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Association of wood use in bedrooms with comfort and sleep among workers in Japan: a cross-sectional analysis of the SLeep Epidemiology Project at the University of Tsukuba (SLEPT) study

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Abstract

Several priority characteristics of wood that have beneficial effects on human beings have been reported. However, the advantages of wood use in bedroom interiors for sleep have not been fully evaluated. The aim of this cross-sectional epidemiological study was to evaluate the association of wood use in housing and bedrooms with comfort in the bedroom and sleep among workers in Japan. The study methods included sleep measurements using actigraphy and a self-administered questionnaire survey. In total, 671 workers (298 men and 373 women; mean age ± standard deviation: 43.3 ± 11.2 years) were included in the analysis. The amount of wood used in bedrooms was significantly associated with comfort in bedrooms, inversely associated with suspicion of insomnia, partly inversely associated with self-rated poor sleep quality, but not associated with low sleep efficiency. On logistic regression analysis, the adjusted odds ratio (aOR) of the "large amount of wood" group relative to the "no wood" group was 3.25 [95% confidence interval (CI) 1.63–6.47] for comfort. The aOR of the "no wood" group relative to the "large amount of wood" group was 2.15 (95% CI 1.11–4.16) for suspicion of insomnia. Wood structure of housing, as well as wood use on either the floor, wall, or ceiling, were not significantly associated with comfort and sleep conditions. Our study suggested that the use of a large amount of wood used in the bedroom interior could be beneficial for comfort, sleep, and therefore, health of workers. Further studies are required to obtain generalizable results.

Keywords: Sleep, Comfort, Bedroom, Wood, Cross-sectional study, Workers, Pittsburgh Sleep Quality Index (PSQI), Athens Insomnia Scale (AIS), Actigraphy, Workers

Introduction

The priority characteristics of wood that have beneficial effects on human beings have been reported in a review article on a dozen studies evaluating physiological indices such as pulse rate, blood pressure, autonomic nervous activity, and brain activity in case of viewing, touching, or smelling of wood [1]. It has been shown that touching hinoki cypress (*Chamaecyparis obtusa*) wood with the palm calms prefrontal cortex activity and increases

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parasympathetic nervous activity, resulting in superior physiological relaxation as compared with that when touching marble [2].

Further, another review article on wood use for built indoor environments reported that autonomic stress responses reduced with the use of wood for interiors compared with the absence of or use of less wood for interiors of rooms [3]. An experimental study with 15 participants evaluated comfort relative to the amount of wood used for interiors and found that the interiors that had 45% wood had the highest score for a subjective comfortable feeling compared with those with 0% and 90% wood in the designated room [4]. In an interview survey with 200 participants, a photograph of a room with no wood materials prompted reactions such as "I do not want to sleep" [5]. A study with 20 participants reported that wooden rooms resulted in less tension and fatigue and were more beneficial to the autonomic nervous system, respiratory system, and visual system than were non-wooden rooms [6].

Sleep is an essential factor for health promotion along with nutrition and exercise. It has been reported that poor sleep is a risk factor for metabolic syndrome, cancers, and mortality [7–9]. Although good sleep is necessary to maintain health and high performance, many workers experience sleep problems. A survey targeting Japanese workers reported that 71.0% of participants were aware of insomnia symptoms within the previous 1 year [10]. Another survey reported that the self-reported prevalence of insomnia among Japanese workers was 23.6% [11].

Sleep may be affected by personal factors including age and lifestyle, social factors such as working hours, and external factors such as environmental factors. Since wood use in the built environment has beneficial effects on human beings, it might provide a superior environment in bedrooms and lead to good sleep. However, the association of wood use in housing and bedrooms with comfort in bedrooms and daily sleep condition is still unclear.

It is necessary to evaluate the daily comfort and sleep of people in their residential environments to clarify this association. Epidemiological studies with a large number of participants should be conducted for this purpose. Observational studies, which are a kind of epidemiological studies, cannot standardize various factors related to comfort, sleep, or participants' characteristics. Therefore, the study design requires a large number of participants to adjust various factors during statistical analyses.

