P1.11 A STUDY OF THE THERMAL COMFORT OF COLLEGE STUDENTS FOR A YEAR

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1. INTRODUCTION

Students, schoolboys and schoolgirls spend a lot of time in schools. To maintain or improve their health and comfort, it is important to study on thermal comfort in school. The studies on thermal comfort of primary school children aged 6-12 years investigated in Japan (e.g., Kawano et al.). But, there is few studies which are concerned with thermal comfort of college students aged 15-20 years. Since children have a higher metabolism than teenager, the results of primary school children may not be possible to apply to college students.

The results of studies on thermal comfort of office workers may be possible to apply to college students. But, college students not only put on business suit, but variety of clothing. Clothing insulation of college students differ from that of office workers. Therefore it can not be assumed that the requirements of college students for thermal comfort are the same as those for office workers.

The purpose oh this field study is to evaluate the thermal comfort of college students for a year. The thermal environmental factors (air temperature, air humidity, air velocity and radiant temperature) were measured in a classroom. Questionnaire about thermal sensation, thermal comfort and clothing were investigated to college students in there.

2. PROCEDURE

2.1 The college and the students

The field study was made for a year from May 2000 to May 2001. A college where the study was conducted is located in temperate-climate zone in Japan. One classroom is chosen in the college. In the classroom about 40 college students aged 18-19 years took a class. For most of their lessons was taught in there from 8:40 am to 3:45 pm. The classroom was located at third floor of three-story reinforced concrete building and had a heating system and ventilating system.

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2.2 The measurement of environmental factors

Air temperature, relative humidity, air velocity and radiant temperature (globe temperature) were measured at the front of the classroom at a height of 80 cm. These factors were measured at 30 minutes intervals automatically. A plan of the classroom and point of measurement is shown in Figure 1.

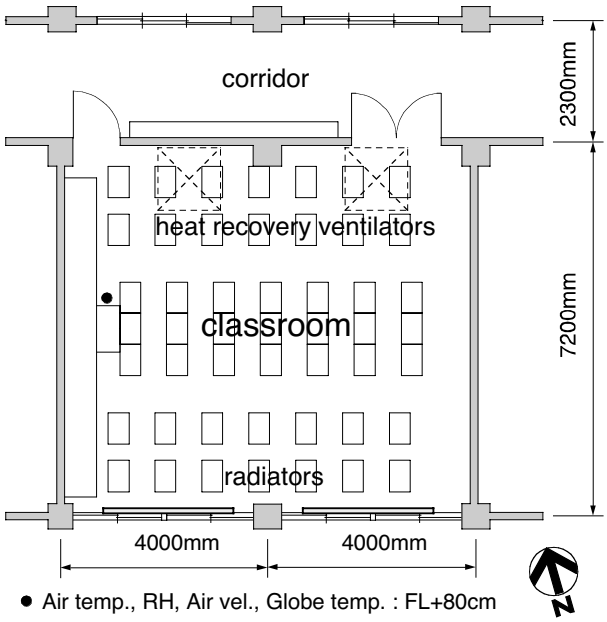

FIGURE 1 Plan of classroom and measurement point

2.3 Questionnaire to the students

At the same as the thermal environmental data were corrected, a questionnaire was investigated to about 40 (male 20 and female 20 approximately) college students. The item of the questionnaire regarded thermal sensation, thermal comfort and clothing. Thermal sensation and thermal comfort were expressed by checking liner scales

on the ballot. Checking point on the liner scales of these was digitize. Clothing was measured by a clothing checklist which illustrated several garments. The clothing checklist was made for male and female respectively. The questionnaire surveys were conducted twice a day at end of lessons (about 10: 30 am and 2:00 pm) and every fortnight.

3. RESULTS

3.1 Air temperature and relative humidity

Figure 2 shows the daily changes in air temperature and relative humidity in the classroom. Air temperature and relative humidity are mean values of residence time of the students (between 8:30 am and 4:30 pm). The hatching zones show the vacations. From the beginning of July to the middle of September, air temperature was higher than recommended value of the school environmental sanitation guidelines, in which recommended value is keeping below 30 ºC and optimum zone is 25-28 ºC in summer. From the beginning of December to the middle of February, when heating system had worked, air temperature was higher than optimum zone of the guidelines, in which recommended value is keeping above 10 ºC and optimum zone is 18-20 ºC in winter. For a year, relative humidity was kept within the guidelines, in which optimum zone is 30-80%.

