in 23 elderly people (10 males, 13 females, age 78.7 ± 6.1 years old) was, when divided into three tertiles according to physical activity, 1,081.7 ± 258.5 ng/hr in a high activity group, 841.0 ± 294.5 ng/hr in a medium activity group and 724.2 ± 205.2 ng/hr in a low activity group (no significant difference between groups) [17]. Compared to the value of 2,487.0 ± 193.2 ng/hr for 6 students (27.3 ± 11.6 years) in this test, the value is lower in the elderly.

Urinary SaMT concentration (Cre corrected value) in 12 subjects (4 males, 8 females, 51.9 ± 7.2 years old) was 11.13 ± 3.72 ng/mg Cre [20]. The value of 11.56 ± 2.94 ng/mg Cre in 6 students (27.3 ± 11.6 years old) in this study was similar to that in middle-aged and elderly people.

If such data can be accumulated, it is expected that urinary SaMT measurement will serve as an evaluation index for melatonin secretion.

Index by "Sleep Cycle^{R}"

This study used the "SleepCycle^{R}" smart phone application, commonly used in the smartphone market, to analyze a pleasant sleep index and sleep duration. However, it is unknown how pleasant sleep is defined. In the two trials, no difference was seen in the "pleasant sleep index" with or without the use of the test panel. SaMT may be more sensitive in assessing sleep quality.

Possible mechanism

The mechanism by which the use of the test panel increased melatonin secretion is speculated as follows. Since the articulation panel has an effect of absorbing unpleasant sounds and leaving comfortable sounds, it is considered that unpleasant sound stress on the brain was reduced and the sleep environment was improved. We have previously reported that the use of comfortable bedding improved the sleep environment, resulting in increased secretion of growth hormone/IGF-I [18], decreased serum cortisol [19], and increased dehydroepiandrosterone (DHEA) production [19].

The following pathways are assumed for the melatonin synthesis pathway [24]. Light stimulation received by the retina is transmitted mainly to the suprachiasmatic nucleus (SCN), the site of the circadian clock, via the retina-hypothalamus tract, thus synchronizing the phase of the circadian clock with the external light cycle (24-hour cycle). The time information generated in the SCN is transmitted to the pineal gland via nerve fibers, through the maxillary ganglion. In this pathway, the nerve activity of the maxillary ganglia is suppressed by light stimulation, so that the activity is actually only performed at night without light stimulation. Noradrenaline is secreted from nerve endings derived from the maxillary ganglion, which stimulates pineal cells, mainly via β receptors, and promotes the synthesis of cAMP, a second messenger, thus activating allylalkylamine N-acetyltransferase activity (AANAT), which is the rate-limiting enzyme of melatonin synthesis. In the daytime, AANAT is minimally activated, and the pineal gland and blood melatonin concentration show a diurnal variation that is high at night and low in the daytime.

On the other hand, the blood concentration of cortisol is regulated by the circadian rhythm, and is highest in the morning, stays high from morning to afternoon, and gradually decreases from afternoon then showing low levels until habitual sleep onset [29]. Excessive mental and physical stress causes an increase in cortisol concentration, resulting in sleep difficulty such as difficulty falling asleep.

Following circadian rhythm, cortisol levels during sleep remain relatively low and rise rapidly 2-3 hours before habitual wake-up time [29]. Sleep has an inhibitory effect on cortisol secretion [30], sleep disruption (sleep deprivation) and insomnia in patients causes increased cortisol secretion and pulsed secretion [31, 32]. Elevated cortisol levels at dawn, especially pulsed secretions, are said to be deeply involved in alertness.

It is known that an increase in cortisol causes a decrease in melatonin secretion [33-36], while, if stress is alleviated by providing a comfortable sleeping environment, cortisol secretion is reduced and melatonin secretion is expected to recover. In this study, it is possible that the use of articulatory panels reduced uncomfortable sound stress, resulting in a decrease in cortisol levels during sleep and restoration of melatonin secretion.

Conclusion

As verification results of the effect of articulating panels in the bedroom on sleep quality examined using the melatonin metabolite SaMT as an index, the panel suggested that

discomfort noise was reduced, urinary SaMT excretion increased, and sleep quality could be improved. In addition, since melatonin secretion is affected by the sleep environment, it is necessary to evaluate test results under constant conditions such as room temperature and illuminance.

