

# ORIGINAL PAPER

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## Perception of feeling cold in the bedroom and sleep quality

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## ABSTRACT

Sleep disorders are drawing the attention of both medical and public health concern worldwide. In Japan, research suggests that one fifth of adults do not receive appropriate sleep and 40% of adults sleep less than 6 hours a day, and sleep rates are decreasing further year by year. Many studies show that cold indoor environments negatively affect sleep comfort and quality. Whereas these studies have focused on the effects of low bedroom temperature, few studies have focused on the effect of perception of coldness. Indoor temperature is typically much lower in Japan than in other countries. Therefore, the current study aimed to identify the effect of perception of bedroom coldness on sleep quality among Japanese adults. After controlling for covariates of age, presence of current disease and pain, smoking and consumption of alcohol (Model 1), participants who sometimes, often or always felt cold in the bedroom exhibited 0.57 (95% CI=0.32–0.83, p=<.0001), 1.08 (95% CI=0.82–1.35, p<.0001) or 2.25 (95% CI=1.83–2.67, p<.0001) higher PSQI scores compared to the group which didn't feel cold in bedroom. Our findings suggest keeping the bedroom thermal environment above a minimum limit as recommended by the World Health Organization or other organization during colder, winter nights when feeling cold during sleep. Additional deficiencies in the housing infrastructure, air quality issues due to the use of a heater, and micro bed environment need to be holistically addressed. Sleep quality can be improved by certain level via providing thermally comfortable sleeping environment.

Keywords: community health, cold bedroom, indoor thermal environment, housing, sleep quality

### Abbreviations:

CI: confidence interval

PSQI: Pittsburgh Sleep Quality Index

MHLW: Ministry of Health, Labor and Welfare

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## INTRODUCTION

Japan is unique about its residential indoor thermal environment. Central heating is less common compared to other developed countries, and the indoor temperature is typically lower in Japan than in other countries.<sup>1</sup> In most modern Japanese homes, each room is heated by its own wall-mounted heating unit. Approximately 39% of existing houses in Japan are uninsulated. Uniformly heating an entire house or apartment is considered wasteful; it is standard to heat the living room, but it is not common practice to heat the bedroom. According to a report from the Ministry of Land, Infrastructure, Transport and Tourism of Japan, the average room temperature in a Japanese house in winter is 17°C or less, and that of the bedroom is lower than 13°C.<sup>2</sup>

Research on thermal comfort in the sleeping environment suggests that thermal environment is one of the primary causes of sleep disturbance among many other factors such as physical states, mental states and bedding conditions.<sup>3-4</sup> Many studies show that cold indoor environments negatively affect sleep comfort and quality.<sup>4-6</sup> Whereas these studies have focused on the effects of low bedroom temperature,<sup>6</sup> few studies have focused on the effect of perception of coldness. No previous study has examined the relationship between the perception of cold and sleep quality in Japan.

Sleep disorders are drawing the attention of both medical and public health concern worldwide. They have been found to increase the risk of developing various diseases such as cardiovascular disease<sup>7</sup> and depression.<sup>8</sup> Sleep has even been linked to mistake rates during exertion and a greater risk of accidents.<sup>9</sup> In Japan, research suggests that one fifth of adults do not receive appropriate sleep,<sup>10</sup> 40% of adults sleep less than 6 hours a day, and sleep rates are decreasing further year by year.<sup>11</sup> Thus, government and other business entities have engaged with various sleep initiatives promoting an awareness of sleep disorders. However, little work has been done examining sleep environment and sleep quality. Therefore, the current study aimed to identify the effect of perception of bedroom coldness on sleep quality among Japanese adults.

## MATERIALS AND METHODS

### *Subjects*

The Ministry of Land, Infrastructure, Transport and Tourism of Japan funded the Smart Wellness Housing project which aimed to quantitatively evaluate the impact of housing condition on residents' health between November and March from 2014 through 2017 all over Japan. With the collaboration of retrofitting companies, we recruited 3,289 participants who were willing to retrofit their houses and visited to the retrofitting companies for consultation across all 47 prefectures of Japan during November 2015 and March 2016. At each residence, both husband and wife were invited to answer paper-based questionnaires. All participants are expected to be re-questioned after retrofitting; however, we only used the data of baseline survey. In the current study, all participants also were questioned about their demographic, socio-economic status, housing conditions and sleeping quality in accordance with Pittsburgh Sleep Quality Index (PSQI), quality of life in accordance with Short form-8 (SF-8) and GHQ-12, diet, pain, presence of diseases. In the current study, we only extracted the data of PSQI, information on bedroom thermal environment and socio-economic factors to suffice the aim of the study.