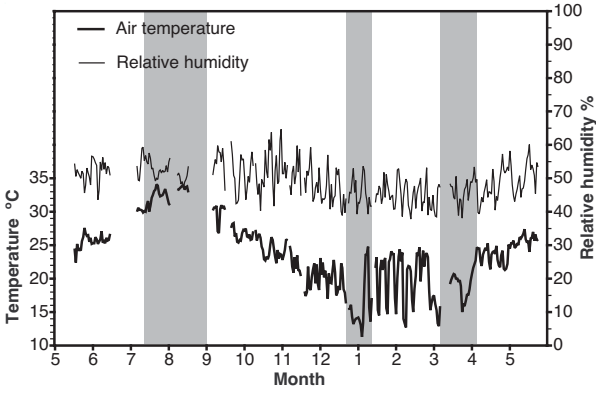

FIGURE 2 Daily changes in air temperature and relative humidity

3.2 Thermal sensation and thermal comfort

Figure 3 shows the fortnight changes in the thermal sensation of the students. In summer, the students felt hot in the classroom. Especially just before summer vacation, they seemed tolerable hot. After October, it seems that they felt thermal neutrality (numeric value is 50). Thermal sensations measured at 2:00 were higher than those at 10:30 for a year.

Figure 4 shows the fortnight changes in the thermal comfort of the students. Just before summer vacation, the students felt most uncomfortable. After October, thermal comfort kept about 40 numerically. Thermal comforts measured at 10:30 were roughly equivalent to those at 10:00 for a year.

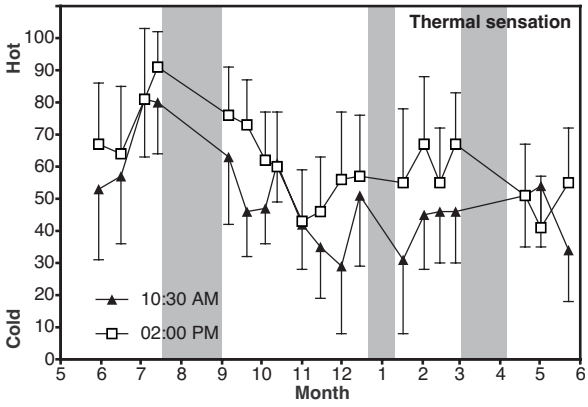

FIGURE 3 Fortnight changes in thermal sensation Values are mean and SD

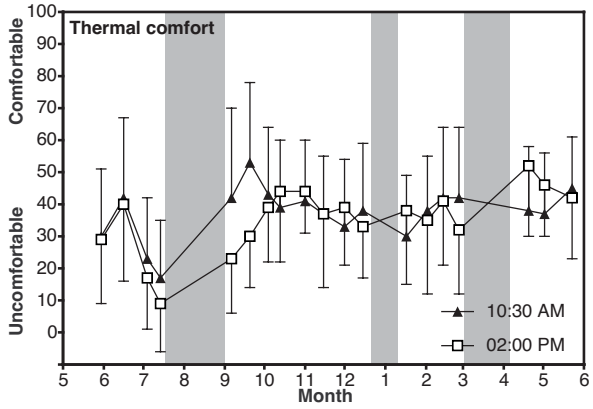

FIGURE 4 Fortnight changes in thermal comfort Values are mean and SD

4. DISCUSSION

4.1 The changes in the SET*

Figure 5 shows the fortnight changes in the Standard Effective Temperature (SET*) in the classroom. When SET* was calculated, metabolic rate was 1.0 Met (=58.2W/m^2) and clothing insulation was calculated from clothing checklist (McCullough et al.). Thermal environ-

mental data was used when questionnaire was investigated. At the middle of July and the beginning of September, SET* was approximately 29 ºC. This value is higher than optimum ET* of ANSI/ASHRE Standard 55-1992. In summer it may be necessary to improve the thermal environment in the classroom. After October SET* kept at 25 ºC approximately.