The aim of this epidemiological study, therefore, was to evaluate the association of wood use in housing and bedrooms with comfort in bedrooms and sleep among workers.

Methods

Data collection

This study was a cross-sectional study, which is a type of observational epidemiological study. The study protocol was approved by the ethics committee of the University of Tsukuba School of Medicine (approval No. 1065). Written informed consent was obtained from all participants.

Data collection for the SLEPT Study (SLeep Epidemiology Project at the University of Tsukuba) was conducted between August 2016 and November 2017 at 4 workplaces—a national university, a national institute, an institute of a company at the Ibaraki Prefecture located near Tokyo, and a health care company in Tokyo—as well as from some workers introduced by the staff or study participants. Participants were enrolled only through open recruitment using flyers, posters, workplace group e-mails, and online workplace bulletin boards. There was no individual solicitation in principle, and we did not ask the participants about sleep status prior to enrollment.

Participants

In this study, 785 individuals were recruited. Among them, 4 participants withdrew their consent, and 110 participants were excluded as they did not fulfill the study criteria [e.g., lack of data on sleep measurements, Pittsburgh Sleep Quality Index (PSQI), or questionnaire responses related to housing or bedroom] or selected "others" for "type of housing" ($n = 13$). In total, 671 participants (298 men and 373 women; mean age ± standard deviation: 43.3 ± 11.2 years, range 22–68 years) who completed the sleep measurements, responded to all relevant questions in the questionnaire, and did not withdraw consent were included in the analysis.

Questionnaire

The participants were requested to complete a self-administrated questionnaire including questions about type of housing (apartment, detached house, or others); style of bedroom (western/Japanese); use of wood, for example, structure of housing (reinforced concrete, steel-frame, or wood), amount of wood used for interiors, furniture, and door(s) in the bedroom ("How much wood is used in your bedroom, including interiors, furniture, and door(s)?": 1: large, 2: rather, 3: rare, 4: not at all), use of wood on floor (yes/no), walls (yes/no), and ceiling (yes/no) of the bedroom; uncomfortableness of noises including snoring in the bedroom (noisy/quiet); health-related parameters such as height, weight, and lifestyle factors such as smoking status, nightcap (defined as drinking within 2 h before sleeping once a week or more), and habitual exercise.

The questionnaire also included items regarding comfort in the bedroom ("Do you feel mental comfort or serenity in the bedroom?"; 1: very, 2: rather, 3: neutral, 4: rather not, 5: not at all) and PSQI, which is one of the most frequently used indices for evaluating self-rated sleep quality in sleep medicine [12, 13]. PSQI, which can assess sleep quality and disturbances over 1 month, consists of the following seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction [12]. The Athens Insomnia Scale (AIS) was developed based on ICD-10 (10th revision of the International Statistical Classification of Diseases and Related Health Problems) by the World Health Organization [14–16]. AIS consists of eight items; for example, one of the eight items is awakenings during the night, which can be graded as 0: no problem, 1: minor problem, 2: considerable problem, or 3: serious problem or did not sleep at all [14]. AIS was added to the questionnaire of the national university from June 2017. The available data for AIS were obtained from 530 participants.

Sleep measurements

Participants were required to wear an actigraphy device on the waist (MTI-210, ACOS Co., Ltd., Nagano, Japan) for 24 h a day, except during bath time, for a week to estimate actual sleep time and sleep efficiency and to record their sleeping and waking times in a sleep diary [17, 18]. The actigraphy data were analyzed using Sleep Sign Act software (Kissei Comtec Company Inc., Matsumoto City, Japan) [18]. We included only the longest sleep time during 24 h (from noon to noon on the next day) but not naps, because it seemed to be highly probable that only the longest sleep time would be spent in the bedroom.

