Investigation of students’ comfort and adaptation in university dormitories in humid subtropical climatic area in winter in Chongqing, China

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Abstract: Students’ comfort and adaption in university dormitories is important for their learning. By controlling different environmental parameters (temperature, humidity, air velocity, etc.), this can provide a great satisfaction in students’ dormitory. In the present study, investigation was performed in students’ dormitories in university in Chongqing, China. A survey was conducted on students’ thermal comfort in typical university dormitories during winter in Chongqing, Southwest China. This also included on-site and continuous measurements of indoor physical parameters and filling out questionnaires about thermal sensation, thermal comfort, and adaptive behaviours by the students. Results showed that staying for longer periods in regions with a colder climate in winter, improved students’ adaptability to lower temperature, closely correlated to behavioural and psychological processes. Although the thermal conditions varied in the international

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PUBLICATION STATEMENT

Thermal and adaptation play a critical role in students’ dormitory for learning purposes, particularly in university buildings. By controlling different environmental parameters (temperature, humidity, air velocity, etc.), this can provide a great satisfaction in students’ dormitory. Although the thermal conditions varied in the international students’ and Chinese students’ dormitories, the thermal environmental conditions in the students’ dormitories were poorer. The average indoor air temperature was 18.7 °C and 18.1 °C in the international students’ and Chinese students’ dormitories respectively, which fell outside the ASHRAE thermal comfort zone, with higher indoor relative humidity. In addition, Chinese students felt more comfortable and satisfied with indoor air temperature and relative humidity compared to international students, evidently showing a higher adaptability to a severe colder winter climate. Improved design in student’s dormitories and sustainable dormitory buildings can enhance students satisfaction in dormitory buildings and improve their learning process. Occupant window opening behavior to temperature sensitivity and adaptability in university dormitories requires further studies. A large gap of adaptability between international students and Chinese students was observed. This general observation may require more research regarding the groups of international and Chinese students.
students’ and Chinese students’ dormitories, the thermal environmental conditions in the students’ dormitories were poorer. The average indoor air temperature was 18.7°C and 18.1°C in the international students’ and Chinese students’ dormitories, respectively, which fell outside the ASHRAE thermal comfort zone, with higher indoor relative humidity. In addition, Chinese students felt more comfortable and satisfied with indoor air temperature and relative humidity compared to international students, evidently showing a higher adaptability to a severe colder winter climate. The study provides information that can support comfort researchers, designers, and policy makers towards improved design in student’s dormitories and sustainable dormitory buildings.

Subjects: Heat Transfer; Civil, Environmental and Geotechnical Engineering; Design

Keywords: Students’ thermal comfort; cold climate; adaptation; Chinese students; international students

1. Introduction
Globally, thermal comfort has been studied since the 1970s in actual buildings, which provided the strongest evidence for adaptation due to their grounding in real-world settings, and human interactions with the environment and various adaptive opportunities (Y. Zhang et al., 2010). Over the past decades, several studies focused on improved thermal conditions in students’ dormitories in universities (He et al., 2016; Ning et al., 2016). Previous studies have revealed that people will take various measures to adapt to the environment (Kim, de Dear, Parkinson, & Candido; Y. Zhang et al., 2010) and factors related to human thermal history include outdoor climate, seasons, and indoor environments (He et al., 2015; Ning et al., 2016). Research has noted that “occupants’ thermal history can influence their thermal responses, incorporated behavioral adjustments, physiological acclimatization and psychological expectation, which can also help people to actively adapt to the environment” (Kim et al., 2017). In this context, understanding occupants’ thermal comfort and adaptation in the built environment is an important aspect.

Several field studies on adaptation have been carried out throughout the world in different countries, for example, Australia (De Dear et al., 2013), Singapore (Chen & Chang, 2012), Denmark (Andersen et al., 2009), and Japan (Takasu et al., 2017). In China, several field studies have been conducted on thermal comfort in different climatic areas. For example, in typical university dormitory buildings in Harbin, China, a severe cold region (Ning et al., 2016), Beijing campus buildings (Cao et al., 2016), naturally ventilated (NV) buildings in a hot-humid area (Y. Zhang et al., 2010), hot-humid climate in summer in dormitories of a university (He et al., 2016), severe cold winter and hot summer in university dormitories (Li et al., 2010) and humid areas (Cheng et al., 2008).

Over the past decade, due to changes in general living styles and consumer expectations, the demand for comfort has increased tremendously and is more personalized (Lee et al., 2012). These personal comfort-level expectations are a major concern in multi-occupant spaces such as corporate office buildings, students’ dormitories, buses, and airplanes, etc., where each occupant has his/her own range of comfortable temperature distribution. To create a more comfortable indoor environment in this kind of environments, it is necessary to carry out further studies on comfort levels for multi-occupant spaces, especially students’ dormitory rooms. In university dormitories, thermal comfort does not only affect students’ comfort and health, but also their learning needs and the quality of their lives (Li et al., 2010). Educational institutions own many buildings, thus resulting in significant demand for comfortable environments to increase occupants’ productivity. Compared to offices and classrooms, dormitories provide more flexibility for occupants to take on adaptive behaviors, like adjustment of clothing, using fans, and operating windows. Since there is an increasing number of students (both Chinese and international students) in dormitories in China, it is worth studying occupants’ comfort and adaptation in such environments for efficient design and sustainable dormitory buildings.
Chongqing City is in Southwest China and characterized by a hot-humid climate in summer and cold winter. The average daily maximum temperature in July is above 35°C and the maximum air temperature can be as high as 43°C. In the cold and wet winter, the annual mean temperature is about 18°C and the lowest temperature is 4°C. It has cloudy and foggy weather; the annual mean number of foggy days is 104 (Ding et al., 2012). Li et al. (2010) presented the occupants’ perception and preferences of thermal environments in free-running university dormitory buildings in China. The authors reported that the acceptable temperatures in university dormitories in Chongqing were between 15.9°C and 28.2°C and the preferred indoor air temperature was 23.2°C, and a higher tolerance of temperature by the occupants in the sub-tropical climatic region of China. However, limited attention has been paid to the difference between Chinese and International students and from different climatic regions currently. Gagge et al. (1941) measured clothing insulation during summer months. They noted that during summer people wore clothing like lightweight dresses, short-sleeved shirts or blouses, underwear, and a thin jacket with insulation values ranging from 0.35 to 0.6 °C. They noted that typical winter clothing included heavy slacks or skirt, long-sleeved shirt or blouse, warm sweater, or jacket, which would have an insulation value ranging from 0.8 to 1.2 °C. In the case of stationary, including a person is sitting on the chair, this generally has the effect of increasing clothing insulation of 0 °C to 0.4 °C depending on the type of chair. It is worth noting that these results were obtained by localized measurements without considering the clothing, use of fans and other appliances. Nevertheless, it is still uncertain whether these materials are applicable for people of different origins living in a sub-tropical climatic region in university dormitory environments. Data on the Chinese and International students’ thermal and adaptation of other typical phthalates (e.g., occupants’ perceptions and preference) in university dormitory building environments are scarce.

