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Smart and Healthy within the 2-degree Limit

Characteristics of Cognitive Temperature Scale under the Thermal Adaptation in Summer

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This paper describes the characteristics of Cognitive Temperature Scale (CTS) under the thermal adaptation in summer. Field measurement and survey in summer for about 640 elementary school students in Sapporo and Kumamoto in Japan from 2009 to 2015 were made. Students put a red sticker on their individual "Thermal Diary Card" when they felt strongly thermal discomfort. They also recorded their CTS to the cards without checking the thermometers. It was found that firstly the CTS are strongly connected to the outdoor temperature in Sapporo and Kumamoto. Secondly, the CTS in Sapporo were around 26 to 27°C when 50% of them felt thermal discomfort. On the other hand, the CTS in Kumamoto were over 30°C. This result suggests that there is significant difference in thermal adaptation to the hot and humid environment in Sapporo and Kumamoto.

KEYWORDS: Cognitive temperature Scale, Adaptive Thermal Comfort, Regionality

1. INTRODUCTION

Many researches on relationship between thermal comfort in the indoor environment and energy use in the buildings have been made since 1970s. PMV (Predicted Mean Vote) has been utilized as most famous index in the world for evaluating indoor thermal environment and comfort in the room as well as they help designers and engineers to confirm indoor conditions that suit occupants' expectations. However, it is pointed out that the PMV cannot adequately predict thermal comfort or discomfort in the room with natural ventilation in the hot and humid climate in summer [1]. In hot and humid climates there are no current standards that define what those "comfortable" or "uncomfortable" conditions that should be in residential buildings and schools without air-conditioners.

"Adaptive model" as thermal environmental adaptation of the human body has been proposed by Humphrey, Nicol, and Rejal [2, 3]. It is composed of physiological, psychological, and behavioural adaptation as well as it is also influenced by the individual thermal history and the lifestyle. Recently, it was found that thermal adaptive comfort of occupants has been related to the exergy consumption speed within the human body, and warm or cool radiant exergy from the interior surface of buildings envelops by Shukuya [4].

On the other hand, we have surveyed "Cognitive Temperature Scale (hereafter CTS)" of the occupants since 2009 [5]. "Cognitive temperature" means the output psychological temperature by the occupants for a simple question as "How temperature you feel in this room?" Thermal comfort or discomfort sensation is a concept that corresponds to the "sense-perception" phase as well as CTS is a concept that corresponds to the "cognition" phase.

According to our previous researches, CTS is strongly connected to thermal discomfort of occupants in summer. It is thought that CTS related to personal thermal history and the lifestyle. Furthermore, it will be expected that we are able to clarify the "limit temperature with thermal discomfort" or "the condition without thermal discomfort" for passive cooling buildings.

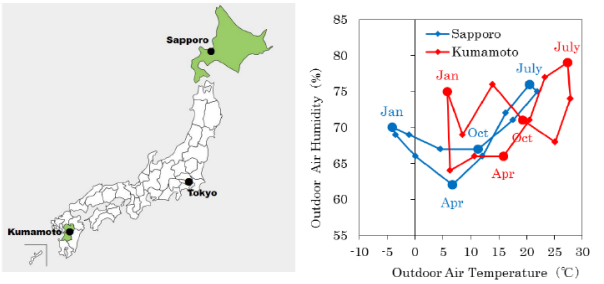

Figure 1: Sites of Sapporo and Kumamoto in Japan (left) and a climograph in Sapporo and Kumamoto (right).

2. MEASUREMENT AND SURVEY

Field measurements and survey in classroom of the elementary schools in Sapporo and in Kumamoto in the beginning of September from 2009 to 2015 were made. Figure 1 shows the sites of Sapporo and Kumamoto in Japan (left) and a climograph in Sapporo and Kumamoto (right). Average outdoor temperature in this period is 20.2 °C in Sapporo versus 26.6 °C in Kumamoto. Relative humidity in Sapporo and Kumamoto is about 70 to 75 % during the survey. The reason for targeting elementary school students is to clarify that the difference in thermal history between Sapporo and Kumamoto influences the CTS. In the case of adults, it is often different the place of birth from the place of residence.

We collected the data of 380 students in Sapporo and 260 of students in Kumamoto. Both schools do not have

air conditioners and they always took natural ventilation. Students put a red sticker on their individual "Thermal Diary Card" if they felt strongly discomfort. At the noon, they wrote their CTS to the cards without checking the thermometers in their room from 2009 to 2012. In 2014 and 2015, their teachers told the students the room air temperature after the students answered their CTS. Room air temperature and humidity, and globe temperature were measured at the window and corridor sides, respectively. Outdoor temperature and humidity were also measured.

3. RESULTS AND DISCUSSION

The data in 2015 was available only in Kumamoto. CTS of the students, room air temperature, and outdoor temperature in Sapporo are shown figure 2. The above figure in 2009 to 2012, the CTS are distributed around 24.0°C. That is close to the average outdoor temperature (24.4°C) than the average room air temperature (26.4°C) because the students did not check the room air temperature. The bottom figure in 2014, the CTS are distributed around 26.0°C. That is close to the average room air temperature (27.1°C) than the average outdoor temperature (23.2°C). These results suggest that the CTS in Sapporo are originally determined based on outdoor temperature in Sapporo, and the CTS have approached the room air temperature by checking every noon in 2014. The result of Kumamoto shown in Figure 3 has the same tendency of Sapporo.