The study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the ethical committee of the Hattori Clinic Institutional Review Board. All participants gave their informed consent for participating in the study. More details of the project can be found at <http://www.umin.ac.jp/ctr/index.htm>. (UMIN Clinical Trials Registry, Trial No.

UMIN000030601.)

#### *Measurements*

**Sleep quality.** We used the Japanese version of the PSQI questionnaire which was translated by Doi et al in 1998 and has been widely used among the Japanese population since then.<sup>12</sup> This is an instrument to measure the quality and patterns of sleep in the older adult. This tool differentiates “poor” from “good” sleep by measuring seven domains: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction over the last month. Mean PSQI values were calculated based on participants’ self-assessment of these seven areas of sleep.<sup>13</sup> Scoring of the answers is based on a 0 to 3 scale, whereby 3 reflects the negative extreme on the Likert Scale. A global sum of “5” or greater indicates a “poor” sleeper.

**Thermal environment.** The Health Maintenance Promoting Housing Research Council and its consortium, established under the Ministry of Land, Infrastructure, Transport and Tourism of Japan, developed the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) Housing checklist to assess the health of residents within the Smart Wellness Housing project. This checklist has six health elements including thermal environment, acoustic environment, lighting environment, hygiene, safety and security for 8 distinctive rooms/places in the home.<sup>14</sup> In the current study, we focused on the impact of bedroom thermal environment including feeling coldness, and a dry nose or throat in the bedroom.

#### *Statistical analysis*

The participants were classified into four groups based on their frequency of perceiving thermal problems in the bedroom (never, sometimes, often and always experiencing problems) to study the relationship between thermal problems and sleep quality. We also compared sleep quality between “heater-users in the bedroom” and “non-user” group. Accordingly, descriptive statistics were calculated with respect to demographic indicators and other variables (sex, gender, education, income etc). Mean PSQI was calculated for each demographic indicator and component of thermal environment. Linear regression was used to identify the relationship between the perceived level of thermal problems and PSQI. Linear regression modeling was conducted by adjusting i) without any variables (univariate), ii) age, smoking and alcohol-drinking habits, presence of disease and pain, and (Model 1) iii) usage of heater in the bedroom along with variables of ii) (Model 2); and an adjusted parameter estimates were calculated. A Chi square test was carried out to check association between perception of thermal comfort and usage of heater in bedroom. Significance was set at the 5% level ( $p<0.05$ ). SAS Version 9.4 was used to analyze the data.

## RESULTS

We sent the questionnaire to 3,289 participants and the response rate was 70 %. We excluded those who did not answer all areas of the PSQI questionnaire because it is not possible to calculate the overall PSQI if one area is missing. In addition, participants who failed to answer questions on thermal comfort or heater usage were excluded from the analysis. Upon exclusion, a total of 2,193 participants were analyzed in the current study.

The demographic characteristics of the study participants are presented in Table 1. The mean age was  $52.6\pm14.1$ ; 47.4% were men and 52.6% were women. The majority of participants were either high school (38.7%) or technical college graduates (26.0%) and 29.5% obtained either a

bachelor's or higher degree. With regard to income, the majority of participants (73.4%) earned from 2 to 9 million Japanese Yen (approx. 19,000–85,000 USD) per year. More than 80% of participants were married. The mean PSQI score was  $4.96 \pm 2.54$  among all participants. The highest ( $5.70 \pm 3.02$ ) and lowest ( $4.48 \pm 1.97$ ) PSQI score were attributed to divorced/widowed people and those who had the highest annual income, respectively. More than 90% of participants were either current or past smokers and almost one-third (27.1%) reported to drink alcohol every day. Half (49.8%) and almost half (40.5%) of participants had pain and any type of diseases during the study period, respectively.