Statistical analysis

The four categories for the amount of wood used in the bedroom interior were modified into three categories in this study by combining the two lower categories ("rare" and "not at all") into one category, "not used", because the number of participants who responded "not at all" was only 16. Comfort was defined by the two higher categories, "very" and "rather". Poor sleep quality was defined as PSQI ≥ 6 [12, 13]. Suspicion of insomnia was defined as AIS ≥ 6 [15]. As no appropriate actigraphy-based cut-off point of sleep efficiency is known at present, we defined low sleep efficiency as sleep efficiency of $< 70\%$ based on the available actigraphy data.

Overweight was defined as body mass index (BMI) ≥ 25.0 kg/m^2. BMI was calculated based on self-assessed height and weight. Exercise habit was defined as exercise activities performed for 30 min or more per session, twice a week or more, and continued for at least 1 year, as same as that defined by National Health and Nutrition Survey by conducted by Ministry of Health, Labour and Welfare, Japan [19].

The percentage difference between the groups was calculated using the Chi-square test. The associations between the ordinal variables were analyzed using the Mantel–Haenszel test for trend.

Since the participants had several different backgrounds and circumstances, multivariate analysis was conducted to adjust for various factors. Two multivariate analyses are commonly used in epidemiology. One is multiple regression analysis, which is performed when the dependent variable is a continuous variable. The other is logistic regression analysis, which is performed when the dependent variable is a binary one, such as presence or absence of a disease. This study adopted several binary variables as outcomes, e.g., presence or absence of the suspicion of insomnia. Therefore, logistic regression analysis was extensively used.

We used two models in the logistic regression analysis. The results of logistic regression analysis might differ according to the set independent variables; therefore, more than one analysis model, which have different independent variables, are often used. Model 1 was adjusted by considering possible confounders without wood-related factors. Model 2 was adjusted by considering possible confounders with the structure of housing for targeting only the wood use in the bedroom.

To assess the relevant factors related to comfort in the bedroom, in Model 1 the dependent variable was comfort in the bedroom (yes/no), whereas the independent variables were sex, age (5 categories: 20, 30, 40, 50, and 60s), type of housing (apartment/detached house), age of the building (4 categories: < 10 years, 10–19 years, 20–29 years, and ≥ 30 years), style of the bedroom, area of the bedroom (3 categories: < 6 Jo, 6–8 Jo, and ≥ 8.5 Jo), noise in bedroom (noisy/quiet), and each one of the wood-related factors in housing or bedrooms (5 factors): structure of housing, wood floor, wood wall, wood ceiling, and amount of wood used in the bedroom interior (3 categories). "Jo" indicates the unit of Tatami (approximately 1800 mm $\times$ 900 mm). In Model 2, the independent variable, structure of housing (3 categories), was added to the independent variables in Model 1, for all calculations.

To evaluate the relevant factors of sleep conditions, characteristics of participants were additionally adjusted in logistic regression analysis. The dependent variable was each one of the three sleep-related factors such as poor sleep quality (PSQI ≥ 6), suspicion of insomnia (AIS ≥ 6), and low sleep efficiency ($< 70\%$), whereas the independent variables were sex, age (5 categories), BMI, habitual exercise (yes/no), smoking (current smokers/other responses), nightcap (yes/no), shift worker (current shift worker/other responses), type of housing, age of building, style of the bedroom, area of the bedroom, structure of housing, noise in the bedroom, and each one of the four wood-related factors in bedrooms; wood floor, wood wall, wood ceiling, and amount of wood used in the bedroom interior.

The data set used was version 20191028. The significance level was set at 5%. IBM SPSS Statistics version 23 for Windows (IBM, Armonk, NY, USA) was used for the statistical analysis.