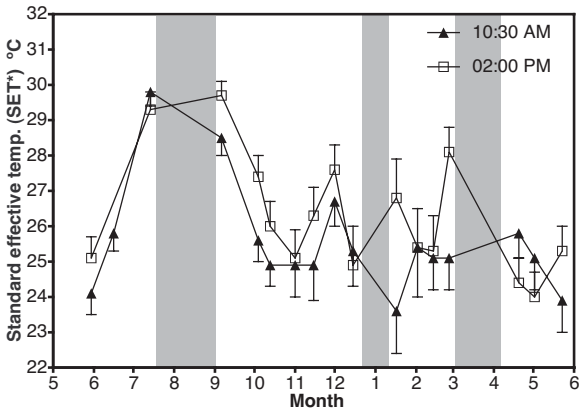

FIGURE 5 Fortnight changes in SET*
Values are mean and SD

4.2 Operative temperature and clothing insulation

Figure 6 shows the relation between operative temperature and clothing insulation. As operative temperature was higher, clothing insulation seemed to decrease. However, when operative temperature was higher than

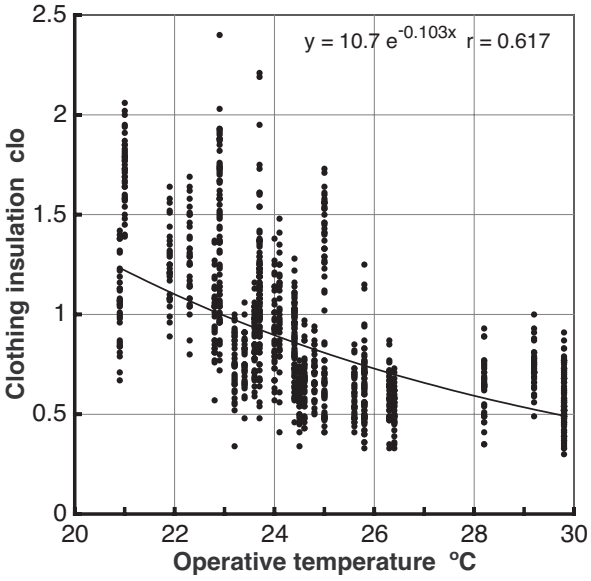

FIGURE 6 Relation between operative temperature and clothing insulation

26 ºC, clothing insulation seemed to be roughly 0.6 clo as a constant value. It may be assumed that when the classroom was hot like operative temperature over 26 ºC, the students minimized their clothing as behavioral thermoregulation.

4.3 Environmental indices and thermal sensation

Figure 7 shows the relation between SET* and thermal sensation. Thermal sensations is mode values divided into 10 classes each data. Thermal sensation seems to be positive correlation with SET*. The regression line indicates the students felt thermal neutrality (numeric value is 50) at SET* 25.6 ºC. This value is within the acceptable range of ASHRAE Standard 55 (23-26 ºC), but near of upper boundary. Shimura et al. proposed optimum temperature range for Japanese as SET*24.5-27.0 ºC and this range is slightly higher than that of ASHRAE Standard 55. The result of this study seemed to agree with shimura et al.

Considering the difference between male and female

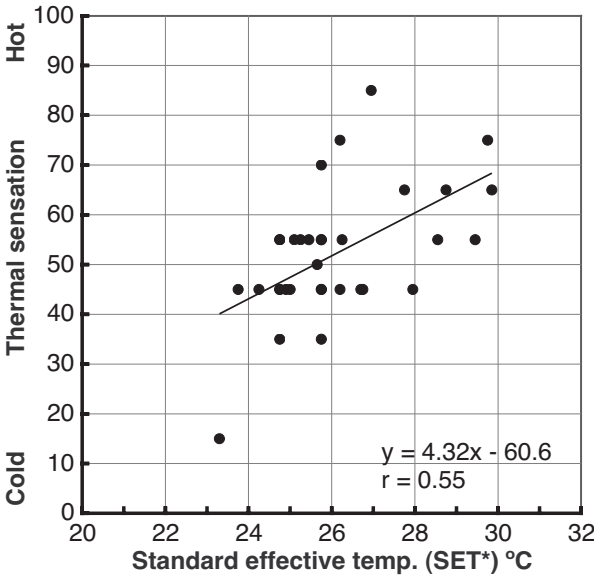

FIGURE 7 Relation between SET* and thermal sensation

in summer and winter, relation between SET* and thermal sensation is shown in Figure 8. In summer thermal sensations for male and female seem to be positive correlation with SET* and their seemed to be equivalent. In winter thermal sensation for male seems not to be correlation with SET*. In winter thermal sensations for male and female may not be equivalent.

