# Setting temperature and clothing insulation in student rooms in summer

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ABSTRACT

A survey of air conditioner temperature settings and clothing insulation was carried out for university student rooms in June–October during daytime on weekdays in Osaka, Japan. The results are as follows. 1) For air-conditioners that were turned on, the temperature setting was 26–28°C in 81.1% of cases. 2) Almost all respondents wore long trousers and T-shirts, or that ensemble plus an inner shirt (78.9%). 3) Temperature settings and thermal sensations differed by building. 4) Effects of socks on thermal sensation were recognized. 5) Both the temperature setting and the clothing insulation changed along with the seasonal change of the outdoor temperatures. 6) In relation to outdoor temperatures, the coefficient of correlation $R^2$ was respectively 0.17 for the temperature setting and 0.28 for the clothing insulation. Furthermore, $R^2$ was 0.02 between the temperature setting and the clothing insulation.

## 1. INTRODUCTION

Recently, an Action program called 'Cool Biz' has been promoted by the government office in Japan to save energy and to reduce carbon discharge in summer. The program appeals to office workers to set a cooling temperature of 28°C and to wear cooler clothing. The university also appeals to students and the staff to set cooling temperatures of 28°C in summer. To clarify the situation related to temperature settings of air-conditioners, clothing insulation and thermal sensation, the survey of students and university student rooms was carried out in this study.

## 2. METHOD

### *2.1 Survey rooms and students*

At Osaka City University, which is located south of Osaka City, 25 student rooms and 516 students were surveyed. The survey rooms were limited to living rooms. The rooms are in two five-story buildings of two types. The areas are 51.12 $m^2$ or 25.56 $m^2$. Both rooms face south or north. The respondents were healthy 20-year-old male and female students.

### *2.2 Survey period and time*

This survey was carried out during June–October 2007 in Osaka, Japan. The total survey days were 13: 4 days in June, 1 day in July, 2 days in August, and 3 days in September–October. The survey was carried out at 13:00–15:00 on weekdays.

### *2.3 Survey items*

Survey items were grouped as follows. For rooms, 1) situation of air-conditioner use and electric fan use, 2) temperature setting, and 3) situation of window-opening or door-opening. The temperature setting value shown on a

thermostat display panel attached to the room wall was recorded by several investigators. For occupants, 1) Sex, 2) Clothing ensemble, 3) Activity, 4) Thermal sensation and thermal comfort, and 5) Living-in time in the room. The subject answers of these items were obtained by several investigators using a questionnaire sheet. Temperatures recorded at a meteorological observatory were available as outdoor temperatures.

### *2.4 Estimation of clothing insulation*

Clothing insulation *Icl* can be estimated as follows. [1]

$$Icl = 0.835 \Sigma Iclu,i + 0.161 \quad (1)$$

In that equation, the following pertain. *Icl* shows the insulation for the entire ensemble, in clo. *Iclu,i* signifies the garment' effective insulation, in clo, where 1 clo = 0.155 $m^2$ deg K/W. The 19 clothing ensemble types, designated as No. 0 to No. 18, were chosen so that respondents could answer easily.

### *2.5 Activity*

According to the survey results, the students' activity types were classified into six patterns: 1) Standing, not relaxed 1.4 met; 2) Typing with PC 1.2 met; 3) Reading, seated 1.0 met; 4) Seated, quite 1.0 met; 5) Reclining, 0.7 met; and 6) Standing, talk 1.2 met. The activity levels were 0.7–1.4 met, where 1 met = 58.2 $W/m^2$.

## 3. RESULTS AND DISCUSSION

### *3.1 Attributes of the respondents*

In all, 516 students and 195 rooms were surveyed. Figure 3.1 presents the occupants and rooms for each survey day. Neither number was constant every day. The numbers of occupants were one to seven per room for each survey. Figure 3.2 and Fig. 3.3 show survey quantities of the rooms and occupants by building and direction. The rooms of B building were 59 and the occupants were 161 in all. The rooms of C building were 136 and the occupants were 355 in all. Actually, B building has more experimental rooms than C building. Furthermore, more of its rooms faced south than faced north.