Table 1 Characteristics of participants ($n = 671$)

Sex: men, *n* (%)	298 (44.4%)
Age (mean ± SD), years	43.3 ± 11.2
Nightcap, *n* (%)	164 (24.4%)
Current smokers, *n* (%)	59 (8.8%)
Exercise habit, *n* (%)	129 (19.2%)
BMI ≥ 25.0, *n* (%)	119 (17.7%)
Shift worker, *n* (%)	60 (8.9%)

SD standard deviation, *BMI* body mass index

Results

Demographics of participants and characteristics of housing and bedroom among the participants

Characteristics of the participants are shown in Table 1. About 17.7% ($n = 119$) of the participants were overweight (BMI ≥ 25 kg/m^2), and being overweight is one of the risk factors of sleep apnea syndrome, which is a disorder in which breathing is interrupted during sleeping, resulting in poor sleep conditions. The percentage of participants with nightcap which may lead to sleep-worthy conditions was 24.4% ($n = 164$).

Characteristics of housing and bedroom among the participants are shown in Table 2. Wooden structures occupied 44.0% ($n = 295$) for structure of housing. Percentage of "large" amount of wood used in bedroom interior was 28.9% ($n = 194$). Structure of housing between apartments and detached houses revealed a statistically significant difference ($p < 0.001$); reinforced concrete occupied 73.8% of apartments, while wood occupied 78.4% of detached houses.

Age of the building was significantly associated with individuals feeling hot during summer (< 10 years, 24.7% vs. ≥ 30 years, 64.7%: Trend, $p < 0.001$) and feeling cold during winter (< 10 years, 27.2% vs. ≥ 30 years, 68.6%: Trend, $p < 0.001$) in bedrooms; higher percentages of hot and cold feelings were observed for individuals living in older buildings than in those that were recently built.

Table 2 Characteristics of housing and bedroom among the participants

Structure of housing	**Reinforced concrete**	**Steel-frame construction**	**Wood**	
	266 (39.6%)	110 (16.4%)	295 (44.0%)	
Type of housing	**Apartment**	**Detached house**		
	328 (48.9%)	343 (51.1%)		
Age of building	**< 10 years**	**10–19 years**	**20–29 years**	**≥ 30 years**
	235 (35.0%)	194 (28.9%)	140 (20.9%)	102 (15.2%)
Style of bedroom	**Japanese**	**Western**		
	194 (28.9%)	477 (71.1%)		
Area of bedroom	**< 6 Jo[a]**	**6–8 Jo**	**≥ 8.5 Jo**	
	46 (6.9%)	498 (74.2%)	127 (18.9%)	
Amount of wood in bedroom	**Large**	**Rather**	**None**	
	194 (28.9%)	364 (54.2%)	113 (16.8%)	
Wood use in bedroom	**Yes**	**No**		
Floor	439 (65.4%)	232 (34.6%)		
Wall	189 (28.2%)	482 (71.8%)		
Ceiling	233 (34.7%)	438 (65.3%)		
Comfortable temperature in bedroom	**Yes**	**No**		
Feeling hot in summer	257 (38.3%)	414 (61.7%)		
Feeling cold in winter	282 (42.0%)	389 (58.0%)		
Noise in bedroom	**Yes**	**No**		
	130 (19.4%)	541 (80.6%)		

[a] Jo: unit of Tatami (approximately 1800 mm × 900 mm)

Amount of wood used in the bedroom interior significantly differed ($p=0.046$) between Japanese style ("large" amount: 37.1%) and western style ("large" amount: 25.6%) bedrooms.

Association of comfort in bedrooms with factors related to housing and bedroom

The proportion of participants who responded to the question regarding comfort in bedrooms was 81.5%. Percentage of comfort according to the structure of housing and the amount of wood in bedroom interior is shown in Fig. 1a, b. Association between comfort and amount of wood in bedrooms was statistically significant (Trend, $p=0.001$); larger the amount of wood in the bedroom higher the percentage of comfort (Fig. 1b).

Percentage of comfort in the bedroom with wood floor (83.8%) or western style (83.4%) was significantly higher than that with a non-wood floor (77.2%, $p=0.03$) or Japanese style (76.8%, $p=0.04$). Comfort in the bedroom between age of housing (< 10 years 86.4%, 10–19 years 82.5%, 20–29 years 80.0%, and ≥ 30 years 70.6%; Trend, $p=0.001$), feeling hot in summer (yes 74.3%, no 86.0%; $p<0.001$), feeling cold in winter (yes 75.9%, no 85.6%; $p=0.001$), and noise in the bedroom (yes 64.6%, no 85.6%; $p<0.001$) was also significantly different.

