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Investigation of indoor thermal environment in the homes with elderly people during heating season in Beijing, China

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ABSTRACT

This study intends to investigate indoor thermal environment in homes with elderly people during heating season in Beijing, China. The investigation was performed from December 2016 to February 2017, involving both urban and rural houses. Heating equipment, indoor clothing and thermal sensation of the elderly, and indoor physical parameters were analyzed through subjective surveys and objective measurements. Results show that different types of heating systems/devices are used in urban and rural houses. Overall, the heating duration of rural houses is longer than that of urban houses in winter. In terms of indoor air temperature, urban elderly people experienced warmer and steadier thermal environments than rural elderly people. During the investigation, the average air temperature in living rooms/elderly people's bedrooms of urban houses was 21.9 ± 2.2 °C/21.5 ± 2.8 °C, significantly higher than 16.1 ± 3.5 °C/14.6 ± 3.3 °C of rural houses. Additionally, rural elderly people usually encountered a large temperature step between indoors and outdoors, due to frequent exit and entry. Despite of relatively low air temperatures in rural houses, the elderly reported that the indoor thermal environment was acceptable, since the elderly in rural areas wear thicker clothes indoors in winter. This also indicated the acceptable temperature for elderly people in rural areas was lower than that for elderly people in urban areas. It is noted that the acceptable temperature may not satisfy long-term physical health requirements of the elderly. More studies are needed to determine reasonable temperature for both thermal comfort and health of the elderly.

1. Introduction

The world's population is ageing: various countries in the world have been experiencing a rapid growth in the number and proportion of elderly people in their population [1–3]. China, as a developing country, is also currently facing a severe population-ageing. By the end of 2015, in China there were 143.86 million elderly people above 65-year-old (the chronological age of 65 years as a definition of the elderly has been accepted by most countries [4]), accounting for 10.5% of the total population [5]. Moreover, the proportion will continue to increase in the next few decades.

In the face of the increasing group of elderly people, apart from challenges in medical security and pension service, the government is also confronted with housing issue for the elderly. Whether the elderly can live a serene and comfortable old age, living environment is considered as a key factor. Actually, back in 2002 the Madrid International Plan of Action on Ageing highlighted the requirement to provide comfortable living environment that would fit for the purpose of accommodating the elderly for their health and wellbeing [1,6].

In the past years, there are a few researchers working on living environment of elderly people, especially elderly service centers or elderly care centers (ECCs). Wong et al. [7] investigated the thermal environmental parameters of 19 community service centers for elderly people in Hong Kong. Yang et al. [8] also surveyed thermal environmental parameters and assessed thermal comfort of the elderly in 26 ECCs in Korea. The study performed by Mendes et al. [9,10] explored environmental variables and buildings characteristics in 22 ECCs in Portugal. Almeida-Silva et al. [11] also measured the indoor air quality in 10 ECCs and assessed the elders' daily exposure to air pollutants. Jiao et al. [12,13] conducted physical measurements of indoor thermal environment in 17 elderly facilities in Shanghai of China and analyzed the factors affecting the thermal satisfaction of the elderly. As

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a matter of fact, for the vast majority of elderly people, they prefer to stay at their own home for the rest of their lives [14]. Moreover, with an increasing proportion of elderly people, home-based care for the aged is encouraged and advocated in China. Therefore, indoor environmental conditions at home are of great importance on health and wellbeing in the elderly. To date, however, there is scant data in the literature concerning indoor environment of existing houses for elderly people.

According to the previous studies [15–18], winter is the season of high incidence of diagnosed disease in the elderly, for instance, cardio-cerebrovascular disease, the leading cause of death and disability in the elderly. Also, in cold winter some elderly people close doors and windows all day for thermal comfort. As thus, breathing exhaust gases from human body, secretions of skin and organs, plus indoor smoking and smoke produced by cooking and heating fuels, can result in poor indoor environmental quality. Therefore, it is essential to understand indoor environmental conditions of existing houses with elder people in winter.

Vast geographic China has five different climatic regions (i.e. severe cold region, cold region, hot-summer and cold-winter region, hot-summer and warm-winter region, and mild region) from north to south [19]. In different climatic regions, outdoor climatic conditions, building characteristics and lifestyles of the elderly have a great difference. These factors can influence indoor environmental conditions in houses of the elderly.

Based on the points above, a large-scale investigation of indoor environmental conditions in the homes with elderly people aged over 65 years old in winter are carried out in several typical cities of China, located in different climatic regions. In addition, because more than half of elderly people in China live in rural areas, the investigation involves both urban houses and rural houses. The research project consists of two parts, a questionnaire survey and a field measurement on housing environmental conditions. The study was firstly conducted in Beijing, one of the typical cities as a representative of the cold region, from December 2016 to February 2017.