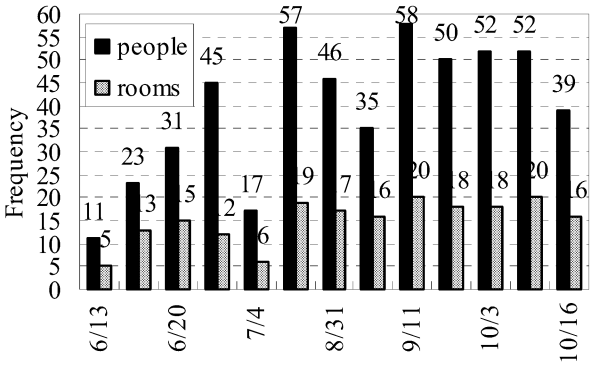

Fig3.1 Numbers of subjects and rooms

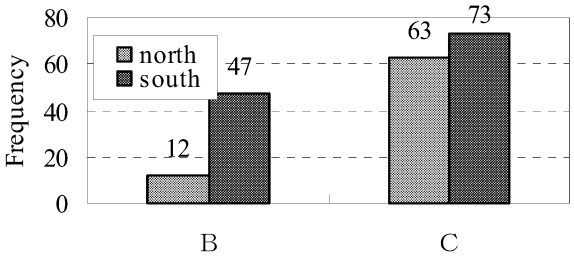

Fig3.2 Building and direction of the rooms

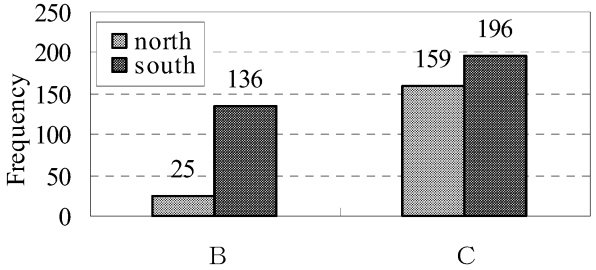

Fig3.3 Building and direction of the subjects

Fig.3.2 and Fig.3.3 show the survey numbers of the rooms and occupants by building and direction. The rooms of B building were 59 and the occupants were 161 in total number. The rooms of C building were 136 and the occupants were 355 in total number. B building has many experimental rooms as compared to C building. And there were more rooms faced to south than rooms faced to north. Of all respondents, males were 91.6%, females were 8.4%.

*3.2 Clothing*

As described previously, the clothing ensembles were classified into 19 patterns. Respondents were assumed to have been wearing some underwear. Figure 3.4 shows the frequency distribution of the clothing ensemble type. The No. 2 type, describing 52.1% of all respondents, consisted of long trousers and a short-sleeve T-shirt. The No. 5 type (long trousers, short sleeve shirt and inner shirt) was 13.6%; the No. 3 type (long trousers, long sleeve T-shirt) was 13.2%. Furthermore, Nos. 7, 8, 11, and 12, which described short trouser ensembles, were 8.9%. The sample number of the survey in the hottest month (July to August) was small. Therefore, the respondents wearing long trousers and a short or long sleeve shirt occupied a large ratio of the total answers. Only two students wore skirts because most respondents were males. Figure 3.5 shows the respondents rate of wearing socks and footwear. Of respondents, 117 persons (22.7%) without socks and/or footwear (category: 'nothing') in living rooms. In such cases, the room floor was covered with carpet. When the respondents wore shoes, they almost all wore them without socks.

*3.3 Thermal sensation and thermal comfort*

The ASHRAE seven-point scale was used for thermal sensation; "hot", "warm", "slightly warm", "neutral", "slightly cool", "cool", and "cold". Figure 3.6 shows the frequency distribution of the thermal sensation vote by the survey duration. For analysis, the survey duration is divided into three periods: Period 1 is the rainy season (13 June – 4 July), period 2 is late summer and early autumn (28 August – 26 September); and period 3 is mid-autumn (27 September – 16 October). Of all respondents, 33.4% answered 'neutral' and 79.6% were in the central three categories in the previously described ASHRAE scale through the survey duration. Naturally, the trend of frequency distribution was different in each period.