No significant difference was observed for comfort in the bedroom with wood walls (yes 79.9%, no 82.2%; $p=0.50$), wood ceilings (yes 81.5%, no 81.5%; $p=0.99$), the structure of housing ($p=0.34$, Fig. 1a), and type of housing ($p=0.38$). Although the area of the bedroom was not significant ($p=0.09$), the percentage of comfort for small bedrooms (< 6 Jo: 69.6%) was lower than that for large bedrooms (6–8 Jo: 82.7%, ≥ 8.5 Jo: 81.1%).

The adjusted odds ratio (aOR) and 95% confidence interval (CI) of wood-related factors for comfort in bedrooms on logistic regression analysis are shown in Table 3. There was a significant association between the

Table 3 Adjusted odds ratios of wood-related factors for comfort in bedrooms

	Model 1		Model 2	
	aOR	(95% CI)	aOR	(95% CI)
Structure of housing				
Reinforced concrete	1	Ref.	–	
Steel-frame construction	1.28	(0.64–2.57)	–	
Wood	0.90	(0.45–1.80)	–	
Wood in bedroom				
Floor (yes/no)	1.05	(0.54–2.05)	1.09	(0.56–2.14)
Wall (yes/no)	1.00	(0.61–1.65)	1.03	(0.63–1.70)
Ceiling (yes/no)	1.08	(0.67–1.76)	1.12	(0.68–1.85)
Amount of wood in bedroom				
Large	2.86	(1.47–5.56)	3.25	(1.63–6.47)
Rather	1.69	(0.99–2.89)	1.76	(1.02–3.03)
None	1	Ref.	1	Ref.

Model 1: adjusted by sex, age, type of housing, age of building, style of bedroom, area of bedroom, and noise in bedroom

Model 2: adjusted by sex, age, type of housing, age of building, style of bedroom, area of bedroom, noise in bedroom, and structure of housing

