Comparative study on thermal comfort responses and sleep quality between Indonesian and Japanese students during summer in Japan

W Budiawan\textsuperscript{1,2}, K Tsuzuki\textsuperscript{3}, H Sakakibara\textsuperscript{4}

\textsuperscript{1}Department of Architecture and Civil Engineering, Toyohashi University of Technology, Toyohashi, Japan
\textsuperscript{2}Department of Industrial Engineering, Faculty of Engineering, Diponegoro University, Semarang, Indonesia
\textsuperscript{3}Department of Architecture, Faculty of Environmental & Urban Engineering, Kansai University, Osaka, Japan
\textsuperscript{4}Nippon Jogesuido Sekkei Co.,Ltd., Nagoya, Japan

wiwikbudiawan@ft.undip.ac.id

Abstract. The comfort temperature and sleep quality of Indonesian residing in Japan during summer might be different from Japanese. As an extended previous research, this study aimed to compare the thermal comfort and sleep quality between Japanese and Indonesian students. Male Indonesian and Japanese students aged 20-35 years participated in this study. The participants completed a survey regarding thermal sensation before sleep. During sleep, actigraphy was used to monitor sleep. Additionally, the temperature and relative humidity of the participants' bedrooms were recorded. The findings of this study indicated that Indonesian students' bedroom temperature and relative humidity were not significantly different from those of Japanese students during the summer. Most of Indonesian students preferred neutral, like the Japanese students. According to a thermal comfort survey, Indonesians had the same sensation as Japanese (slightly comfortable). However, the Griffiths method revealed that the mean comfort temperature of Indonesian was higher than those of Japanese students. We also discovered that Indonesian students had shorter duration on bed and sleep minute than Japanese students. Furthermore, the sleep rate of Indonesian students was comparable to that of Japanese students. In conclusion, Indonesian students as tropical native became capable of adjusting to the hot and humid conditions in temperate climate, Japan.

1. Introduction
Sleep is a critical daily activity for health maintenance and accounts for approximately one-third of the day. It has been noted that insufficient sleep can impair health, and that individuals who sleep fewer than six hours or more than eight hours considerably increase their risk of health problems \cite{1}. Additionally, sleep deprivation impairs immune function and biological defense and maintenance functions \cite{2}. During sleep, the human body is sensitive to air temperature \cite{3}. In general, inadequate sleep and fatigue contribute to the discomfort associated with summer heat \cite{4}. Sleep disorders and fatigue were the two most frequently reported summer symptoms \cite{5}. Scientific evidence established a link between sleep duration: photoperiod \cite{6}, and ethnicity and culture \cite{7,8}.
Among the bedroom's physical environmental conditions, light and temperature are the two most significant environmental factors affecting sleep. Variation in indoor temperatures across seasons may have a varying effect on sleep measures. Moreover, maintaining a comfortable temperature is critical for sleep quality [9,10]. Thermal comfort is typically improved by adhering to the applicable standard's recommendations. Thermal comfort standards (ASHRAE 55, ISO 7730) may be applied to all people regardless of ethnicity or nationality. Havenith et al. (2020) illustrated how an adaptive model could be used to incorporate numerous standards for calculating thermal comfort in persons from different nations [11].

In Japan, extensive research on adaptive comfort temperature has been conducted. Earlier research examined the summer comfort temperatures in residences [12–14]. These studies primarily examined occupants' daily activities. Only a few studies have been conducted on sleep activity, and even fewer have been conducted on foreign nationals living outside their home countries. Previously, during the summer, it was reported that Indonesian students' bedrooms were cooler than the Japanese government's recommended temperature [8]. However, the comparison of thermal comfort and sleep quality with Japanese people is still limited. The purpose of this study was to compare the thermal comfort and sleep quality between Japanese and Indonesian students in order to further assess the differences. Thus, we conducted a comparative study of bedroom comfort temperatures during the summer season among Japanese and Indonesian students as an extended previous research [8]. Additionally, sleep qualities were assessed to ascertain the relationship between the actual bedroom's thermal environment and the participants' sleep quality. It is hypothesized that someone who had previously lived in a tropical zone would recognize summer.

