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Overall and local thermal sensation & comfort in air-conditioned dormitory with hot-humid climate

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ABSTRACT

This study aims to investigate students' overall and local thermal sensation & comfort in air-conditioned dormitories of university. A field survey was conducted in air-conditioned dormitories in Changsha, a big city in south of China with hot-humid climate in summer. This survey combined environmental parameters measurements and questionnaires. The obtained results indicated that head exerted the highest influence on overall thermal sensation, followed by calf and foot, then the influences of chest and back were comparatively lower. Such a result can be explained by physiological, environmental and local-disturbed factors. As for overall thermal comfort, it was determined by the most and the second most comfortable body parts. In this study, those two body parts usually went to head and chest. Characteristics of body parts and indoor environment explained the relationship between overall and local thermal comfort. Moreover, in most cases, overall comfort was higher than local comfort of any other body part due to the high-level control over the indoor environment. Nevertheless, because of various factors in real environment, there were significant differences of local thermal sensation among current studies. Therefore, more studies are still in need to establish a more universal model.

1. Introduction

Thermal environment of dormitories in university is important for students' health and study. Nowadays, most dormitories of universities in south of China are naturally ventilated in both winter and summer. While in north of China, most dormitory rooms are naturally ventilated in summer and heat-supplied in winter. This condition usually causes discomfort for students in dormitory rooms, especially in southern regions of China [1–3]. With the development of economics and increasing number of university students, better indoor environment of dormitories in universities are quite in need. In recent years, air-conditioned dormitories are gaining popularity in some universities located in big cities in south of China, but they are not so wide-spread. Meanwhile, thermal environment and comfort in school buildings have been concerned by many researchers and related organizations [4–11], but attention for dormitories was insufficient.

Xia et al. [1] carried out a survey in three naturally-ventilated dormitory buildings located in Xi'an in summer. They reported high percentage of unsatisfied and attributed this to the terrible natural ventilation condition, which resulted in high indoor temperature even though the outside temperature remained comparatively low. Similarly, Tan et al. [2] declared that indoor environment of naturally-ventilated dormitories in summer didn't meet 80% acceptability criteria prescribed by ASHRAE Standard [12]. Wang and Xiao [13] conducted a field measurement in naturally-ventilated dormitories of universities located in Chongqing, China. The obtained results showed that the average air temperature reached 32.4 °C during daytime which far deviated from the comfort zone suggested by ASHRAE Standard [12] due to hot climate in summer. In their another survey [14], they found that few effective methods were available for students to control indoor environment of dormitory rooms, but students still exerted endurance ability to hot-humid condition. Wan et al. [15] found that students took various adaptive behaviors to reduce the stimulation caused by cold environment in naturally-ventilated dormitories. Similar phenomenon was observed in the survey of Lu et al. [3]. They confirmed that adaptive behaviors were taken by occupants in dormitory rooms located in Shanghai, China in summer. However, the proportion of occupants who complained about high temperature and bad ventilation condition was pretty high. Cheng et al. [16] investigated thermal comfort requirements of

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students in both naturally-ventilated and air-conditioned dormitories, while the differences of neutral temperature and prefer temperature were quite small between two conditions. After a wide survey with 3712 students participated in, Sun et al. [17] pointed out that more than 30% of students in heat-supplied dorm rooms had sick building syndrome (SBS) symptoms in winter. They also found that girls suffered more SBS symptoms than boys. He et al. [18] conducted a field survey in 25 air-conditioned dormitory rooms of Chongqing University in winter in Chongqing, China. The results indicated that more than 30% of students voted on cool side even though the mean indoor temperature reached 23 °C, and this probably resulted from the humid climate in winter.

However, some problems remains unclear. For instance, previous researches mainly focused on naturally-ventilated dormitories which were common for most universities in summer in China, while few researches on students' comfort in air-conditioned dormitories were found, especially in summer. It's insufficient for the popularization of air-conditioned dormitories. Further, current studies focused on occupants' overall thermal sensation and comfort, while local thermal sensation and comfort for individual body parts were often ignored. It's indicated by Zhang et al. [19–21] that special attention must be paid on local thermal sensation and comfort before higher level of comfort of occupants' is achieved in air-conditioned environment.

This paper aims to investigate students' overall and local thermal sensation & comfort in air-conditioned dormitories of university in summer. A field survey was conducted in dormitory rooms with split-type air conditioners during July to September in 2015 in Changsha, which is located in south of China with hot-humid climate in summer. This survey combined indoor environmental parameters and questionnaires to occupants. Based on obtained data, occupants' local thermal sensation and comfort were analyzed. Then, the influencing factors were discussed. Also, the obtained results were compared with those of previous literature. This paper also provided references for improving students' comfort in dormitories with air conditioners.