There is a paucity of data concerning occupant’s thermal comfort and adaptation of international and Chinese students in university dormitories in subtropical humid climate in China, which might lead to the limited subjective assessment of thermal comfort within dormitory buildings in a university. More attention is needed to explore occupant’s comfort and adaptation of these different groups in dormitory buildings. In the last decades, due to globalization and China’s increasing openness, more and internationals throughout the world arrive in China to seek academic and employment opportunities. Against, this backdrop, the number of international students has grown more than twice doubled in every 10 years. More attention should focus on thermal comfort and adaption, but on the international student in the university dormitories. In view of this, the aim of the study was to investigate occupants’ comfort and adaptation in students’ dormitories in subtropical humid climatic areas of China, using measurements on-site and continuous measurements and questionnaire surveys on thermal comfort and indoor thermal conditions in typical university dormitories in Chongqing. The main reason for this is that a comfortable thermal environment plays an important role in students’ dormitories as; (1) allows students to study well, directly influencing the living conditions of the learners and (2) provides improved health conditions. The information can provide a better understanding of comfort and adaptation in students’ dormitories in sub-tropical humid climatic area in winter climates and provide fundamental knowledge to improve the design of dormitories and sustainable dormitory buildings based on different on occupants’ adaptation. This could possibly be developed to meet indoor thermal comfort requirements of individuals from various regions of the world in cold winter climate zones in China.

2. Materials and methods

2.1. Dormitory buildings and location of measuring devices

Thermal comfort and adaptation survey was carried out during winter, from late November 2016 to January 2017 in eight (8) dormitory buildings, Chongqing University. Eight dormitories were selected as target study buildings (two international students’ dormitories and six Chinese students’ dormitories. All the targeted buildings were low-rise building, with five (5) to twelve (12) floors, and a cellular structure, constructed of concrete columns. The dormitories were all
constructed from steel, cement, hollow cement blocks and concrete. It worth noting that most of the buildings in Chongqing City are designed to adapt to the dominant sub-tropical climate, naturally ventilated spaces with split unit air-conditioning. Generally, the Chinese students’ room area is about 25 m², with about four (4) students sharing. The windows of most of the Chinese dormitory buildings are single-glazed sliding, with an average volume of 0.135–0.200 cubic meter per window space. In some cases, the dormitories are equipped with two (2) doors, one front and one rear door. On the other hand, in the two international students’ dormitories, there are double-glazed sliding windows, and the room size is approximately 20 m², with a bathroom. The windows in the international students’ dormitory buildings are bigger than in Chinese students’ dormitory rooms. The room have display of glass curtain wall, which allows maximum natural daylight into the corridor. In these buildings, two types of rooms are available, single rooms and shared rooms for two people. Figure 1 shows the interior space of both Chinese and International student rooms. As noted by Li et al. (2010) general residential buildings compared to dormitory buildings are characteristically small with a high occupant density but without heating ventilation and air-conditioning (HVAC), indicating that the indoor thermal environment in dormitory buildings would be generally worse than normal residential buildings in China, especially in winter or summer season. In our study this can present a different scenario in winter.

For the study analyses, the measurements were conducted based on Fanger’s heat balance of the human body theory, which included four environmental parameters that could affect human thermal comfort, namely, air temperature, relative humidity, global temperature and air velocity. Ten recorders were installed on the walls of the two international students’ dormitories and six Chinese students’ dormitories. All measurements were taken at 0.3 m from the participants, and at three different heights (0.1, 0.6 and 1.1 m) above the floor in the vicinity of the test participants. This was to ensure a realistic representation of the thermal environments encountered directly by the participants was collected. Continuous recording of indoor air temperature and relative humidity based on Ning et al. (2016) and Cao et al. (2014).

Indoor air temperature and relative humidity were continuously recorded using the devices at 5-minute intervals. Temperature/humidity recorders were installed in a way that they did not affect the mobility of the occupants in the rooms, and far away from walls or openings and electrical appliances, to limit exposure to heat sources. Field measurements on air temperature and relative humidity data were collected each week and stored on a secure digital card (SD card), which was installed in the data logger. All data was saved in a computer at the end of the field investigation. To ensure their functionality, the recorders were continuously checked, and if needed, the batteries were replaced. Table 1 provides a list of the instruments used to measure environmental parameters, including temperature and relative humidity. Figure 1a-d shows some of the interior space of the international and Chinese students’ rooms and the location of devices.

