A questionnaire investigation on people's sleep and health in constant temperature and humidity environment in China

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Abstract. In recent years, constant temperature and humidity air-conditioning systems have been widely used and promoted in residential buildings all over the world. At the same time, the influences of long-term stable indoor environment on people's lives, especially on sleep quality and health, have attracted wide attention. Therefore, in this paper, a questionnaire investigation on people's sleep and health in constant temperature and humidity environment was carried out in China. By comparing the questionnaire investigation results from the users of constant temperature and humidity air-conditionings with unused, it could be found that people living in constant temperature and humidity houses have better performance in sleep quality, but worse health condition. These results suggested that constant temperature and humidity air-conditioning had an effect on human bodies. The findings can also inform future study on the role of thermal environment on sleep and health.

1 Introduction

Indoor environment is a key factor affecting people's life quality. Therefore, people have been committing to building an optimal residential environment. In recent years, constant temperature and humidity (CTH) air-conditioning systems in residential buildings have been widely used all over the world including China. These buildings were equipped with radiant ends for heating and cooling. Meanwhile, independent fresh air systems were used for ventilation and humidity control. The indoor climate with CTH systems could remained within a thermal comfort range[1]. Reviewing the research on thermal comfort environments, it had been documented that people were allowed to have a better sleep quality in thermal comfort environment than a too cold or too hot environment[2]. However, some studies showed that long-term stable thermal comfort environment might result in a reduce on human immunity[3,4]. Human bodies' health could be improved through a training under extreme temperature[5]. It was worth mentioning that above studies were conducted while person were awake but not asleep. Therefore, it is necessary to study the sleep and health condition of people in CTH environment.

Sleep quality was affected by sleep environment, such as temperature, humidity and air quality. These three factors were all related to air conditioning. Imanari[6] studied that the conventional upward air supply home air-conditionings created a large vertical temperature gradient in rooms. Especially in winter, the temperature of sleeping area was lower than ceiling area, which indicated these systems could not create a good thermal environment. For CTH air-conditions, some scholars held the view that the airflow in CTH environment was well organized[7]and that occupants had a high level of comfort[1]. These seemed to mean that CTH systems could make up for the shortcomings of conventional air-conditionings in temperature, humidity and air quality.

In the past for a long time, people regarded thermal comfort and health as two different fields of study. Actually, experimental studies by Zhang[8] and Tong[9]et al. showed that thermal environments did have an effect on human immunity. Although the use of air-conditionings kept people away from heat stroke and frostbite, however, Zhu[10] noted that a long-term stable thermal environment could negatively affect human health. Meanwhile, Chen held the view that there were health risks of occupants in CTH residences[11].

Actually, the above viewpoints related to CTH systems were only put forward based on theories but not experiments or data. Therefore, this study sought to obtain data which could help to address the above controversies about CTH systems. The paper aimed to explore sleep and health condition of people in CTH environments, and provide new insights into sleep thermal environments and health.

2 Method

Questionnaire survey method is a widely used and reliable method in the study of indoor environments. The advantages of this method are: high-efficient, classified, unified, extensive[12]. Therefore, in this paper, a questionnaire was designed to investigate the sleep quality and health condition of people in China. Respondents were asked to recall their sleep and health condition in the past year and answer questionnaires.

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2.1 Contents of questionnaire

The contents of questionnaire were designed according to the objectives of this study. They consisted of following three parts:

(1) Background questions: gender, age, city of residence, whether use CTH system, time of residence, temperature setting at home and living experience;
(2) sleep quality: total sleep time per day, sleep latency, number of night-time sleep awakenings, self-perceived sleep quality and factors affecting sleep in their home;
(3) health condition: number of illnesses in the last year, duration of each illness, types of illnesses, whether catch a cold when the first cold wave invade in winter.

2.2 Sample characteristics

The survey questionnaires were distributed in December 2021. Subjects were residents in CTH and non-CTH residential buildings with different occupations. A total of 402 valid questionnaires were received, with 214 males and 188 females. Respondents varied in ages and climate zones for architecture in China, as shown in Fig. 1.