2. Methodology

2.1. Location and climate

This field investigation was conducted in dormitory rooms with split-type air conditioners in Hunan University which is located in Changsha, China. The survey was carried out in sunny or cloudy days.

Changsha, a big city located in central-south region of China, belongs to Hot Summer & Cold Winter zone which covers most regions of south China. As for Changsha, the air temperature during day time is often higher than 30 °C while it did not decrease much at night in summer [22]. Changsha is also faced with high level humidity through whole year [22]. Other cities in the this climate zone experience similar climate [22]. As a result, Changsha can be regarded as a typical city in south of China.

2.2. Subjects and dormitory rooms

All people participated in this survey were undergraduate or graduate students. To avoid the difference of subjective response between people from different climate zones, only students who lived in Changsha or other places with similar climate for more than one year were involved. Before measurement, occupants were inquired about health condition. Students who were wounded, ill, drank alcohol or smoked were not allowed to take part in the survey.

All dormitory rooms in this survey were standard ones for four students, thus differences of indoor distribution among those rooms were negligible. The indoor distribution of dormitory rooms was shown in Fig. 1. The split-type air conditioners were about 2.5 m height above the floor. Moreover, there was one thermostat in each room, so students were free to control the air conditioners.

2.3. Measurement and questionnaire

Details of instruments used in this survey are shown in Table 1. Indoor air temperature was measured at 0.1, 0.6 and 1.1 m; other parameters, like relative humidity, air velocity and black globe temperature, were measured at 0.6 m height. Mean radiant temperature (MRT) were calculated on the basis of black globe temperature according to ISO Standard 7726-2002 [23]. For one certain room, the environmental parameters were recorded after the instruments reached steady.

Questionnaires were distributed to students in dormitory rooms after instruments reached steady. Firstly, students were asked to answer some questions like age, gender, inhabit time, activity, etc. For properly determining metabolic rate, occupants were told to fill out their activities during four periods, i.e. (1) 60-30 min, (2) 30-20 min, (3) 20-10 min and (4) 10-0 min prior to conduct questionnaires. The final metabolic rate of a certain person was the average value of these four periods. Then, occupants were asked to answer subjective feelings, including overall thermal sensation (OTS), overall thermal comfort (OTC), local thermal sensation (LTS) and local thermal comfort (LTC). Local body parts included head, neck, chest, back, abdomen, upper arm, lower arm, hand, thigh, calf and foot. A seven-point scale for rating thermal sensation suggested by ASHRAE Standard 55–2010 [12] was adopted. Similarly, seven-point scale was also used to rate thermal comfort. Detailed scales of subjective response are listed in Table 2.

Lastly, For properly determining clothes insulation, clothes of each person was recorded through observation and inquiry, then the clothes insulation was calculated according to ASHRAE Standard 55–2010 [12].

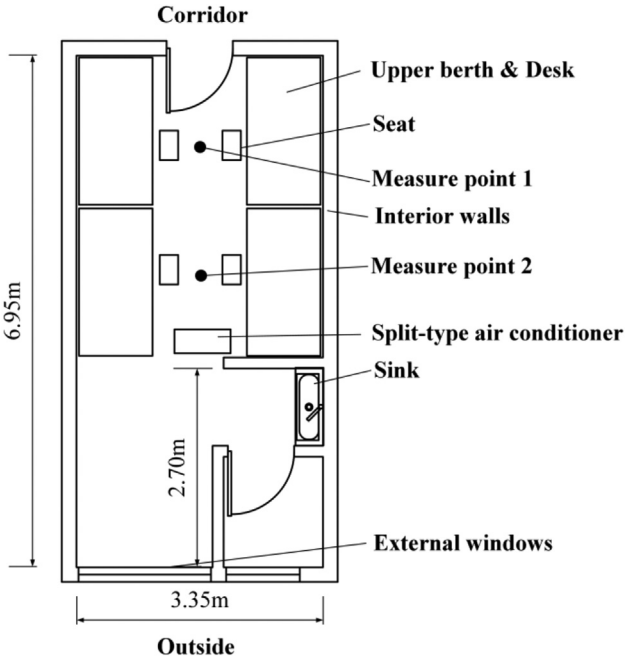

Fig. 1. Indoor distribution of dormitory rooms in this study.