2.2. Subjects
In this study, a total of 30 volunteers of undergraduate and graduate college subjects were sampled. The representative sample was from international and Chinese students’ dormitories, who were randomly selected. To avoid biased results, a balanced sample (15 international students and 15 Chinese student) from each category were recruited, from six Chinese students’ dormitories and two international students’ dormitories (all the international students were from three climatic regions), to explore comfort and adaptation to both temperature and humidity. For the Chinese students, the inclusion criteria were based on residence in the Yangtze River Region, which corresponded to their experiences of the same hot summer and cold winter climate; and stayed in the investigated buildings for more than 2 years. The sampled participants were found to have adapted to the local climate of Chongqing and were familiar with the investigated buildings. The most widely used Climate Classification system is that of Köppen, which recognizes five major climatic regions (Pidwirny, 2016).
2.3. Subjective assessment

In-situ measurements were collected simultaneously, while the respondents were simultaneously completing the questionnaire. Questionnaires administered by the researchers were based on perception of thermal and humidity conditions, preference, acceptability, and adaptive behaviors. Each building was visited once a week. During each visit, the subjects completed a questionnaire on indoor environmental conditions. The questionnaire was divided into two parts: (1) thermal aspects and (2) microclimate. The first part of the questionnaire asked the occupants about their clothing condition and activity level, using a checklist of clothes for assessment of thermal insulation and a checklist of activities for evaluation of the metabolic rate. The occupants were asked about perception of thermal comfort,
including thermal sensation, thermal preference, and thermal acceptability in the dormitories. This was quantified by using the ASHRAE 7-point scale (American Society of Heating, Refrigerating and Air-Conditioning Engineering ASHRAE, 2013), i.e., −3 cold, −2 cool, −1 slightly cool, 0 neutral, 1 slightly warm, 2 warm, 3 hot. For thermal preference, the McIntyre 3-point scale (McIntyre, 1980), i.e., −1 cooler, 0 no change and 1 warmer, was implemented. To determine thermal acceptability, the following question was asked: “Do you accept the current thermal environment?” (Yes or No). To assess occupants’ humidity sensation, the 7-point scale (humidity sensation vote: −3 too dry, −2 dry, −1 slightly dry, 0 neutral, 1 slightly humid, 2 humid, 3 very humid) and 3-point scale (humidity preference: −1 humid, 0 no change and 1 drier) were implemented. The second part of the questionnaire asked the occupants to answer questions on thermal adaptation. For each subject, the data collection exercise lasted for 20 to 25 minutes. All the field surveys were conducted during days with suitable weather (when the subjects were in their rooms and indoor environmental conditions changed in the afternoon and evening, which representative of cold climates), particularly in the afternoons (12–2 pm) and evenings (8–10 pm).

All the participants in the single rooms and double rooms were informed about the study, its objectives and aim before the consent was signed. Confidentiality and anonymity were ensured by asking the subjects not to write their names or any information related to their personal details in the questionnaire (Motlatla & Maluleka, 2021). The questionnaires were destroyed after the completion of data analysis.

Prior to field measurements, a selection of criteria was set for inclusion of the subjects in the study. The selection criteria, among others, covered health status, age, body mass index (BMI), country of origin (only for international students), length of stay, cities of origin (only for Chinese students) etc. This was done to ensure the accuracy of the subjects’ subjective responses and to have a homogeneous sample.

### 2.4. Analysis of the data

Analyses of the data were performed in Microsoft Office Excel 2007 software using descriptive and inferential statistics. Data were cleaned and entered (Motlatla & Maluleka, 2021). T-test statistics was used to test statistical difference at 95% intervals and p-values (p < 0.05). The results are presented in graphs and tables. Due to its low risks, ethical clearance was waived to conduct the study in international and Chinese students’ dormitories.

### 3. Results

#### 3.1. Demographic characteristics of the subjects

In total, there were 30 volunteer subjects, who partook in the study (balanced number of subjects, that is, 15 international and 15 Chinese students). The demographic information is presented in Table 2. From Table 2 it can be observed that in the first group, the participants were aged 20–28 years, with a mean of 25.5 years and a standard deviation of 2.2 years. Regarding the length of stay, it can be observed that...
most of the students lived in Chongqing for approximately 2 years, with a maximum of 6 years. All the Chinese students had spent more time in the city than the international students. Most of the students are familiar with the local climate of Chongqing and conditions in the dormitories because they have stayed in the students’ dormitories at Chongqing University for a considerable length of time, indicating potential for adaptation, and could be responsible for the participants’ acclimatization to the climate in Chongqing.

### 3.2. Indoor climatic parameters

Indoor environmental parameters are shown in Table 3. Figures 1 and Figures 2 illustrate indoor air temperature and indoor relative humidity in international and Chinese students’ rooms. The mean radiant temperature was calculated based on the global temperature, air temperature and air velocity (Z.J. Wang et al., 2015). The indoor air temperature in the international students’ rooms ranged from 14.7°C to 26.6°C, while in the Chinese students it was from 14.9°C to 26.8°C. The mean indoor temperature of the international students’ and Chinese students’ rooms was lower at 18.7°C, and 18.1°C, respectively. In accordance with the prescribed limit in ASHRAE 55–2013 (American Society of Heating, Refrigerating and Air-Conditioning Engineering ASHRAE, 2013), the comfortable air temperature in winter ranged from 20°C to 24°C. The indoor air temperatures of both international students’ and Chinese students’ room fell within the comfort zone during the winter although in the international students’ dormitories it was two times higher than in the Chinese students’ dormitories. The findings showed that the mean air temperature in the international students’ rooms and Chinese students, rooms varied significantly. A similar pattern was observed by previous studies (Han et al., 2009; Li, 2006; Yao et al., 2010), which showed that the indoor air temperature in winter had been increasing. For instance, it has been found that in 2006, the mean indoor air temperature during winter was 9.9°C, and in 2009 was 12.1°C and 14.6°C in 2010. The difference in these studies is that they were conducted in free-running buildings, while our study was conducted in split air-conditioned buildings, with sufficient natural ventilation. The use of split air-conditioning may have improved indoor air temperature in the last years, resulting in the difference between the findings of our study and the earlier studies. Increasing trend of air temperature has also been observed worldwide. This was supported by Nicol and Humphreys (2002), who noted that in the 1990s, the mean indoor air temperature during the cold season was 2°C higher than in the 1970s. This may be explained by the current effects of the global warming, which leads to climate change (leading to temperature fluctuations).