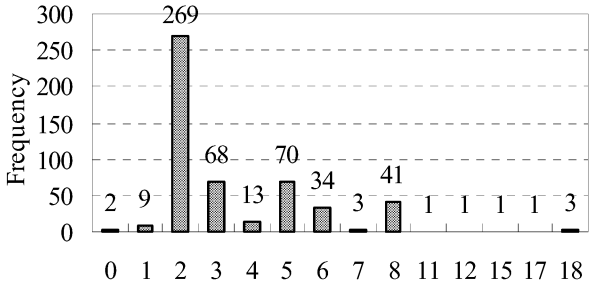

Fig3.4 Frequency of the clothing type

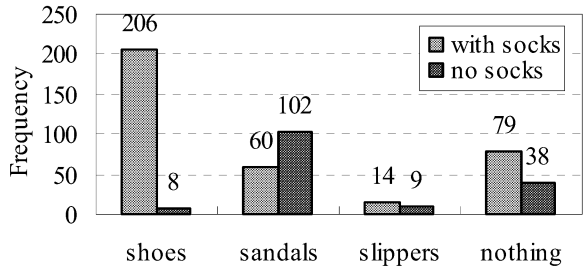

Fig.3.5 Socks and footwear

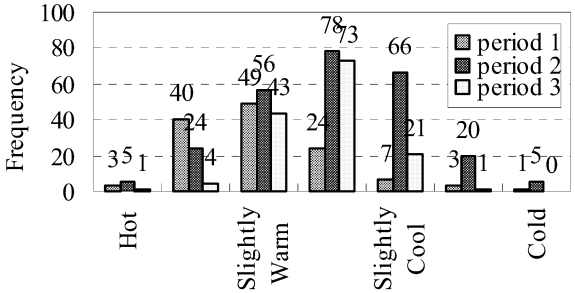

Fig3.6 Thermal sensation by periods

Figure 3.7 shows the frequency distribution of the thermal comfort vote by the survey duration. The survey of thermal comfort vote was carried out except for the period of 13 June – 31 August. The respondents were 275 persons; 82% of them voted as “comfortable”.

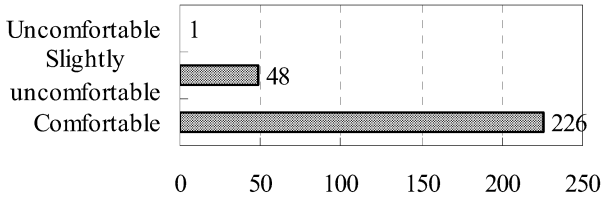

Fig.3.7 Thermal comfort

*3.4 Living-in time*

Figure 3.8 shows respondents’ time spent in the room. People staying more than 1 h were 254; those staying less than 1 h were 253. Of all respondents, persons staying more than 10 min were 418 (82.4% in all).

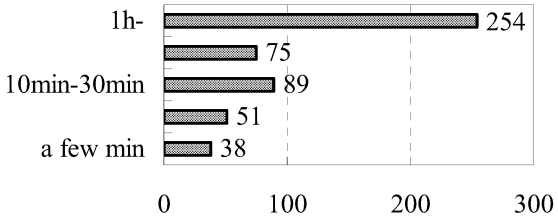

Fig.3.8 Living-in time in the room

*3.5 Setting cooling temperature*

Figure 3.9 portrays a frequency distribution of temperature setting by period. The air-conditioner was turned off for 34.4% of the survey rooms in all. For air-conditioners that were turned on, the temperature settings of 26°C, 27°C, and 28°C were, respectively, 22.7%, 27.3%, and 31.1%. In addition, 13.5% of the rooms had temperatures set to less than 25°C.

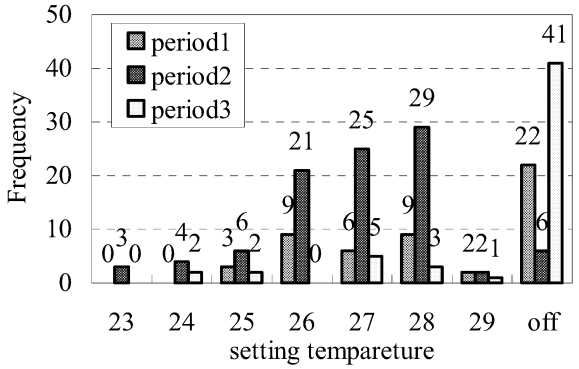

Fig.3.9 Setting temparetures by periods

*3.6 Relation among outdoor temperature, setting cooling temperature, and clothing insulation*

As depicted in Fig. 3.10, the outdoor temperature changed from 22.4°C to 34.0°C. The mean clothing insulation and average of the temperature setting decreased as the outdoor temperature increased. The coefficient of determination for a regression equation between the outdoor temperature and the clothing insulation was 0.28 ($R$=0.53); the $R^2$ value was 0.17 ($R$=0.41) between the outdoor temperature and the temperature setting. On the other hand, the temperature setting was unrelated to the clothing insulation ($R^2$=0.02).