**Table 1** Demographic characteristics of study participants and mean PSQI

Demographic Indicators	# (or Mean)	% (or SD)	Mean PSQI	SD
Age <sup>1)</sup>	52.6	(14.1)	4.96	(2.54)
Sex <sup>2)</sup>				
Male	1039	(47.4)	4.77	(2.43)
Female	1154	(52.6)	5.13	(2.63)
Education <sup>2)</sup>				
Junior-high school	122	(5.8)	5.31	(3.15)
High school	819	(38.7)	4.95	(2.55)
Technical college	550	(26.0)	5.06	(2.5)
University or over	624	(29.5)	4.80	(2.4)
Income (annual) <sup>2)</sup>				
Up to 2 million JPY	95	(9.5)	5.52	(3.19)
2–5 million JPY	403	(40.5)	5.00	(2.46)
5–9 million JPY	328	(32.9)	4.70	(2.33)
Over 9 million JPY	170	(17.1)	4.48	(1.97)
Marital status <sup>2)</sup>				
Married	1790	(82.1)	4.89	(2.47)
Single	244	(11.2)	5.03	(2.66)
Divorced/Widowed	145	(6.7)	5.70	(3.02)
Smoking status <sup>3)</sup>				
Current smoker	339	(16.4)	4.90	(2.55)
Past smoker	1562	(75.7)	4.92	(2.5)
Never smoked before	164	(7.9)	5.08	(2.68)
Alcohol consumption				
Everyday	589	(27.1)	4.73	(2.39)
Sometimes	640	(29.4)	4.94	(2.39)
Not drinking	947	(43.5)	5.10	(2.69)
Presence of pain				
Yes	1082	(49.8)	5.37	(2.65)
No	1091	(50.2)	4.55	(2.36)
Presence of diseases				
Yes	626	(40.5)	5.30	(2.74)
No	918	(59.5)	4.62	(2.28)

<sup>1)</sup> Shown as mean and SD

<sup>2)</sup> Shown as number and percentage

<sup>3)</sup> Current smoker: Had smoked 100 or more cigarettes during entire life or had smoked during last 6 months

The descriptive statistics for estimated PSQI in relation to the bedroom thermal environment are in Table 2. The majority of participants reported feeling cold (66.9%) and dry nose and throat (81.3%) in the bedroom. More than 70% of participants didn't use any type of heater in the bedroom. Those who felt cold and experienced a dry nose and throat more frequently in the bedroom showed higher PSQI score.

Also presented in Table 2 is the relationship between PSQI and perception of bedroom thermal environment and heater usage. We ran three separate models as described in the Methods section. By the univariate model, participants who sometimes, often or always felt cold in the bedroom exhibited 0.61 (95% CI=0.36–0.86, p=<.0001), 1.14 (95% CI=0.88–1.41, p<.0001) or 2.38 (95% CI=1.96–2.79, p<.0001) higher PSQI scores compared to the group which didn't feel cold in bedroom. After controlling for covariates of age, presence of current disease and pain, smoking and consumption of alcohol (Model 1), participants who sometimes, often or always felt cold in the bedroom exhibited 0.57 (95% CI=0.32–0.83, p=<.0001), 1.08 (95% CI=0.82–1.35, p<.0001) or 2.25 (95% CI=1.83–2.67, p<.0001) higher PSQI scores compared to the group which didn't feel cold in bedroom.

Compared to those who didn't use a heater in bedroom, those who used a heater had significantly higher PSQI scores. This result pattern was consistent for Model 1 and Model 2 (Table 2).

**Table 2** Descriptive statistics of PSQI by thermal comfort and relation between PSQI and thermal comfort

Subjects	PSQI	Univariate	Model 1 <sup>1)</sup>	Model 2 <sup>2)</sup>		
			n (%)	M (SD)	PE (95% CI)	PE (95% CI)
<b>Feeling coldness in bedroom</b>						
Not at all	726 (33.1)	4.3 (2.3)	Reference			
Sometimes	725 (33.1)	4.9 (2.4)	0.61 (0.36–0.86) <sup>***</sup>	0.57 (0.32–0.83) <sup>***</sup>	0.57 (0.32–0.82) <sup>***</sup>	
Often	579 (26.4)	5.4 (2.6)	1.14 (0.36–0.86) <sup>***</sup>	1.08 (0.82–1.35) <sup>***</sup>	1.07 (0.80–1.34) <sup>***</sup>	
Always	163 (7.4)	6.7 (2.9)	2.38 (1.96–2.79) <sup>***</sup>	2.25 (1.83–2.67) <sup>***</sup>	2.23 (1.81–2.65) <sup>***</sup>	
<b>Feeling dry nose and throat in bedroom</b>						
Not at all	410 (18.7)	4.2 (2.4)	Reference			
Sometimes	521 (23.8)	4.7 (2.5)	0.46 (0.14–0.78) <sup>**</sup>	0.40 (0.09–0.72)*	0.40 (0.08–0.72)*	
Often	918 (41.9)	5.1 (2.4)	0.95 (0.66–1.24) <sup>***</sup>	0.90 (0.60–1.19) <sup>***</sup>	0.89 (0.60–1.18) <sup>***</sup>	
Always	344 (15.7)	5.9 (2.7)	1.68 (1.32–2.03) <sup>***</sup>	1.60 (1.24–1.97) <sup>***</sup>	1.59 (1.22–1.95) <sup>***</sup>	
<b>Using heater in bedroom</b>						
Yes	1571 (71.8)	4.9 (2.5)	Reference			
No	622 (28.2)	5.2 (2.6)	0.34 (0.10–0.57) <sup>**</sup>	0.29 (0.06–0.52) <sup>**</sup>	NA	

\*\*\*p<0.001, \*\*p<0.01, \*p <0.05

PSQI: Pittsburgh Sleep Quality Index

M: mean

SD: standard deviation

PE: parameter estimates

CI: confidence interval

<sup>1)</sup> Adjusted with presence of pain, disease, age, smoking, and alcohol.