Figure 2 shows that when indoor relative humidity was above 50%, occupants experienced high indoor air humidity, with an average of 68.83% and 69.37% for international and Chinese students respectively. The indoor relative humidity range was higher than the ASHRAE 55–2013 standard for winter, which predicts indoor relative humidity between 30% and 35%. The mean indoor relative humidity was relatively higher than the comfort zone during winter, which might be associated

### Table 2. Demographic information of the study subjects

| Subjects          | Age (mean ± std dev) | Living years (mean ± std dev) | Height (mean ± std dev) | Weight (mean ± std dev) | BMI (mean ± std dev) |
|-------------------|----------------------|-------------------------------|-------------------------|-------------------------|----------------------|
| International     |                      |                               |                         |                         |                      |
| students          | 25.5 ± 2.15          | 3.81 ± 1.13                   | 1.71 ± 0.05             | 66.25 ± 6.96            | 22.36 ± 1.6          |
| Chinese students  |                      |                               |                         |                         |                      |
| Mean              | 24 ± 1.11            | 4.28 ± 1.48                   | 1.66 ± 0.05             | 58.57 ± 7.78            | 21.1 ± 1.8           |
| Std Dev           | 2.5 ± 0.5            |                                | 1.76 ± 0.05             | 73 ± 23.95              | 18.6 ± 2.6           |
| Maximum           | 28 ± 2              | 6                             | 1.6 ± 0.05              | 80 ± 24.96              | 24.96 ± 5.5          |
| Minimum           | 20 ± 2              | 2                             | 1.58 ± 0.05             | 53 ± 19.95              | 18.6 ± 2.6           |
Table 3. Indoor environmental parameters in the students’ rooms

| Parameters                        | Statistical summaries | International Students | Chinese students |
|-----------------------------------|-----------------------|------------------------|------------------|
| Air temperature (°C)              | Mean                  | 18.7                   | 18.1             |
|                                   | Std Dev               | 1.1                    | 1.4              |
|                                   | Maximum               | 26.7                   | 26.9             |
|                                   | Minimum               | 14.7                   | 15.0             |
| Radiant temperature (°C)          | Mean                  | 18.1                   | 17.8             |
|                                   | Std Dev               | 2.2                    | 1.8              |
|                                   | Maximum               | 24.6                   | 23.9             |
|                                   | Minimum               | 15.0                   | 14.6             |
| Relative humidity (%)             | Mean                  | 68.8                   | 69.4             |
|                                   | Std Dev               | 6.71                   | 5.85             |
|                                   | Maximum               | 82.35                  | 85.61            |
|                                   | Minimum               | 47.16                  | 48.52            |
| Air velocity (m/s)                | Mean                  | 0.05                   | 0.08             |
|                                   | Std Dev               | 0.04                   | 0.06             |
|                                   | Maximum               | 0.21                   | 0.4              |
|                                   | Minimum               | 0.01                   | 0.01             |
| Predicted mean vote (PMV)         | Mean                  | −1.14                  | −1.41            |
|                                   | Std Dev               | 1.28                   | 1.09             |
|                                   | Maximum               | 1.09                   | 0.98             |
|                                   | Minimum               | −3                     | −3               |
| Predicted percent of dissatisfied (PPD) | Mean                  | 37.73                  | 48.85            |
|                                   | Std Dev               | 43.22                  | 38.85            |
|                                   | Maximum               | 100                    | 100              |
|                                   | Minimum               | 5.                     | 5.               |

Figure 2. Indoor relative humidity distribution.
with the use of natural ventilation in the buildings. The mean air velocity was lower than 0.1 m/s in the two groups, which was lower than the human sensitivity threshold for air flow (0.2 m/s) (Zhu et al., 2010). Even though the indoor environmental conditions in students’ rooms were poor, they were better for international students than Chinese students. However, a different pattern was observed in the previous, which lower than the human sensitivity threshold for air flow (0.2 m/s) (Zhu et al., 2010). In general, the thermal environmental conditions in the students’ rooms were relatively poor, indicating that environmental conditions of Chongqing were harsh. Overall, it was observed that thermal environmental conditions were warmer or cooler in the international students’ rooms than in the Chinese students’ rooms.

3.3. Clothing level and metabolic rate
This section intended to present findings about how clothing and metabolic rate affected adaptation during winter season. Clothing has been viewed as an important behavioral adaptation to achieve thermal comfort at varying temperatures (Bauden & Grab, 2005). Clothing insulation is considered as an essential variable to examine regarding behavioral adaptation especially in dormitory buildings, as individuals would have much more flexibility to adjust their clothing in dormitories compared to workplaces where a certain dress code is most likely required. In calculating clothing insulation of the participants, the ASHRAE Standard 55–2010 (American Society of Heating, Refrigerating and Air-Conditioning Engineering ASHRAE, 2013) and ISO 7730 (ISO 7730, 1994) was used. In this study, students’ clothing insulation was recorded during the whole period of the survey in the questionnaire. The clothing insulation was calculated based on the recommended garment insulation value in ASHRAE Standard 55 and ISO 7730. Table 4 illustrates how value of means of clothing insulation varied for international students and Chinese students, which were 1.37 Clo units and 1.29 Clo units, respectively. There was a significant variation in thermal insulation, with average values from 0.513 to 2.16 Clo units in winter. The results indicated that occupants of case study buildings more clothes or heavy clothes during winter. This is like previous studies by Yao et al. (2007) and Lan, (2013), who found that residents living in hot summer and cold winter region of China are accustomed to wearing heavy clothes indoors in winter, with clothing insulation levels varied between 1.15 and 1.42 Clo units.