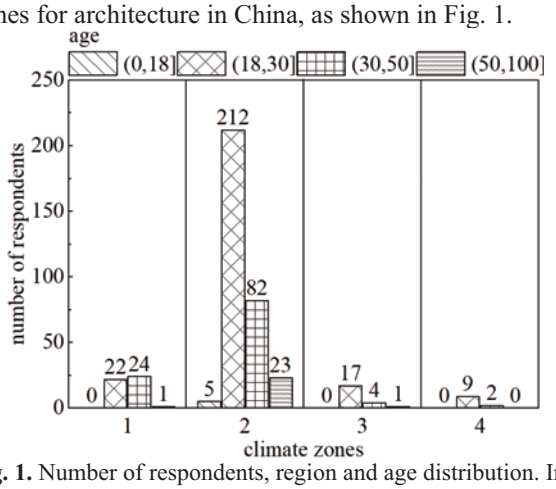

Fig. 1. Number of respondents, region and age distribution. In the horizontal coordinate: 1-severe cold climate zone, 2-cold climate zone, 3-hot summer and cold winter climate zone, 4-hot summer and warm winter climate zone.

3 Results and discussions

3.1 Indoor temperature and sleep quality for respondents between CTH and non-CTH environment

This paper investigated the residential temperature both in CTH and non-CTH environment. In CTH environment, indoor temperature was set in range of 18-28℃ in summer and 15-30℃ in winter. 67.21% of users set bedroom temperature in range of 24-26℃ in summer. 69.81%of users set bedroom temperature in range of 20-26℃ in winter. In non-CTH environment, temperature range were 15-35℃ in summer and 16-31℃ in winter. 63.12%of non-users set bedroom temperature in range of 24-26℃ in summer. 67.96%of non-users set bedroom temperature in range of 20-26℃ in winter. It can be seen a higher percentage of users set indoor temperature in a more comfortable range than non-users. Moreover, the different forms of airflow organization between CTH environment and non-CTH environment resulted in different indoor temperature distribution. Sleep could be influenced by temperature. Therefore, weather there were differences in sleep quality should be studied.

To analyse data and find regularities, the respondents were divided into two groups according to use CTH air-conditionings in their houses or not.

Questions and answers about sleep of all respondents are shown in Fig. 2. Firstly, the proportion of respondents whose sleep latency less than 20 minutes was 25.24% higher in CTH environment than non-CTH. Secondly, the percentage of complete night-time sleep was 15.60% higher in CTH environment than non-CTH. Thirdly, the percentage of those who considered themselves have good sleep quality was 15.16% higher in users than non-users.

From these data, it can be seen respondents in CTH environment had a better experience of sleep. It can also be informed by the questionnaires that 82.86% of users liked their residential environment while 64.28% of non-users. Especially for respondents using conventional upward air supply home air-conditionings, the percentage of people who liked their residential environment was only 38.24%. In summary, people in CTH environment had a better living experience both in day and night.

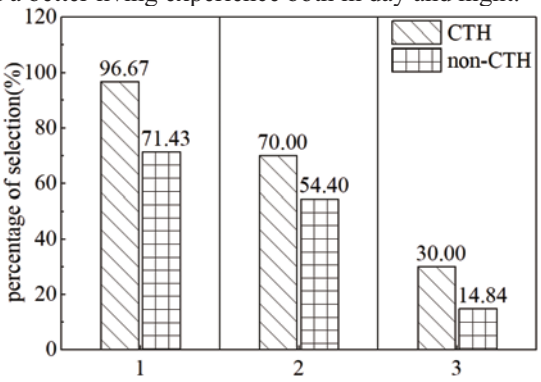

Fig. 2. Questions and answers about sleep of all respondents. In the horizontal coordinate: 1-sleep latency<20min, 2-wake up <1time during whole night sleep, 3-have good sleep quality. Percentage of selection=number of people who select/total numer of people using CTH air-conditionings in their houses or not.

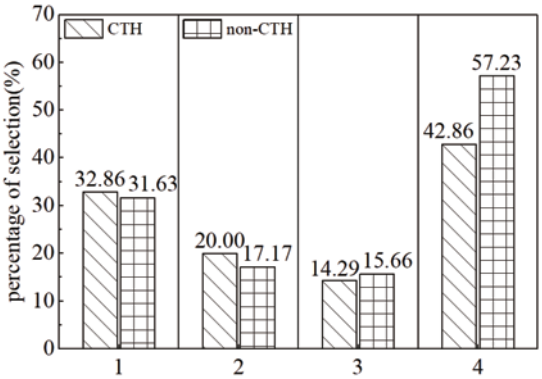

Fig. 3. Factors influencing sleep and their percentage of selection in two groups of respondents. In the horizontal coordinate: 1- temperature, 2-humidity, 3-air freshness, 4-noise. Percentage of selection=number of people who

select/total numer of people using CTH air-conditionings in their houses or not.