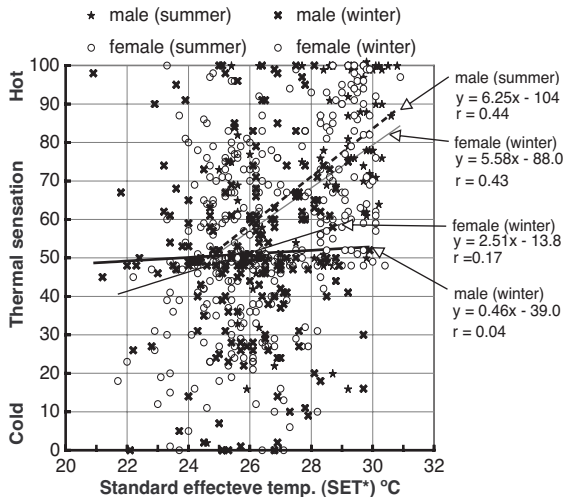

FIGURE 8 Relation between SET* and thermal sensation (Difference between male and female)

Figure 9 shows the relation between Predicted Mean Vote (PMV) and thermal sensation. Thermal sensations is mode values divided into 10 classes each data. PMV was calculated as SET*. Thermal sensation seems to be positive correlation with PMV but not to be good relation. Thermal sensation of the students may be more sensitive than PMV. The regression line indicates the students felt the thermal neutrality at PMV +0.2. The students may prefer fairy warmer environment than thermal neutral environment of PMV.

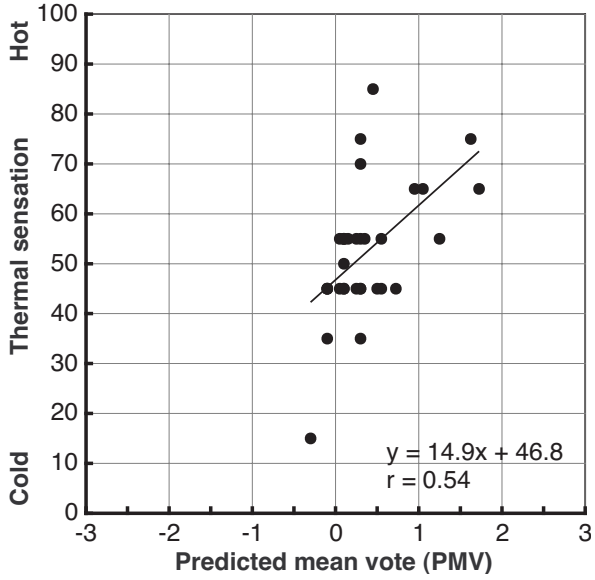

FIGURE 9 Relation between PMV and thermal sensation

4.4 SET* and thermal comfort

Figure 10 shows the relation between SET* and thermal comfort. Thermal comforts is mode values divided into 10 classes each data. The regression curve indicates the student felt the most comfortable at SET* 25.6 ºC. In this study when the students felt thermal neutrality in the classroom, they seemed feel the most comfortable. When the classroom has SET* of about 25.5 ºC, most of the students may feel thermal comfort.

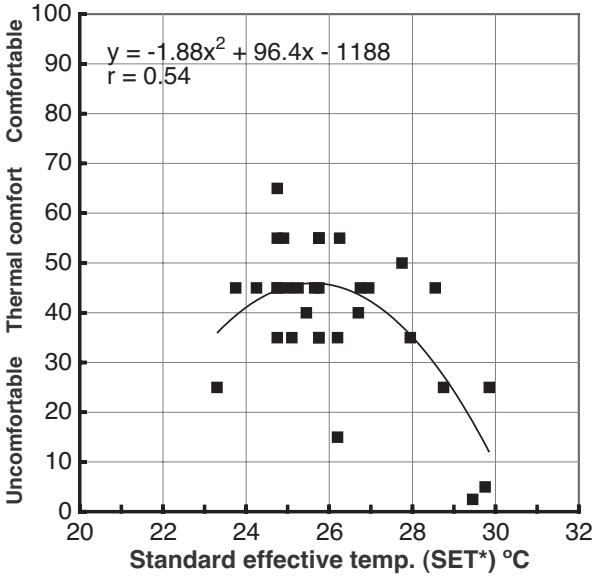

FIGURE 10 Relation between SET* and thermal comfort

5. REFERENCES

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