During the survey, it was observed that most of the subjects were doing sedentary activity, with a mean value of metabolic rate in both groups near to 1.2 met (70 W/m²). The average metabolic rate of international students was 1.14 met, suggesting that they performed more dynamic activities compared to Chinese students who had an average metabolic rate of 1.12 met. This can be related to the available space in each type of room because space can be a limiting factor to mobility in the room.

| Table 4. Clothing insulation and metabolic rate of the subjects |
|---------------------------------------------------------------|
| **Parameters** | **Statistical summaries** | **International students** | **Chinese students** |
| Clo Insulation (Clo) | Mean | 1.37 | 1.29 |
| | Std Dev | 0.62 | 0.49 |
| | Maximum | 2.16 | 1.97 |
| | Minimum | 0.53 | 0.46 |
| Metabolic rate (met) | Mean | 1.14 | 1.12 |
| 58.2 W/m² = 1 met | Std Dev | 0.26 | 0.23 |
| | Maximum | 1.6 | 1.6 |
| | Minimum | 0.8 | 0.8 |
3.4. Perceptions of thermal indoor environment

3.4.1. Thermal sensation

The mean thermal sensation vote (TSV) was calculated at each 1.0°C interval of the operative temperature in our study. Research suggested that TSV could be influenced by three factors: physiology, psychology, and behavioral adaptation (Cao et al., 2014). Previous studies suggested that different occupants might have different TSV in the same environment. It has been also suggested that even for the same occupant experiencing a similar environment at different moments or with different emotions, this may lead to different TSV (N. Zhang et al., 2017). In this study, thermal sensation was evaluated using thermal sensation vote (TSV) in thermal environmental conditions during winter. Figure 3 illustrates the thermal sensation vote for international and Chinese students. As expected, Chinese students felt more comfortable than the international students, corresponding to over 76% of Chinese students. In this case, Chinese would prefer “slightly cool”, “neutral”, and “slightly warm” (−1< TSV<1) compared to over 72% of international students. The thermal neutral vote (TSV = 0) of Chinese students was very larger compared to international students. Most of the subjects voted cold side instead of hot side, but international students (53.33%) voted cold side than Chinese students (44.66%). The vote confirmed that the indoor air temperatures was low in all dormitories. The findings of the study indicated that even though the indoor environment in international students' rooms was greater than in Chinese students' rooms, they felt colder than Chinese students.

When a comparison of thermal sensation vote between Chinese students and international students (IS) of different climatic regions and international students was made as shown in Figure 4, it appeared that even though 14.28% of international students from cold winter region voted neutral, they felt more comfortable (80%) than students in other groups. International students from tropical climate had the lowest vote in the comfort zone, 65.71% of them voted in the range of “slightly cool” to “slightly warm” (−1< TSV<1). In general, the thermal sensation of Chinese students was greater than international students, indicating that they had a better ability to adapt to the environmental conditions than the other groups. This findings demonstrated the impact of climatic regions on the thermal sensation votes, which indicated that the students from the coldest regions were the most comfortable, while those from the tropical climate regions felt less comfortable.
3.4.2. Neutral temperature and acceptable temperature range
Neutral temperature is defined “as the temperature at which people would, on an average, feel neither warm nor cold, or temperature at which people would feel comfortable” (Li et al., 2010; Po, 1973). The mean thermal sensation vote was calculated in each 1°C interval of indoor air temperature. By plotting the values of indoor air temperature for international and Chinese students, a correlation between the thermal sensation value and the indoor air temperatures was demonstrated. Figure 5 displays the regression of thermal sensation (TS) and indoor air temperature of the two groups and Eqs (1)-(2) shows the resulting regressions.

International students: $TSV = 0.4506x + 8.9427 \quad R^2 = 0.8491$ (1)

Chinese students: $TSV = 0.3963x + 7.3843 \quad R^2 = 0.7054$ (2)

where $TSV$ is the thermal sensation vote and $T_{op}$ represents operative temperature °C.

Figure 4. Thermal sensation vote for Chinese students and the three categories of international students.

Figure 5. Mean thermal sensation votes and indoor air temperature for international and Chinese students.
The findings of the study showed that there is a good correlation in both cases between the mean thermal sensation vote and indoor air temperature. The indoor air temperature at which the thermal sensation regression equation is equal to zero (TSV = 0) is regarded as the neutral temperature. Chinese students felt neutral with the indoor air temperature at a temperature lower than international students and the difference between the two neutral temperatures was over 1°C. The neutral temperature of winter for the first group was 19.84°C, while that for the second group was 18.63°C. The thermal neutral temperatures were higher than the mean indoor air temperatures. The acceptable temperature ranges for international and Chinese students were between 17.62°C and 22.06°C and 16.1°C and 21.15°C respectively. When comparing the two regression lines, the mean thermal sensation votes of Chinese students were higher than for international students, suggesting that international students preferred a higher temperature range than subjects of the second group.

3.4.3. Thermal preference
Thermal preference shows the occupants’ expectation to indoor environment. To assess the students’ thermal preference, the following question was asked: “How would you like to adjust temperature in your room?” with cooler (−1), no change (0) and warmer (1). Figure 6 displays the subjective answers on air temperature preference for Chinese and international students. From Figure 6, it can be observed that the proportion of students expecting “warmer” was the highest, with less than a third (32.38%) of international students not preferring any change on the indoor air temperature, while 40.77% of Chinese students voted “no change”. Figure 7 illustrates occupants’ thermal preference for Chinese students and the three categories of international students. Within the international students, it was observed that students from cool winter regions were the mostly satisfied with the indoor air temperature, corresponding to 40% of them voting for “no-change”; followed by students from cold winter regions (34.28%) whose votes were close to that of Chinese students. Meanwhile, a large majority of students from tropical climate regions were expecting “warmer” conditions. In all the groups, the proportion of preferring “warmer” was higher. From these findings, it appears that students from cool or cold regions were more satisfied than those from tropical climate regions.