aOR adjusted odds ratio, *CI* confidence interval

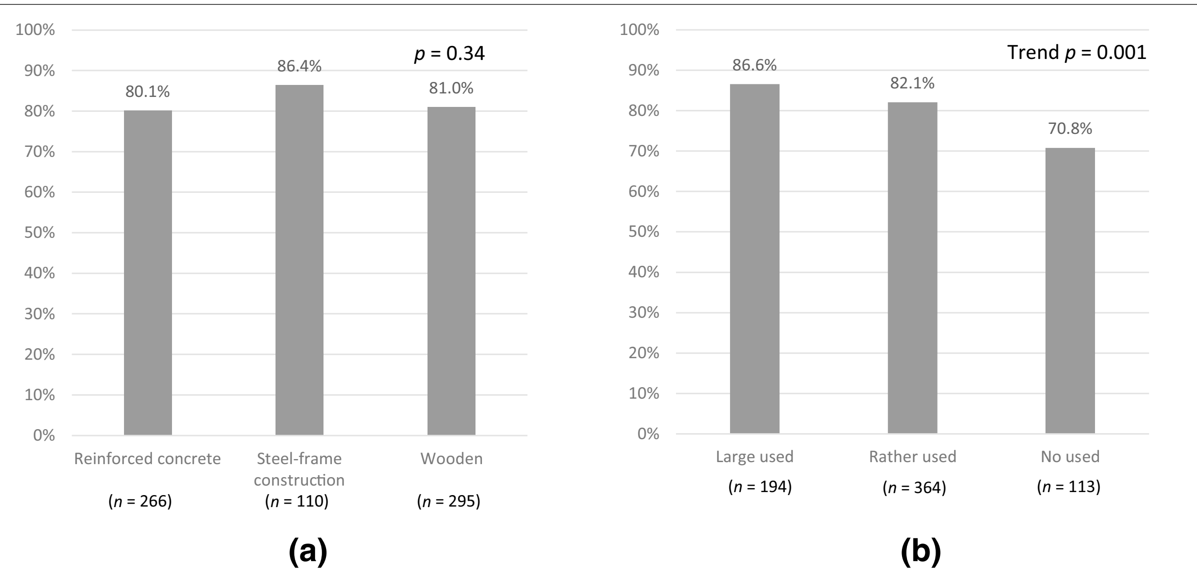

Fig. 1 Proportion of comfort in bedrooms. **a** According to the structure of housing, **b** according to the amount of wood used in bedroom interior

amount of wood used in the bedroom interior and comfort. The aORs for the "large amount of wood" group relative to the "no wood group" were 2.86 (95% CI 1.47–5.56) in Model 1 and 3.25 (95% CI 1.63–6.47) in Model 2. Even after adjusting for possible relevant factors, the amount of wood used in the bedroom interior was significantly associated with comfort in the bedroom.

Similarly, there was a significant association between comfort and quietness in the bedroom in both models [quiet (reference: noisy); Model 1: aOR, 3.32 (95% CI 2.08–5.28); Model 2: aOR, 3.21 (95% CI 2.01–5.13)].

Association of sleep conditions with housing and bedroom characteristics

Proportions of participants with poor sleep quality (PSQI ≥ 6), suspicion of insomnia (AIS ≥ 6), and low sleep efficiency were 49.2% ($n = 330$), 33.8% ($n = 179/530$), and 14.8% ($n = 99$), respectively. Percentages of poor sleep quality, suspicion of insomnia, and low sleep efficiency according to the amount of wood are shown in Figs. 2a–c. Suspicion of insomnia (Trend, $p = 0.013$) was inversely associated with the amount of wood in the bedroom, while no significant associations were observed between the amount of wood in the bedroom and poor sleep quality (Trend, $p = 0.11$) or low sleep efficiency (Trend, $p = 0.62$).

The aORs and 95% CIs on logistic regression analysis of factors related to wood for poor sleep quality, suspicion of insomnia, and low sleep efficiency are shown in Table 4. After adjusting for the possible relevant factors in logistic regression analysis, the amount of wood was significantly associated with suspicion of insomnia and showed a partly significant association with poor sleep quality, but not with sleep efficiency. The aOR of the "no wood" group relative to the "large amount of wood" group was 2.15 (95% CI 1.11–4.16) for suspicion

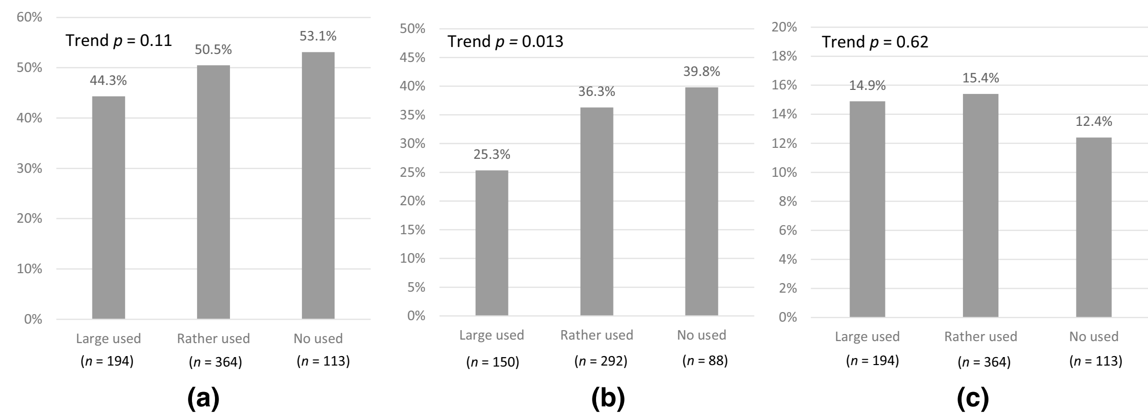

Fig. 2 Proportion of poor sleep conditions according to the amount of wood in bedrooms. **a** Proportion of participants with poor sleep quality (PSQI ≥ 6) according to the amount of wood in the bedroom. **b** Proportion of participants with suspicion of insomnia (AIS ≥ 6) according to the amount of wood in the bedroom. **c** Proportion of participants with low sleep efficiency (< 70% by actigraphy) according to the amount of wood in the bedroom