<sup>2)</sup> Further adjusted with using heater in the bedroom.

Table 3 shows the association between perception of thermal comfort and heater usage in the bedroom. A significant association was found between heater usage and perception of coldness

( $p=0.0257$ ) and throat and nose dryness ( $p=0.0388$ ) in the bedroom. By looking at cell chi-square, those who use a heater in bedroom tend not to feel cold but always feel a dry nose and throat.

**Table 3** Association between perception of thermal comfort and usage of heater

	Using heater in bedroom			Not using heater in bedroom			P value
	Frequency	%	Cell $\chi^2$	Frequency	%	Cell $\chi^2$	
<b>Feeling coldness in bedroom</b>							
Not at all	182	8.3	2.78	544	24.81	1.10	0.0257
Sometimes	202	9.21	0.06	523	23.85	0.03	
Often	183	8.34	2.15	396	18.06	0.85	
Always	55	2.51	1.66	108	4.92	0.66	
<b>Feeling dry nose and throat in bedroom</b>							
Not at all	104	4.74	1.30	306	13.95	0.51	0.0388
Sometimes	137	6.25	0.79	384	17.51	0.31	
Often	264	12.04	0.05	654	29.82	0.02	
Always	117	5.34	3.87	227	10.35	1.53	

## DISCUSSION

Our study on the impact of perception of bedroom thermal environment on sleep quality found out that compared to those who didn't feel cold in the bedroom, participants who felt cold had significantly higher PSQI scores indicating poor sleep quality. The result was very consistent for both non-adjusted and adjusted models which may reflect that people's perception of coldness is a significant contributor to sleep quality regardless of their demographic background and heater usage.

Several researchers and organizations recommend a minimum air temperature in the bedroom. For example, the World Health Organization recommends a minimum air temperature of 18°C for bedrooms<sup>15</sup> and the European standard<sup>16</sup> recommends a minimum temperature of 20°C for heating in living spaces including bedrooms. Pan et al predicted the thermal neutral temperature to be 18.5°C, but the subjects had better sleep quality at a much higher temperature of 23°C in winter.<sup>17</sup> Some people feel comfortable sleeping in a warmer environment while others prefer a cooler bedroom because thermal sensation varies person to person, and therefore affect a subject's whole-body thermal comfort and sleep quality.<sup>18</sup> Consequently, it is quite complicated to define the ideal bedroom temperature for good quality of sleep and no widely accepted explicit bedroom temperature has been established.<sup>19</sup> Bedroom thermal sensation and ideal temperature is likely to be further complicated due to differences in local climates, use of bedding systems and sleeping habits worldwide.<sup>20,21</sup>

Thus, we strongly recommend that a bedroom temperature should be properly controlled to one's own comfort along with improving the bed microclimate to avoid feeling cold either at bedtime or during sleep regardless of recommended room temperature.

To date, whereas several studies have examined the impact of low bedroom temperature on sleep quality,<sup>6</sup> research on the perception of cold and its relationship with sleep quality is limited. Research on bedroom thermal environment reports that sleeping in cold environments significantly affects the sleep quality in naked subjects, although this negative effect could be reduced by the

use of bed coverings and clothing.<sup>22,23</sup> In reality, people don't sleep naked and without bed coverings, especially in a cold bedroom. Several other studies confirm that sleeping within a range of 13–20°C will not affect sleep quality when a blanket is used.<sup>4</sup> Similarly, without increasing room temperature, a thermally comfortable sleeping environment can be created and sleep quality can be maintained in cold bedrooms<sup>24,25</sup> by improving micro-bed factors such as mattress, covering, sleep wear and percentage of coverage, and the total insulation of the bedding system.<sup>26</sup>

While there are extensive studies emphasizing that sleep quality may be maintained in a cold bedroom, we should not ignore the available evidence from laboratory and clinical studies on the negative effects of cold air inhalation. Cold air can cause pathophysiological responses (eg, vasoconstriction in the respiratory tract mucosa and suppression of immune responses) that increase the susceptibility to infections.<sup>27</sup> Cold air inhalation was found to significantly affect the autonomic cardiac response without affecting sleep quality.<sup>4</sup> Thus, the entire sleep system, which includes the bedding ensemble and sleepwear, should be considered holistically along with the ambient conditions.