3.4.4. Humidity sensation
Humidity sensation vote was predicted based on each 5% bin of relative humidity. Figure 8 displays the regression of humid sensation (TS) and relative and Eq. (3)-(4) shows the resulting regressions. The p-value for the international students was less than 0.05 (t-test, p < 0.05), which showed that
they experienced more humid conditions, whilst Chinese students experienced much drier conditions. This illustrated that there were significant differences between the two groups.

International students: \( HSV = 0.0532 \times RH - 2.6024 \quad R^2 = 0.5521 \) (3)

Chinese students: \( HSV = 0.0517 \times RH - 2.8959 \quad R^2 = 0.7931 \) (4)

Where \( HSV \) is human sensation vote, \( RH \) represents relative humidity, %.
The neutral relative humidity can be calculated when HSV equals to 0 (HSV = 0). Considering the neutral relative humidity, the results showed that for international students and Chinese students, it was 48.9% and 56%, respectively. Regarding the adaptation to humidity, there was greater difference between the two groups, which indicated that the experience of staying for longer periods in colder regions did not help a lot to improve the neutral relative humidity of international students.

The findings in Figure 9 sought to understand if international and Chinese students were comfortable on relative humidity and indoor air temperature in Chongqing during winter season. The results revealed the following: most Chinese students (79%) felt a humid sensation within the range of slightly dry to slightly humid (−1< HSV<1), corresponding to a relative humidity range between 56.6% and 71.5%. Indoor air temperature varying between 17.9°C and 20.1°C; and for the international students, the neutral relative humidity was 52.1–57.9%, with an indoor air temperature range of 18.3–20.3°C. Additionally, the international students voted within the three central categories, which indicated that the environment was more humid for them than for the Chinese students. Most international students, who were from the tropical climate, cool winter and cold winter regions exerted strong adaptation to neutral (HSV = 0). The students from cold winter regions had the highest votes within the three central categories. Concerning students from cool winter and tropical climate regions, the humidity sensation votes were slightly around dry or slightly humid (−1< HSV<1). The higher level of indoor relative humidity recorded in the students' rooms did not significantly influence the vote of the occupants. This demonstrated that higher relative humidity might be acceptable for students in their rooms. All the students' votes within the three central categories were adapting to relative humidity of 54.1–71.1%. Our findings were consistent with McIntyre's (1980), which indicated that the difference in relative air humidity of 20–70% could be undetectable within the comfort zone.

3.4.5. Humidity preference
Air humidity preference was evaluated in the international and Chinese students’ dormitory as displayed in Figures 10 and Figures 11. As shown in Figure 10. A total of 35.23% of students of the first group preferred a drier environment, with the majority of them opting for the current indoor air humidity. Meanwhile, the indoor air humidity in the Chinese students' rooms was satisfactory, corresponding to 62.13%. The higher indoor air humidity in subjects' rooms did not prevent majority of them from voting “no-change” in both groups. From Figure 11 it appears that students...
from cold winter regions have the highest satisfaction (68.57%) of the indoor air humidity preference. They were followed by Chinese students, students from cool winter regions and students from tropical climate regions (48.57%). This is despite the fact the humidity recorded in students’ rooms was very high and well above the set limits in ASHRAE 55 (American Society of Heating, Refrigerating and Air-Conditioning Engineering ASHRAE, 2004). All the groups voted the drier three times higher than those preferring humid conditions.

3.4.6. Thermal acceptability
Participants were asked about their perception on thermal acceptability as shown in Figure 12, referred to as “the percentage of the respondents who found ‘acceptable’ their thermal

Figure 10. Occupants’ humidity preference for international and Chinese students.

Figure 11. Occupants’ humidity preference for Chinese students and the three categories of international students.
environment conditions”. About 61% of the students in the first group and 73% of students in the second group considered their thermal environment acceptable, indicating a considerable thermal acceptability to indoor environments. When comparing all the groups, it appeared that the highest acceptance was shown by the Chinese students, suggesting strong adaptation to the cold winter climate in Chongqing. The results showed that the acceptability vote was closer to the thermal sensation vote between the three central categories (as shown in Figure 6) for most of the groups. The subjects from tropical climate regions with the least adapted group to colder environments, which explained why they were the least satisfied. This explained the significant effects of these factors concerning adaptation. Comparatively, the students from cold winter regions were expected to be more satisfied; however, upon our analysis, this was not the case. This could be explained by the fact that in most cases, the colder regions were excessively heated in winter. This pattern is like a study by Yu et al. (2013), which suggested that staying in a warmer environment might weaken peoples’ thermoregulatory system and can cause discomfort or even health problems when experiencing a colder stressor. This demonstrated that over-reliance on heating can prevent people from exercising their acclimatization to cold environments, which they should have inherited through generations.

3.5. Adaptive behaviours
This section intended to present the findings on the actions taken by students in the dormitories to keep themselves comfortable to indoor conditions when they felt discomfort. It is important to understand the behavior of occupants in buildings, especially in dormitories considering the high density of occupants. As mentioned earlier, thermal comfort in dormitory buildings was not significantly satisfactory when the occupants were indoors. In analyzing the relationship between comfort and adaptation in dormitory buildings, interviews were conducted with the thirty (30) participants. We extended our investigation on understanding students’ adaptive behaviours when they were in the rooms. For this situation, we asked students to answer the following question, and classify the adaptive actions based on their priorities when indoors:

(1) When your room is too cold, what adaptive actions do you frequently take to make yourself more comfortable?