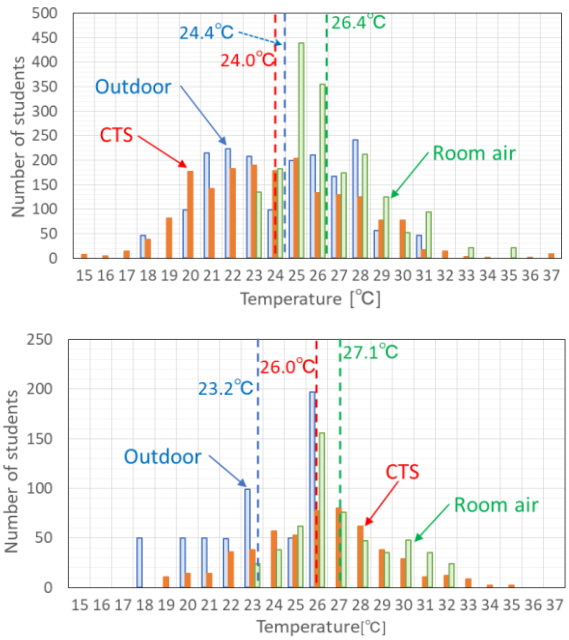

Figure 2: CTS, Room air temperature, and Outdoor temperature in Sapporo (Above: 2009-12, bottom: 2014)

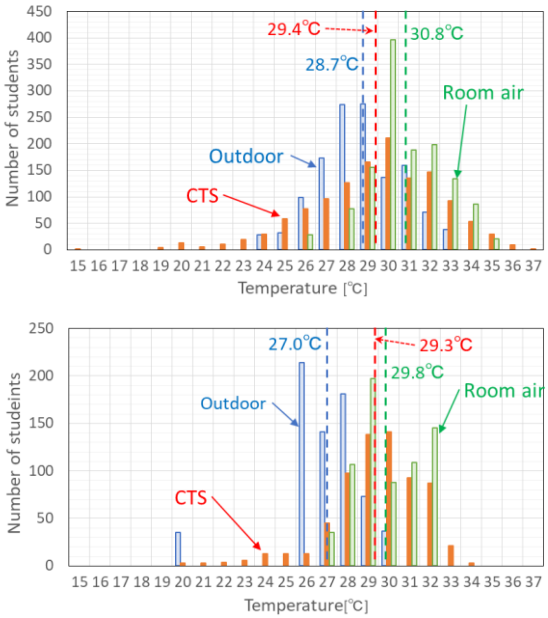

Figure 3: CTS, Room air, and Outdoor temperature in Kumamoto (Above: 2009-12, bottom: 2014, 15)

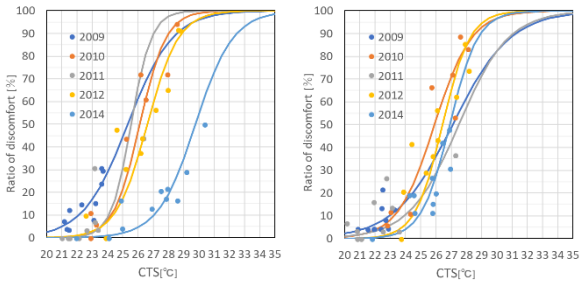

Figure 4: CTS and the ratio of discomfort in Sapporo (Left: at the window side, Right: at the corridor side)

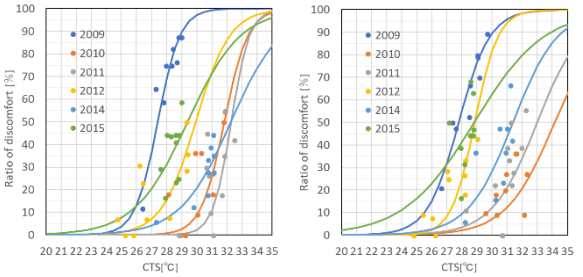

Figure 5: CTS and the ratio of discomfort in Kumamoto (Left: at the window side, Right: at the corridor side)

Figure 4 and 5 show the CTS and the ratio of thermal discomfort in Sapporo and Kumamoto from the result of logistic analysis based on the measured data in 2009 to 2015. In Sapporo, CTS is around 26 to 27°C when 50 % of the students feel thermal discomfort. In contrast, in Kumamoto most of CTS are over 30°C under the same condition, although there are variations.

This result suggests that students in Sapporo and Kumamoto have remarkable differences in tolerance and adaptation to the hot and humid environment. In addition, the CTS in Sapporo and Kumamoto have a

strong correlation of the maximum of outdoor temperature. In other words, CTS has regional characteristics.

4. CONCLUSION

This paper showed the relationship between occupant's Cognitive Temperature Scale (CTS) and thermal discomfort in Sapporo and Kumamoto. According to the regional characteristics of CTS, there is significant difference in tolerance and adaptation in Sapporo and Kumamoto.

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