The questionnaire came up with four factors relating to air-conditionings which could influence sleep. Fig. 3 shows the factors and their percentage of selection in two groups of respondents. Users appeared 0.23% and 2.38% higher percentage for bedroom temperature and humidity, respectively. There were 1.37% and 14.37% lower percentage for air freshness and noise in users, respectively. It can be seen that a small difference in proportion of selecting temperature, humidity and air freshness between users and non-users, but large in noise.

Actually, people had the choices to set temperature and humidity at a thermal comfortable number before they going to bed. So, it is necessary to figure out what caused the poor sleep quality in non-CTH environment. Previous study showed indoor air quality had influence on sleep quality[13]. In the poll on degree of air freshness in their residences in this paper, the percentage that people felt indoor air was fresh was 70% in users, while the percentage was only 46.1% in non-users. However, there were only about 15% of all respondents considered air freshness as a factor which affected sleep. Therefore, it can be assumed that a large proportion of respondents did not consider air quality as a reason of poor sleep quality.

Based on questionnaire data in Fig. 3, the lower selection percentage of air freshness in CTH environment indicated a view against the poorer air quality in CTH environments[13,15]. Besides, in the poll on degree of air freshness in their residences, the percentages that people felt indoor air was fresh were 70% and 46.1% in users and non-users, respectively. This result also proved that the CTH air-conditioning systems could provide better indoor fresh air environment.

3.2 Health condition for respondents between CTH and non-CTH environment

To investigate the health condition of respondents, there were three questions designed in questionnaire. Question 1 was designed to identify the number of times that respondents fall ill while question 2 reflects how quickly people healed after ill, and question 3 reflects the immunity of human body in the face of winter cold wave shocks. The questions and answers are shown in Fig.4.

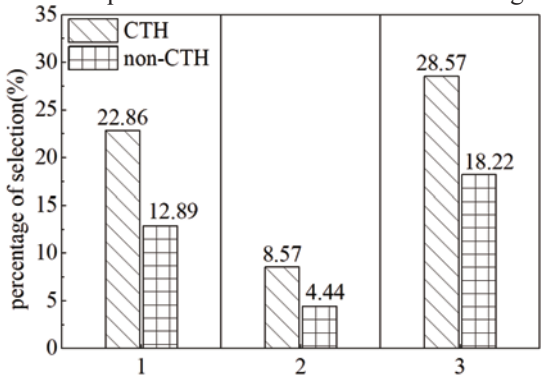

Fig. 4. Questions and answers about health of all respondents. In the horizontal coordinate: 1-fall ill more than 3 times in past year, 2-illness last for more than 7 days once they fall ill, 3-catch a cold when the first cold wave invaded in winter. Percentage of selection=number of people who select/total number of people using CTH air-conditionings in their houses or not.

In Fig. 4, it can be seen that a higher percentage of selecting sick more than three times in past year and illnesses lasted for more than seven days in users. Meanwhile, when first cold wave invaded in winter, higher percentage of respondents in CTH environment catch a cold.

To avoid differences in health condition due to age and region, respondents in same age group and same climate zone were selected. Since the highest number of respondents are aged 18-30 in cold climate zone, they were selected for analysis, as shown in Fig. 5. Moreover, in this paper, the types of diseases were asked. Fig. 6 showed five diseases relating to air-conditionings[16] and the percentage of selection.