The results showed identical for priorities 1 and 2 in most of the groups but varied from one group to another for priorities 3 and 4. It can be found that there were mainly four kinds of
adaptive behaviors: (1) window closing, (2) adjustment of clothing, (3) eat or drink something and (4) turning on an air conditioner or lowering its set temperature. The result of adaptive behaviours of the Chinese students and international students in the university dormitories from different climatic regions in winter are shown in Figure 13a-b.

![Figure 13. Occupants' behavioral adjustments for all international and Chinese students and the three categories of international students.](https://doi.org/10.1080/23311916.2021.1968740)

(a) adaptive behaviors of international students.  
(b) adaptive behaviors of Chinese students.

(c) adaptive behaviors of IS tropical climate.  
(d) adaptive behaviors of IS cool winter.

(e) adaptive behaviors of IS cold winter.
In Figure 13a-b, the most frequently cited adaptive behavior for both international and Chinese students in response to thermal stress indoor was “window closing”, followed by “adjustment of clothing”. Additionally, the international students kept their windows somewhat closed or very closed, as outside temperature was lower than indoor air temperature when felt cold. This result confirmed that the international students had not adapted to this sudden decrease in indoor temperature, because they actively closed their windows, and their choice of clothing remained relatively sensitive to thermal sensation. These results suggested that, among all the students, the international students are the only ones that chose to close the window to achieve the highest comfort even when they felt warm, and the habit helped them to maintain acceptable temperature in their rooms by preventing fresh air from entering. Based on the students ranking of adaptive behaviours, the second predominant way to increase thermal insulation and prevent heat loss was “adjustment of clothing”. However, “adjustment of clothing” during winter by the international students was lower than that of Chinese students. For the “adjustment of clothing”, the same habit was observed in the three other groups. The results showed that “eat or drink something” and “turning on an air conditioner or lowering its set point” were the third and fourth priorities of adaptive behaviours for the second group. It can also be found that “drinking hot water” during winter was an effective adaptive behavior to the Chinese students’ compared to most of the international students. Therefore, this explains the importance of the traditional norms being influential more than the stimulus itself in determining Chinese students’ choice of drinking hot water in winter. For the international students, “adjustment of clothing” and “turning on their air conditioner” were both effective adaptive behaviours to rapidly heat indoor air to obtain excellent thermal comfort conditions. When the three climate groups on the third and fourth priorities were compared, the predominant adaptive behaviours for students from cold winter regions and students from tropical climate regions were “turning on an air conditioner” as third priority, while students from cool winter regions preferred “eating or drinking something” as third priority. Other adaptive behaviours such as “the use of a hand warmer”, “move to another area of the room”, “use fan heater” and “increasing activity level” seemed less significant among the groups the university dormitories. The results of our analysis indicated the importance of occupant window opening behavior to temperature sensitivity and adaptability in university dormitories, which requires to be further studied.

4. Discussions

4.1. Perception on adaptation to humidity

The perception of the participants on adaptation to humidity was critical in the study for the authors to understand how international and Chinese students might feel and adapt in hot and cold regions and draw scientific conclusions. The findings of this study indicated that staying for longer periods in colder areas had an important effect on comfort and adaptation to humidity, with Chinese students showing an absolute advantage of adaptation to higher humidity compared to international students. This scenario may imply that the upper limit of acceptable relative humidity for the Chinese students reached approximately 70%. This may have a high effect on their humidity sensation due the higher mean temperature in dormitory rooms, which was far higher than that of the comfort zone (American Society of Heating, Refrigerating and Air-Conditioning Engineering ASHRAE, 2013). However, this is higher than the comfort zone suggested by ASHRAE Standard (American Society of Heating, Refrigerating and Air-Conditioning Engineering ASHRAE, 2004), where the relative humidity is usually lower than 60%, and when temperature is over 26°C, it needs to be lower than 50% (He et al., 2016). Previous studies illustrated the role of period of stay in a humid climate in accelerating adaptations to humid conditions (Dhaka et al., 2015; He et al., 2016; Mishra & Ramgopal, 2014; Nakano et al., 2002). They found that people could accept high humidity if they had long history of exposure to a humid climate. However, adaptation to humidity is still a slower process compared to temperature (He et al., 2016), since a large gap of adaptability between international students and Chinese students was observed. This general observation from these findings may require more research regarding the new groups of international and Chinese students.
The findings revealed that behavioral adaptation plays an important role in comfort and adaptation in hot and cold climatic regions. This is like that of a study He et al. (2016), where activities and clothing influenced occupants’ perception of humidity. Walking out/in can have an influence on increased humidity sensation.

Participants were asked about their perception on adaptation to humidity. Many of them indicated that “the use of a hand warmer”, “move to another area of the room”, “use fan heater” and “increasing activity level” were not considered adaptive behavior; therefore, there was no valid relationship found between humidity and occupants’ activities or “increasing activity level”. About a considerable number of students had acknowledged that “turning on an air conditioner or lowering its set point” was an effective way to dehumidify indoor air. This could be an indication of some level on dehumidification among the students. These findings were consistent with He et al. (2016), whereby students in humid regions did not really find or realize effective behaviors to adapt to high humidity, which meant that the students’ behavioral adaptation to humidity was also limited.

The findings of the study showed that psychological adaptation played an important role in comfort and adaptation. This result suggested that student’s expectation was significantly lowered after staying longer periods in colder regions. As mentioned earlier, the international students showed lower acceptance to drier environments even when indoor humidity remained higher. The results of similar study conducted in dormitory in hot and cold region showed that there was association between higher psychological endurance of the students, adaptation, and comfort (He et al., 2016). Therefore, this would help occupants strengthen adaptation to a humid climate.