Considering that indoor thermal environment is identified as a sensitive and dominant factor contributing to an acceptable indoor environment for elderly people, this paper mainly summarizes the survey results related to indoor thermal environment and thermal comfort of the elderly during heating period in Beijing area. These results may be beneficial to understand indoor environment of existing houses with the elderly and design comfortable housing environments for elderly people in China.

2. Methodology

2.1. Geographical and climatic conditions

Beijing, as the capital of China, locates in the cold region, with four distinct seasons. In winter, there are three months during which the monthly mean temperature is below 0 °C. Due to low outdoor air temperature, building heating is essential for occupants' thermal comfort. Normally, the heating period prescribed by the government starts on 15 November and ends at 15 March, lasting 120 days. The surveyed houses in this study are mainly distributed in 9 urban communities and 2 rural villages in Beijing area, as shown in Fig. 1.

2.2. Questionnaire survey

The survey was aimed at the elderly aged over 65 years old. A total of 100 questionnaires were distributed to the families with elderly people, including 50 houses in urban areas and 50 houses in rural areas. The average age, height and weight was 73.9 ± 5.8 years old, 162.6 ± 6.6 cm and 65.1 ± 10.2 kg for urban subjects and 72.0 ± 6.7 years old, 164.4 ± 7.1 cm and 66.1 ± 9.4 kg for rural subjects, respectively. The survey conditions are shown in Fig. 2. The main contents of the questionnaire covered the following information: (1) general information of the elderly such as such as gender, age, height and weight; (2) residential characteristics, heating equipment and life style; (3) thermal comfort levels of the elderly using the 7-point ASHRAE scale (numerical values of −3, −2, −1, 0, 1, 2, and 3 indicate cold, cool, slightly cool, neutral, slightly warm, warm, and hot, respectively) of thermal sensation vote; (4) clothing of the elderly in the home in cold season; (5) dietary habit and health status of the elderly. To ensure that elderly people could easily understand the questions, each item in the questionnaire was explained by the investigators before the elderly completed the questionnaires. Even so, among the returned questionnaires, two questionnaires from urban house were invalid, thus a total of 98 effective questionnaires were eligible for inclusion in the analysis. In the present paper, the items associated with indoor thermal environment and human thermal comfort are analyzed.

2.3. Field measurement of indoor thermal environment

During the questionnaire survey, there were some elderly people showing interests in the field measurement of indoor environment in their houses. We selected separately ten participants from the urban and rural respondents with consideration on gender and age, to conduct field measurements of indoor thermal environment in their houses during heating period. All of the measured urban houses were multi-family apartment houses and all of the rural houses were single-storey detached houses, as shown in Fig. 3. The information of the elderly and their houses are presented in Table 1.

The data logging instruments with temperature and humidity sensors were used to monitor air temperature and relative humidity (RH). Due to the limit of the number of instruments, two types of instruments, TR-76Ui T & D Corp (measurement accuracy: ± 0.5 °C, ± 5% RH; valid range: 0–55 °C, 10–95% RH) and Testo 175-H1 (measurement accuracy: ± 0.5 °C, ± 3% RH; valid range: −10–50 °C, 0–100% RH) were used. In each house in urban areas, measured rooms included living room, older people's bedroom, bathroom and the coldest room reflected by the elderly. In individual houses, the bathroom was also the coldest room reflected by the elderly. Monitoring air temperature in the coldest room aimed to analyze the temperature step encountered by the elderly in the house. In rural areas, however, the toilets in most of the houses were usually outdoors. Also, the different rooms having different function were detached in the majority of rural houses. Therefore, occupants frequently entered into and exited from their houses [20]. The temperature step encountered by the elderly is mainly the temperature difference between indoors and outdoors. Thus, the thermal and humidity parameters in the coldest room in the rural house were not monitored. Overall, measured rooms in each house of rural areas included living room, older people's bedroom and bathroom (if bathroom is indoors). The logging instruments in living rooms and bedrooms were located at a height of about 1.1 m above the floor, as prescribed in ISO 7726 [21], and away from indoor heat sources and direct sunlight through windows. The data loggers in bathrooms were away from wet source to avoid being splashed. In addition, corresponding outdoor climate was also simultaneously monitored. And care was taken to avoid the direct influence of both solar radiation and rainfall on outdoor sensors. All of the data logger was mounted one by one in homes during the first visit to each house, and removed during the second visit one week later. The data logging instruments recorded data at an interval of 10 min for one week.

2.4. Statistical analysis

Independent Samples T-Test was used to compare the difference of indoor climates and clothing insulation between urban areas and rural areas. These analyses were performed using SPSS Statistics software (ver. 19.0; IBM SPSS).