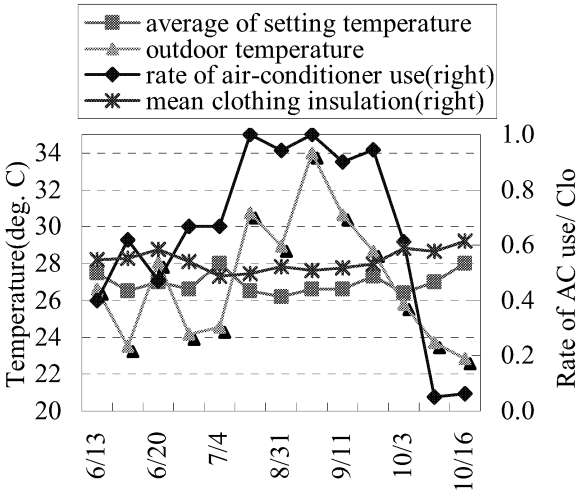

Fig.3.10 Change of temperature, clothing insulation and rate of air-conditioner use

*3.7 Relation among thermal sensation, outdoor temperature, temperature setting, and clothing insulation*

Figure 3.11 presents the relation between thermal sensation and each item. The mean outdoor temperatures were 28.5, 29.0, and 28.0°C for "slightly cool", "cool", and "cold" respectively, whereas 26.5°C included "warm" to "neutral". The mean temperature setting was 27.0°C for "neutral" and "slightly cool", and 26.7°C for "slightly warm" and "cool". The mean clothing insulation was 0.54–0.56 clo for "warm" to "slightly cool", and between 0.51 and 0.52 clo for "cool" to "cold". These results show that the clothing insulation and temperature setting were determined according to the outdoor temperature. However, occupants felt cooler because clothing insulation and temperature settings were low.

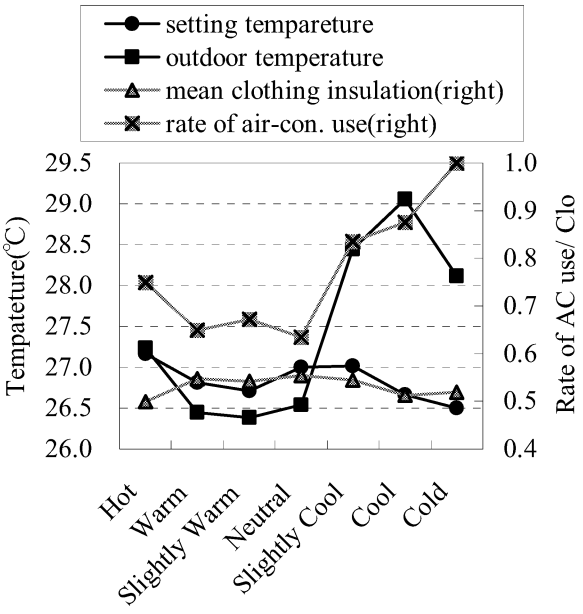


Fig.3.11 Temperature, clothing insulation and rate of AC use for sensations

*3.8 Relation between thermal sensation and wearing socks or no socks*

Insulation from socks is very low. However, as depicted in Fig. 3.12, socks affected thermal sensations. Thermal sensations changed to the cool side as the wearing rates of socks decreased. The thermal environment might be controllable with or without socks and might save energy.

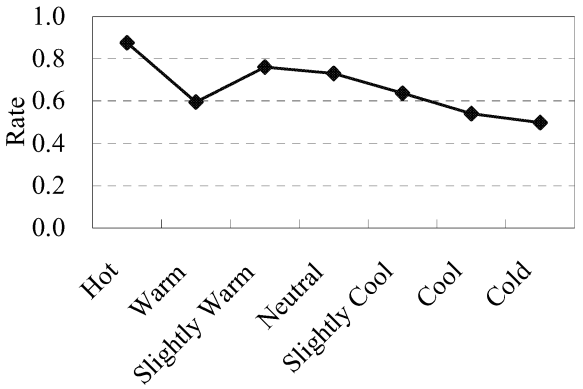


Fig.3.12 Rate of subjects with socks

*3.9 Relation between living-in time and thermal sensation*

As depicted in Fig. 3.13, thermal sensation approached the "warm" side with living-in time. Reaching a steady state in a thermal environment, in general, takes 30–40 min. Effects of living-in time were classified into three stages: less than 10 min, 10 min – 1 h, and more than 1 h. Here, 3 on the axis of ordinates represents "slightly cool" and 4 signifies "neutral".