Table 4 Adjusted odds ratios of wood use in bedrooms for sleep conditions

	Poor sleep quality (PSQI ≥ 6)		Suspicion of insomnia (AIS ≥ 6)		Low sleep efficiency	
	aOR	**(95% CI)**	**aOR**	**(95% CI)**	**aOR**	**(95% CI)**
Wood in bedroom						
Floor (no/yes)	1.57	(0.93–2.66)	1.63	(0.82–3.24)	1.00	(0.51–1.97)
Wall	1.34	(0.91–1.98)	1.17	(0.72–1.90)	1.36	(0.77–2.42)
Ceiling	1.05	(0.72–1.53)	1.14	(0.72–1.81)	0.88	(0.51–1.51)
Amount of wood in bedroom						
Large	1	Ref.	1	Ref.	1	Ref.
Rather	1.48	(1.00–2.19)	1.90	(1.17–3.10)	0.91	(0.52–1.59)
None	1.66	(0.97–2.83)	2.15	(1.11–4.16)	0.54	(0.24–1.18)

Adjusted by sex, age, body mass index, habitual exercise, smoking, nightcap, shift worker, type of housing, age of building, style of bedroom, area of bedroom, structure of housing, and noise in bedroom

aOR adjusted odds ratio, *CI* confidence interval, *PSQI* Pittsburgh Sleep Quality Index, *AIS* Athens Insomnia Scale of insomnia. The aOR of the "rather amount of wood" group ($n=364$) relative to the "large amount of wood" group was 1.48 (95% CI 1.00–2.19; $p=0.049$) for poor sleep quality, but the aOR of the "no wood" group relative to the "large amount of wood" group ($n=194$) did not reach statistical significance [1.66 (95% CI 0.97–2.83; $p=0.062$)]. Regarding wood use in housing and the bedroom, the structure of housing, wood floor, wood wall, and wood ceiling were not significantly associated with poor sleep quality, suspicion of insomnia, and low sleep efficiency.

The results on these logistic regression analyses, except for the above-mentioned wood-related factors, were as follows: poor sleep quality was significantly associated with noise in the bedroom (aOR: 1.68; 95% CI 1.12–2.53); suspicion of insomnia was associated with noise in the bedroom (aOR: 1.67; 95% CI 1.05–2.66), nightcap, and age group; and low sleep efficiency was found to be associated with sex and BMI.

Discussion

The study revealed that among the wood-related factors assessed, the amount of wood used in the bedroom interior is the most relevant factor associated with comfort in the bedroom. The amount of wood used and quietness in the bedroom were also relevant factors associated with self-rated sleep conditions such as less suspected insomnia. This study suggested that the use of a large amount of wood in the bedroom interior is beneficial for comfort and sleep, although the choice of material for the interior depends on the preference of individuals.

Our study suggested that a higher percentage of wood use was associated with higher levels of comfort and less suspected insomnia. However, it has been reported that the highest scores for a comfortable and restful state were obtained with 45% wood use for the interior in the experimental room compared with 0% and 90% wood use in the room [4]. These conflicting results may be due to the inconsistency between the study methods. For example, the evaluation in the previous study was conducted on the room designated for the study. One of the reasons for the inconsistent results in this study could be the use of dark-colored wood for the room interior in the previous study, which may impart a heavy feel. If a light-colored interior had been used, the results might have been different. Furthermore, our study was evaluated using a self-administered questionnaire. "Large amount of wood" was not evaluated by percentage. Our study included not only interior finish, but also furniture in the actual bedroom of the participants, and therefore, we assumed that it would be difficult for the participants to determine the percentage of the amount of wood. In addition, the volume of furniture and size of the bedroom would be different between the participants. In contrast, the previous study mainly evaluated the interior finish and a few items of furniture (limited to a sofa and a low table) in an experimental room instead of the actual bedroom of the participants.