In Japan, it is standard practice to heat only the living room, rather than heating the entire apartment or house, as seen in Europe and America. It is not common to heat the bedroom in Japan. As a result, average bedroom temperatures are much lower in Japan. A nationwide survey in 2014 evaluating the winter heating situation reported that bedroom temperatures are lower than 14.4 throughout all prefectures in Japan except Hokkaido, where central heating systems are common, and Okinawa, which is the warmest prefecture in Japan.<sup>28</sup> "Warming up at bedtime" in the Japanese culture means to sleep wearing warm nightwear and covering up with a thick blanket. This behavior would seem to support sleep quality under cold conditions. Indeed, about 50% of elderly Japanese use two to six layers of sleepwear and three to five layers of bed covers.<sup>29</sup> Wearing too many layers in bed may also disrupt sleep comfort. This, again, suggests that a holistic approach is needed to maintain good and comfortable sleep by considering the micro bed climate and sleepwear along with the bedroom temperature.

The cold indoor temperatures are often a consequence of a dwelling's structural deficiencies, including a lack of insulation and airtightness, and lack of heating. In addition, countries with mild winters often have homes characterized by poor domestic thermal efficiency that are harder to heat than well insulated houses in more extreme climates.<sup>15</sup> This is the case in Japan. As of 2017, 39% of all Japanese houses were estimated to be uninsulated.<sup>1</sup> Therefore, retrofitted insulation may help to improve mitigate the effect of cold housing in Japan.

Our current study showed that heater use in the bedroom was associated with poorer sleep. We predicted the opposite because we believed that people are unlikely to feel cold when a heater is used and thus have better sleep quality. We suggest two possible explanations. First, Japanese people may only turn on a heater when they feel cold, and not constantly to keep the bedroom warm. Therefore, study participants might have been disturbed by coldness during the night, which made people wake up and turn on a heater. Second, people who use a heater in the bedroom usually set their bedroom temperature based on their pre-sleep state. Thus, participants who felt cold before sleeping could have set comparatively higher temperature which in turn disrupted the sleep during later stage of sleep. Therefore, in case of studying the effect of heated room on sleep quality, it is suggested to set a standard bedroom temperature, as recommended by the World Health Organization or other organization before sleeping.

Our study showed that those who felt dry nose and throat in the bedroom experienced poorer sleep quality. Supplying fresh air to the head and face of sleeping people could be used as a potential ventilation principle for sleeping people. However, bedrooms are poorly ventilated in winter time because opening a window makes the room much colder. In addition, some type of heaters creates carbon emission and almost all types of heaters pull moisture from the air.<sup>30</sup> Long

use of forced air heating systems, and both electric and gas heaters cause substantial dryness and deters people from using these kinds of heaters. Our study showed that those who use a heater in the bedroom tend not to feel cold but frequently experience a dry nose and throat. This may deserve more studies on a holistic approach of cost efficient and health-friendly heating systems along with good ventilation. Thus, sleep quality can be improved by certain increment via providing thermally comfortable sleeping environment.

The current study has two notable strengths. First, more than half of family involved in the current study had annual income over 4 million Japanese Yen (approximately 38,000 USD) which is higher than median annual family income in Japan.<sup>31</sup> In addition, all families included in the study were those who contacted to retrofitting companies for their renovation of their houses and were able to pay the expenses, therefore, the study population is likely to be quite homogeneous in terms of their socioeconomic status, which should have reduced the confounding effects related to socioeconomic factors (eg, poverty level). Second, this survey covered all 47 prefectures of Japan, thus, sampling bias is significantly reduced in terms of regional variation.

Our assessment is all subjective. In the present study, we did not measure the participants' room temperature, but rather questioned their perception of feeling. This could be considered a limitation of the current study. We were unable to examine whether increasing or decreasing room temperature could change the sleep quality, nor can we offer a recommended temperature that appears to support good health.

## CONCLUSION

The current study adds important information to the growing body of evidence that proper thermal environment contributes to people's quality of sleep. Our findings suggest keeping the bedroom thermal environment above a minimum limit as recommended by the World Health Organization or other organization during colder, winter nights when feeling cold during sleep. However, consistent heating in the bedroom may not be a sufficient measurement. Additional deficiencies in the housing infrastructure, air quality issues due to the use of a heater, and micro bed environment need to be holistically addressed. Sleep quality can be improved by certain level via providing thermally comfortable sleeping environment.

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## CONFLICT OF INTEREST

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