Although the participants experienced similar humidity sensation, staying in an area with a colder climate in winter for a longer time could also strengthen adaptability to higher humidity. It is important for the students to know that this ability mainly comes from psychological adaptation. Adaptation strategies is an important and critical point to humidity compared to temperature because it provides a novel strategy towards energy efficiency.

4.2. Perception of adaptation to temperature
Based on our results, for perception on thermal sensation and neutral temperature, and perception on acceptable temperature range, the length of stay in a region with colder climate in winter strengthened the occupants’ adaptability to low temperature. Therefore, neutral temperature and upper limit of acceptable temperature range of international students was lower than in Chinese students. The result showed that the values were almost within the limits suggested limits in ASHRAE Standard (American Society of Heating, Refrigerating and Air-Conditioning Engineering, ASHRAE, 2010). This is similar to findings detailed in Z.J. Wang et al. (2015) and Ning et al. (2016).

The findings revealed that there was a difference of adaptation to temperature between international students and Chinese students. It is evident that the behavioral adaptation (based on adaptive behaviours), including closing windows and clothing adjustment in the students’ dormitories had an effect for international students who acclimated to the cold climate. These adaptive behaviours often rendered important ways to retain a warmer sensation in the rooms for international students than the Chinese students did. Most of the Chinese students had more advantages to feel a neutral sensation with lower temperatures. This could be an indication that experience of staying longer periods in Chongqing did not significantly reduce the ratio of window closing but limited international students to prefer clothing adjustment and enhanced their adaptability.

Most of the international students in the university dormitories were in preference of relatively higher temperature than Chinese students, and the preference of temperature increased after staying in Chongqing for more than 1 year. This could be an indication that staying in areas with a colder environment for a longer period lowered occupants’ expectations and increased their adaptation to lower temperatures psychologically. Staying for a longer period in regions with colder climate in winter improved the students’ behavioral and psychological adaptation to
lower temperatures. These finding were like He et al. (2016) and N. Zhang et al. (2017), whereby they reported that behavioral and psychological adaptation played an important role for adaptation and comfort of students in university dormitories.

Unlike in areas such as Beijing, Harbin, etc., with centralized heating, in Chongqing students living in university dormitories were free to change temperature set points of air-conditioners in their indoor environment and assisted them to adjust to their acceptable comfort levels every day. The adjustment of temperature using air conditions among the students could provide obvious differences for neutral temperature between split-running and free-running environment control although adaptability to lower temperature existed. The results of a similar study conducted among students in university dormitories in Harbin showed that the neutral temperature was 23.0–24.0°C (Z. Wang et al., 2011). Some of the similar findings were also obtained in Harbin (Z.J. Wang et al., 2015). In other words, the international students had acclimatization to a colder climate neutral temperature reached 18.7°C in this study, but it was still lower than that in buildings with centralized heating as shown in the previous studies.

Due to the low indoor air temperature and high relative humidity, students adopted different measures to feel more comfortable, such as window closing, clothing changing, eat or drink something and use air conditioner. Students in the different groups took the same actions with limited difference. As already indicated above, behavioral adaptation of students was always associated with preference of closing windows when feeling cold. The result of our study showed that they favored the adaptive behaviors, which could effectively prevent lower indoor temperatures rather than those that could still make them exposed to lower temperatures. This kind of behavioral approach could reduce the chances of student’s exposure and adaptation to cold environments.

5. Limitations
The limitations of the present study are highlighted with suggestion for future research. The study focused on occupant comfort and adaptation of students in Chongqing University’s dormitory buildings (eight dormitories) in cold winter regions dormitory during the cold season, which may represent only the winter season. Therefore, the study findings may not be generalizable to all types of university dormitories. In addition, the sampled dormitories were restricted to Chongqing University. It may not be accurate to generalise the findings to all dormitories in Chongqing or cold areas in China since the comfort and adaptation may vary in different geographic areas and environmental conditions. Therefore, comfort and adaptation to cold climate might be underestimated in this present study. Detailed information regarding students’ window opening behavior in dormitory buildings, air-conditioned dormitory buildings, and occupants’ behavior and sleeping patterns in dormitory buildings is required in the future to clarify inner mechanisms of adaptability in dormitory buildings. In addition, surveying students all year round or during the major seasons (winter and summer) and increasing the size of the sample need to be considered for improved design of dormitory buildings in universities in hot summer and cold winter (HSCW) climate zones. Detailed information considering international students from the five climatic regions and Chinese students from different climatic regions of China needs to be further studied. A comparison of university students’ dormitories and off-campus apartments to assess comfort and adaptation differs in these two environments is also required in the further dormitory during the cold season, which may represent only the winter season. These are areas for future refinements. Although more needs to be done, the findings of the present study provide preliminary results to subjective assessment of comfort and adaptation in cold regions in China, which might be useful for dormitory building designs and energy efficiency in the future.

6. Conclusions and recommendations
This study has provided information on students’ comfort and adaptation in university dormitories in a cold area in China. The study suggested that thermal conditions between the international-and-Chinese students’ dormitories varied significantly although both were relatively poor. The average
indoor air temperature in the international students’ and Chinese students’ dormitories were 18.7°C and 18.1°C, respectively, which fell outside the ASHRAE thermal comfort zone, and the indoor relative humidity was relatively higher. This had an impact on comfort and adaptation between the Chinese students and international students during winter. This translated to Chinese students feeling more comfortable and satisfied with indoor air temperature and relative humidity compared to the international students. Closing windows and make clothing adjustments were both effective adaptive behaviours of the students to maintain heat, particularly the international students. The international students were more sensitive to lower temperature compared to the Chinese students. The students’ adaptation was significantly influenced by the length of stay in areas with severe cold winter climate, which improved students’ behavioral and psychological adaptation to lower temperatures. The experience of staying for longer periods in this area also strengthened students’ acclimatization to higher humidity. Future research on the use of big data to understand occupants’ acclimatization in dormitory buildings in hot summer and cold winter regions is required.

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