Conflict of Interest Statement

The present study was partly supported by Tokyo Steel Industrial Co., Ltd.

Acknowledgement

This work was supported by JSPS KAKENHI Grant Number #26350917. The outline of this study was presented at the 16th Meeting of Glycative Stress Research on October 18, 2018, Tokyo.

Reference

1) Takemae R, Okamoto H, Takemae Y, et al. Relationship between subjective oral health and lifestyle among Japanese elderly people in local city Tokyo: A cross sectional study. *The Japanese Journal of Health and Human Ecology*. 2014; 80: 226-234.
2) Kageyama M, Odagiri K, Mizuta I, et al. Health-related behaviors associated with subjective sleep insufficiency in Japanese workers: A cross-sectional study. *J Occup Health*. 2017; 59: 139-146.
3) Konishi M, Tomotaki A, Yamamoto-Hanada K, et al. Sleep status varies by age among Japanese women during preconception and pregnancy in a nationwide birth cohort study [the Japan Environment and Children's Study (JECS)]. *Sleep and Biological Rhythms*. 2019; 17: 161-172.
4) Sakakibara H, Torii Yasuda M, Shimoi K. Effects of environmental and social stressors on biological rhythms. *The Journal of Physical Fitness and Sports Medicine*. 2016; 5: 143-152.
5) Hiratsuka Y, Tamaki Y, Okamoto E, et al. Relationships between medical expenditures and the Specific Health Checkups scheme in Japan: A Study of outpatient medical expenditures and questionnaire responses concerning lifestyle that form part of the Specific Health Checkups scheme in Japan. *Journal of the National Institute of Public Health*. 2017; 66: 75-84.
6) Ozawa M, Kodama M, Uchino S, et al. Influence of optimism and images and perspectives related to lifestyle related diseases of employed workers on everyday health promoting behaviors: Analysis of cognitive factors to the results of health check-ups. *Shoin J Nursing*. 2017; 2: 1-16.
7) Ida S, Kaneko R, Nagata H, et al. Association between sarcopenia and sleep disorder in older patients with diabetes. *Geriatr Gerontol Int*. 2019; 19: 399-403.
8) Higami Y, Yamakawa M, Shigenobu K, et al. High frequency of getting out of bed in patients with Alzheimer's disease monitored by non-wearable actigraphy. *Geriatr Gerontol Int*. 2019; 19: 130-134.
9) Hirota T, Morioka T, Yoda K, et al. Positive association of plasma leptin with sleep quality in obese type 2 diabetes patients. *J Diabetes Investig*. 2018; 9: 1100-1105.
10) Otaka H, Murakami H, Nakayama H, et al. Association between insomnia and personality traits among Japanese patients with type 2 diabetes mellitus. *J Diabetes Investig*. 2019; 10: 484-490.
11) Narikawa K, Kanazawa Y, Kawamata H, et al. Obesity and craniofacial abnormalities are independent causal factors for obstructive sleep apnea-hypopnea syndrome. *Dokkyo Journal of Medical Sciences*. 2014; 41: 13-19.
12) Hongyo K, Ito N, Yamamoto K, et al. Factors associated with the severity of obstructive sleep apnea in older adults. *Geriatr Gerontol Int*. 2017; 17: 614-621.
13) Ueyama M, Kokuto H, Sugihara H, et al. Investigation of obstructive sleep apnea using portable monitors and health check data in Japanese drivers. *J Atheroscler Thromb*. 2018; 25: 1118-1127.
14) Otake K, Sasanabe R, Hasegawa R, et al. Glucose intolerance in Japanese patients with obstructive sleep apnea. *Intern Med*. 2009; 48: 1863-1868.
15) Nagayoshi M, Punjabi NM, Selvin E, et al. Obstructive sleep apnea and incident type 2 diabetes. *Sleep Med*. 2016; 25: 156-161.
16) Muraki I, Wada H, Tanigawa T. Sleep apnea and type 2 diabetes. *J Diabetes Investig*. 2018; 9: 991-997.
17) Tsuruta A, Zheng T, Ogura M, et al. Sleep quality, physical activity, and glycative stress in the elderly: The Yurin Study. *Glycative Stress Res*. 2019; 6: 39-48.
18) Takabe W, Ogura M, Yagi M, et al. Effect on sleep quality of bedding with a high user rating in a post-marketing survey: A non-controlled open-label study. *Glycative Stress Res*. 2016; 3: 110-123.
19) Ogura M, Takabe W, Yagi M, et al. Effect of mats with "A Distinctive 4-Layer 3-Dimensional Structure" on sleep quality, anti-oxidative and immunological function. *Glycative Stress Res*. 2017; 4: 172-183,