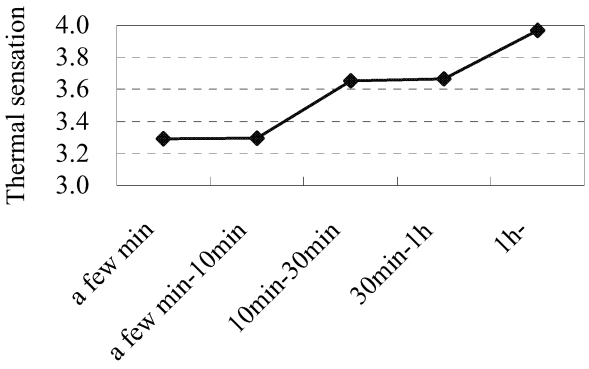


Fig.3.13 Living-in time and thermal sensation

*3.10 Effects of the building and its orientation on thermal sensations and temperature settings*

Figure 3.14 and Fig. 3.15 show that the rooms of B and C building facing south greatly increased the rate of feeling "warm"; its thermal environment was found to be poor. Figure 3.16 shows that temperature settings differed by building. Compared to B and C buildings, the rates of air-conditioner use were nearly equal, although the occupants in B rooms felt cooler than the C room occupants. That was true even though the temperature settings of B rooms were higher than those the C rooms. The reason for this is not clear. The difference might be produced by the buildings' surrounding conditions.

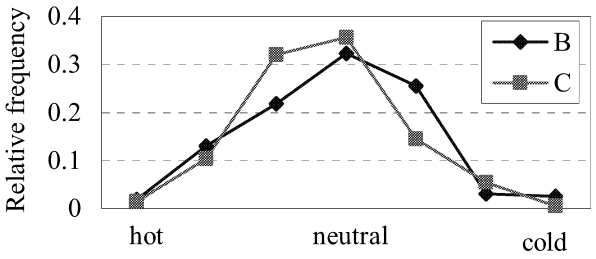


Fig3.14 Thermal sensation by buildings

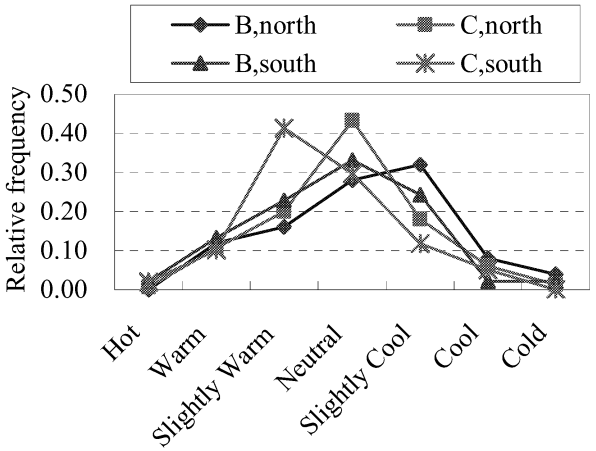


Fig.3.15 Thermal sensation by buildings and directions

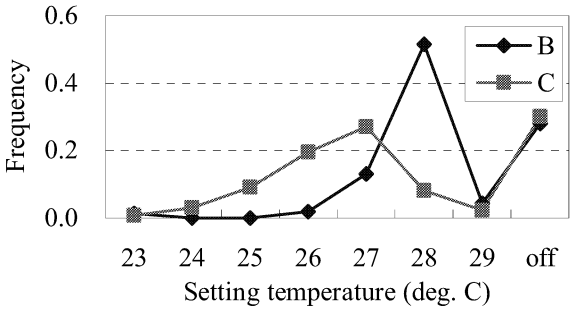


Fig.3.16 Setting temperature by buildings

## 4. CONCLUSION

This study shows that the student spent time comfortably using air-conditioners and adjusting their clothing ensemble. Their consciousness for the thermal environment might be high because the average temperature setting of air-conditioners was around the 28°C temperature promoted by the recent 'COOL BIZ' campaign of the Japanese Government.

## REFERENCES

(1) *ASHRAE Handbook of Fundamentals* (2005), Chapter 8 Thermal Comfort, p.8-9.