2. Methodology
Summer 2019 and 2020 surveys were conducted in Toyohashi city, Aichi prefecture, Japan. Toyohashi is classified as having a Köppen-Geiger climate classification of Cfa: humid subtropical climate [15,16]. Summers were hot and humid. Similar to previous study, the current study was conducted at the home of a participant [8]. The cooling modes were not specified in the current study. During the summer, occupants of the university dormitory and private apartment used split-type air conditioning and occupants of public apartments relied on window-mounted air conditioning. The subject's preferred temperature for the bedroom air was set using the air conditioner. Although they are of different types, both air conditioners perform similarly in a small room.

2.1 Instruments and protocol
Before providing written consent form, all participants were briefed on the research procedure and risks. The study was approved by the Toyohashi University of Technology's Ethics Committee in Toyohashi, Japan. The protocol was conducted in accordance with the Helsinki Declaration. Physical and mental health of participants were determined by their responses to a subjective vote. The current study's approach required participants to wear an actigraphy to track their sleep and to set up a thermal recorder for monitoring the temperature and relative humidity of their bedroom environment while they slept. Figure 1 illustrates the instrumentation configuration used to measure sleep (the sensor closer to the head and parallel to it). It is necessary to precisely configure the position of the sensor because the type of house and the type of furniture in the bedroom may affect the air temperature and relative humidity in the room. Moreover, the behavior of respondents in the indoor thermal regulation might vary over the season [17], such as opening window [18], using fan/AC [19,20], and clothing and bedding [21,22].

Prior to and following sleep, participants completed a thermal sensation voting. In this survey, clothing, sleep time and wake-up times, and temperature were not regulated (naturally). Thermal perception was assessed using the thermal sensation questionnaire. The questionnaire was divided into two sections. The first section contained demographic information about the participants. The second section included questions about sensation (thermal, humidity, airflow, sweating, thermal comfort), thermal preference, and thermal satisfaction. The thermal sensation questionnaire was developed by the Japanese society of heating, air-conditioning, and sanitary engineers and utilized a nine-point scale.
2.2 Analysis
The survey was intended to be longitudinal (repeated measurements of same variables and a limited number of participants). The study lasted four nights during the summer. The Anderson-Darling test was used to determine normality. If the probability (p value) of the normality hypothesis was less than 0.05, a non-parametric test was conducted. The current study used a descriptive statistic and two-sample t-test. Minitab version 19 (Minitab, LLC, United States) was used to analyze all data. A p-value less than 0.05 was considered statistically significant.

3. Result and discussion

3.1 Bedroom thermal condition
Sixteen healthy male students participated in this study from 20 to 35 years of age (26.0 ± 4.1 years of age, 21.7 ± 2.8 kg/m² of body mass index). The total number of sample points was 64 (Indonesian: 32, Japanese: 32). In the current study, the average sunrise time was at 05:07 JST (Japan Standard Time) and sunset was at 18:27 JST in summer. The daylight hours were 799 ± 47 min during summer. The Japan Meteorological Agency provided information on the outdoor environment [16]. During summer (June to August), the outdoor air temperature and relative humidity were 25.4 ± 6.7°C, and 84 ± 8%, respectively. In the same months, the average outdoor air temperature and relative humidity in Indonesia were 27.8 ± 0.9°C, and 68 ± 7%, respectively [23]. Given these data, Indonesian students accustomed to hot temperatures in their home country (tropical climate area).

Figure 1. Procedure and set-up of instruments.

Figure 2. Bedroom air temperature (°C) and relative humidity (%).
Abbreviations: IDN, Indonesian; JPN, Japanese. The error bars represent standard deviations.

In the current study, the average bedroom air temperature and relative humidity of Indonesian (26.8 ± 2.2°C; 67 ± 12%) and Japanese (26.1 ± 2.0°C; 68 ± 13%) were not different during summer (see Figure 2). Additionally, during sleep, the clothing and bedding insulation preferences of Indonesian (0.2 ± 0.1 clo.; 2.3 ± 1.2 clo.) and Japanese (0.2 ± 0.1 clo.; 2.2 ± 1.1 clo.) were not different. Most participants wore short sleeves (96.9% for Indonesian, 100% for Japanese) and short pants (84.4% for Indonesian,
78.1% for Japanese). To improve their sleeping comfort, Indonesian students generally protect their bodies with thick blankets during the summer. Meanwhile, Japanese students used a thin blanket to cover their bodies. The thermal sensation and thermal comfort percentages for each nationality in summer prior to sleep are summarized in Figure 3.