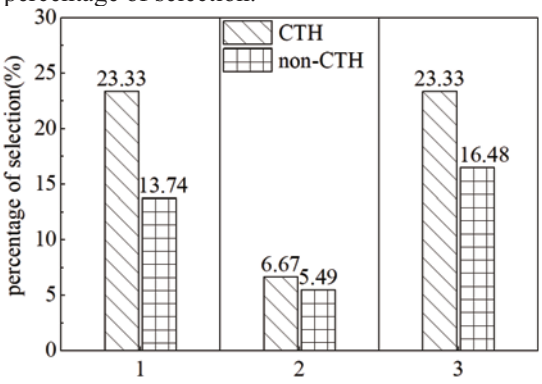

Fig. 5. Questions and answers about health in two groups of respondents aged 18-30 in cold climate. In the horizontal coordinate: 1-fall ill more than 3 times in past year, 2-illness last for more than 7 days once they fall ill, 3-catch a cold when the first cold wave invaded in winter. Percentage of selection=number of people who select/total number of people aged 18-30 in cold climate using CTH air-conditionings in their houses or not.

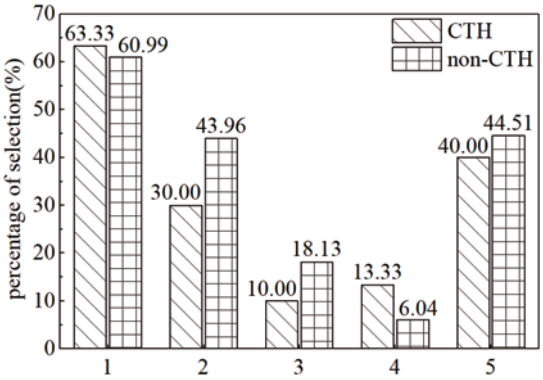

Fig. 6. Diseases relating to air-conditionings[16] and their percentage of selection in two groups of respondents aged 18-30 in cold climate. In the horizontal coordinate: 1- have a flu, 2- have a cold, 3- allergic rhinitis, 4- skin allergy, 5-gastrointestinal discomfort. Percentage of selection= number of people who select/total number of people aged 18-30 in cold climate using CTH air-conditionings in their houses or not.

It can be seen in Fig. 5 that 23.33% of users sicked more than three times in past year, compared to 13.74% in non-users. The percentage of those who needed more than seven days to heal after falling ill was 6.67% in users while 5.49% in non-users. When the first cold wave invaded in winter, the percentage of people catching a cold was 6.85% higher in CTH environment than non-CTH. From these data, it can be seen that people living in

CTH environment were easy to get ill and hard to heal, which might mean their health condition was poor.

To figure out possible reasons about it, the questionnaire firstly collected the total hours per day that respondents use air-conditionings in their homes. Analysing the data of respondents aged 18-30 in cold climate, the percentage that people used CTH air-conditionings at home for more than 12 hours per day was 19.2%, while non-CTH was 6.8%. Secondly, in CTH environment, 73.9% of respondents set the bedroom temperature at 20-26°C in winter while non-CTH was 69.0%. The percentage of users and non-users who set the temperature at 24-28℃ in summer was 88.9% and 83.8%, respectively. This indicated that users spent more time in thermal neutral rooms. As we all know, it has been suggested[10] that a long-term thermal neutral environment may cause a decrease in health levels. The results of this questionnaire supported this view. Long-term thermal neutral environment during sleep could also has an impact on human health.

Fig. 6 shows the diseases relating to air-conditionings[16] and their percentage of selection in two groups of respondents aged 18-30 in cold climate. It can be seen people using CTH air-conditionings were more like to have a flu and skin allergy while the non-users were cold, allergic rhinitis and gastrointestinal discomfort. Some scholars pointed out that people living in CTH environment may have problem of indoor condensation due to improper operation of system. This would allow bacteria to grow and result in allergic diseases of residents[15]. However, the data in Fig. 6 shows that respondents in CTH environment had a lower percentage of allergic rhinitis and a higher percentage of skin allergy. It did not provide an accurate answer to the question about allergy. Therefore, the problems of condensation in CTH environments and the occupants suffering from allergic diseases need a further field research.

4 Conclusion and limitation

In this paper, a questionnaire investigation on people's sleep and health in constant temperature and humidity environment was analysed. The results suggested that people living in constant temperature and humidity houses had better performance in sleep quality but worse in health. However, it should be noted that the respondents filled out the questionnaire by recalling their own experiences and feelings, which might make their evaluation of sleep and health condition subjective and resulted in the limitation of conclusion. In addition, only 402 questionnaires were received for this survey, which may affect the accuracy of conclusion. Therefore, future work will involve extensive investigation, incorporating physiological indicators of sleep quality and health condition of people in CTH residences.

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