20) Ogura M, Hattori A, Yagi M, et al. Effect of mats with "A Distinctive 4-Layer 3-Dimensional Structure" on sleep quality and nocturnal blood glucose: A crossover trial. *Glycative Stress Res*. 2019; 6: 49-63.
21) Fukushima M. Characteristic and function of the newly developed articulatory panels (Aural Sonic). *Glycative Stress Res*. 2019; 6: 103-112.
22) Kawamoto T, Takabe W, Maruyama Y, et al. Relationships between urinary melatonin metabolites and glycative stress and body functional age. *Glycative Stress Res*. 2016; 3: 15-22.
23) Kondo M, Tokura H, Wakamura T, et al. Physiological significance of cyclic changes in room temperature around dusk and dawn for circadian rhythms of core and skin temperature, urinary 6-hydroxymelatonin sulfate, and waking sensation just after rising. *J Physiol Anthropol*. 2007; 26: 429-436.
24) Yonei Y, Hattori A, Tsutsui K, et al. Effects of melatonin: Basics studies and clinical applications. *Anti-Aging Med*. 2010; 7: 85-91.
25) Chen W, Cao H, Lu QY, et al. Urinary 6-sulfatoxymelatonin level in diabetic retinopathy patients with type 2 diabetes. *Int J Clin Exp Pathol*. 2014; 7: 4317-4322.
26) Fideleff HL, Fideleff G, Boquete HR, et al. Decreased 6-sulfatoxymelatonin excretion in male GH-deficient children and adolescents. *Horm Res Paediatr*. 2015; 84: 88-93.
27) Roach GD, Lamond N, Dorrian J, et al. Sleep health at work: Changes in the concentration of urinary 6-sulphatoxymelatonin during a week of simulated night work. *Ind Health*. 2005; 43: 193-196.
28) Yamauchi H. Effects of night work on urinary excretion rates of 6-sulfatoxymelatonin, norepinephrine and estriol in pregnant women. *Ind Health*. 2004; 42: 268-276.
29) Tagaya H. Measurements of sleep-related hormones. *Transactions of the Japanese Society for Medical and Biological Engineering*. 2008; 46: 169-176. (in Japanese)
30) Weibel L, Follenius M, Spiegel K, et al. Comparative effect of night and daytime sleep on the 24-hour cortisol secretory profile. *Sleep*. 1995; 18: 549-556.
31) Späth-Schwalbe E, Gofferje M, Kern W, et al. Sleep disruption alters nocturnal ACTH and cortisol secretory patterns. *Biol Psychiatry*. 1991; 29: 575-584.
32) Vgontzas AN, Bixler EO, Lin HM, et al. Chronic insomnia is associated with nyctohemeral activation of the hypothalamic-pituitary-adrenal axis: clinical implications. *J Clin Endocrinol Metab*. 2001; 86: 3787-3794.
33) Lindholm H, Sinisalo J, Ahlberg J, et al. Attenuation of vagal recovery during sleep and reduction of cortisol/melatonin ratio in late afternoon associate with prolonged daytime sleepiness among media workers with irregular shift work. *Am J Ind Med*. 2012; 55: 643-649.
34) Ramachandran N, Smyth N, Thorn L, et al. Relationship between post-awakening salivary cortisol and melatonin secretion in healthy participants. *Stress*. 2016; 19: 260-263.
35) Valent F, Mariuz M, Liva G, et al. Salivary melatonin and cortisol and occupational injuries among Italian hospital workers. *Neurol Sci*. 2016; 37: 1613-1620.
36) Schmidt C, Xhrouet M, Hamacher M, et al. Light exposure via a head-mounted device suppresses melatonin and improves vigilant attention without affecting cortisol and comfort. *Psych J*. 2018; 7: 163-175.