![Figure 3](image-url)  
**Figure 3.** Percentage of: (a) thermal sensation, and (b) thermal comfort.  
Abbreviations: IDN, Indonesian; JPN, Japanese.

### 3.2 Sleep quality

In the summer, Indonesian students went to bed varied from 22:14 to 01:24 JST and woke up from 04:02 to 07:38, while the Japanese lay down ranged from 00:06 to 02:34 JST and became awake from 08:03 to 09:21 JST. In the summer, 21.9% of Indonesian students and 34.4% of Japanese students napped during the day. Actigraphy revealed significant differences in the duration on bed and sleep minutes between Indonesian and Japanese students \((p < 0.01)\). However, the sleep rate and sleep efficiency were not dissimilar. We discovered that the times of waking up and sunrise were identical. Actigraphy measurements indicated that the participants in Indonesia awoke at the same time as the sunrise. On the other hand, Japanese participants awoke later than Indonesian students.

![Figure 4](image-url)  
**Figure 4.** Sleep quality by actigraphy: (a) duration on bed and sleep minute and (b) sleep rate and sleep efficiency.  
Abbreviations: IDN, Indonesian; JPN, Japanese. Significancy: *, \(p < 0.05\). The error bars represent standard deviations.

Additionally, we assessed sleep sensation (sleep depth, wellness, and morning "clear-headedness") using the St. Mary's Hospital questionnaire 15 minutes after waking up and measured bedroom temperature during sleep. In the summer, there was a significant difference between Indonesian (sleep depth: 5.3 ± 1.2, wellness: 4.2 ± 0.7, clear-headed: 3.9 ± 0.5) and Japanese (sleep depth: 4.5 ± 1.6,
wellness: 3.6 ± 1.1, clear-headed: 2.0 ± 0.6) in all sleep sensation (all ps < 0.05). Based on actigraphy and sleep sensation, Indonesian students had a better sleep experience than Japanese students during summer.

3.3 Comfort temperature

The average bedroom air temperature and relative humidity of Indonesian and Japanese students were comparable during the summer. According to Japanese government recommendations, participants' rooms should be set to a temperature that is close to the outdoor temperature. Rijal et al. [14] stated that the linear regression model was ineffective at predicting the ideal temperature. Thus, we used Griffiths' method to predict each participant's thermal comfort temperature based on their TSV votes [25]:

\[ TC_g = T_a + (0-TSV)/\alpha \] (1)

Where \( TC_g \) is the Griffiths comfort temperature, \( T_a \) is the indoor air temperature (°C) and \( \alpha \) is the regression coefficient. Griffiths method was used to calculate the three regression coefficients of the nine-point thermal sensation in the current study: 0.33, 0.44, and 0.67 [26]. The present study revealed that Indonesian students' comfort temperature was higher than that of Japanese students, and a previous study conducted in Japan found a similar result (see Figure 5). Indonesian students, according to these findings, were accustomed to warm temperatures.

![Figure 5. Griffiths comfort temperature.](image)

Abbreviations: IDN, Indonesian; JPN, Japanese.
Significance: **, \( p < 0.05 \). The error bars represent standard deviations.

4. Conclusion

As an extended study, a comparative study of thermal comfort survey and sleep quality in Indonesian and Japanese students of Toyohashi city (Chubu area of Japan) was conducted during summer. In the current study, we found that the duration on bed and sleep minutes of Indonesian students were shorter than those of Japanese students. Indonesian students awoke at the same time as the sunrise. Although Indonesian students had fewer sleep minutes, their sleep rate and sleep efficiency were comparable to those of Japanese students. Moreover, the comfort temperature of Indonesian students using the Griffith method was higher than that of Japanese students in all regression coefficients.

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