The study evaluated both objective and subjective sleep conditions. Self-rated sleep conditions were mostly associated with the amount of wood used in the bedroom interior, while sleep efficiency, which is an objective sleep condition, was not associated with it. Thus, disagreements between objective and subjective results can occur, because each item is used for a different assessment. For example, the International Classification of Sleep Disorders, Third Edition (ICSD-3) diagnostic criteria for insomnia do not include sleep duration [20].

This study had some limitations. First, since this research was an epidemiological study in which certain biases are common, the evaluation was limited. For example, the evaluation was conducted only once, and therefore, seasonal differences in sleep could not be evaluated. Moreover, the risk factors for poor sleep were not fully assessed in this study (e.g., genetic factors, measurement of temperature in the bedroom, etc.). Furthermore, we could not conclude clearly what factors (e.g., vision) related to a large amount of wood used in the bedroom interior were relevant for comfort or sleep. Second, the study was a cross-sectional study which could not identify a causal relationship. Cohort studies will be required to evaluate the causal relationship between the use of a large amount of wood in the bedroom interior and good sleep by identifying the incidence of poor sleep in follow-up participants who do not have complaints of poor sleep at baseline survey, although the limitations of an epidemiological study design will still remain. Third, if the number of participants had been larger, a detailed stratified analysis could have been conducted, e.g., based on sex or age groups. Fourth, this study was not specific to wood use, so there might have been a lack of information on the wood used. However, because the study was not specific to wood use, there might have been less bias in favor of favorable responses for association between wood use and sleep.

The strength of this epidemiological study was that evaluation of the association between wood use in bedroom interior and sleep was conducted on a relatively large number of participants based on the actual daily situations and not in an artificial setup of an experimental room. A review article described that one of the limitations of previous studies was that the number of participants was generally small and a high proportion of these studies only recruited men and women in their 20s, and therefore, studies with large numbers of participants including a greater range of ages are essential to obtain generalizable results [1]. In addition, most of the sleep epidemiological studies in Japan had been conducted using only questionnaires. However, we conducted sleep measurement using actigraphy in more than 600 workers. Thus, our study highlighted a new aspect of research in this field.

In general, the results of different targeted populations in epidemiological studies are often inconsistent. Therefore, further studies should be conducted across different populations. Finally, it would also be beneficial to conduct a meta-analysis to assess the results of a large number of well-designed studies.

Conclusions

In conclusion, the use of a large amount of wood in the bedroom interior was associated with comfort in the bedroom, inversely associated with suspicion of insomnia, and partly inversely associated with self-rated poor sleep quality in this study on more than 600 workers in Japan. Noise, including that of snoring in the bedroom, was also a relevant external factor for self-rated poor quality and suspicion of insomnia. However, the amount of wood was not associated with low sleep efficiency measured by actigraphy. Our study suggested that the use of a large amount of wood in the bedroom interior could be beneficial for comfort, sleep, and therefore, health of workers. Further epidemiological studies are required to obtain robust results.

Abbreviations

aOR: adjusted odds ratio; CI: confidence interval; PSQI: Pittsburgh Sleep Quality Index; AIS: Athens Insomnia Scale; BMI: body mass index.

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Authors' contributions

EM, MY, YO, SS, IM, and MS designed the study protocol. All authors, except YI and CS, contributed to data collection. EM and YI conducted data management. EM, YI, and CS contributed to the data set generation. EM was the main contributor in writing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available. Dataset use by third parties is not approved by the ethics committee of the University of Tsukuba due to research on humans, but will be available from the corresponding author on request after the approval of the ethics committees in both institutions to provide and to receive such datasets.

Competing interests

The authors declare that they have no competing interests.

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