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EXPERIMENTAL STUDY ON THERMAL SENSATION OF HUMAN BODY IN NATURALLY VENTILATED ROOMS

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Abstact

The authors conducted the experiments on the effect of cross-ventilation on thermal sensation of people in dwelling units from June through August in two years. Comfort is highly related to air flow sensation. Speed, strength and fluctuation sensations of air flow have high correlation with each other and air flow sensation of the whole body. Women are more sensitive to thermal sensation and change their sensation votes more correspondingly to air velocity than men.

Introduction

Cross-ventilation is one of the most popular and traditional cooling means against the hot humid summer in Japan/2/. Preference of people for it might be attributed in main to that fluctuating air flow caused by natural wind makes people feel refreshing. However it is to be regretted that many studies on thermal sensation to air flow have been conducted from the viewpoint of uncomfort/1 / and there are few reports on the comfort caused by natural air flow/3,4/. This paper describes the experiments on the effect of cross-ventilation on thermal sensation of people carried out in the dwellings from June through August in 1984 and 1985.

Expetimental procedure

The experiments are composed of 64 runs in total, using five male and five female subjects in college age. In a run of the experiment a subject in 0.3clo clothing was sedentary in 60 or 90 minutes, facing to the windward. Comfort sensation was voted on 7-category scale. Whenever it changed, the subject responsed by pushing a button and orally voted sensations to air flow at whole and local bodies. Air flow sensation was voted on 6-category scale and six kinds of impression of air flow on 7-category scale.

Results and discussion

Environmental conditions of the experimental rooms are as follows in terms of average with the range in parenthses.

air temperature	, ta :	30.5°C	(26.4-35.4°C)
globe temperature,	tg :	31.1°C	(26.1-35.4°C)
relative humidity,	rh :	63 %	(48 - 91 %)
air flow velocity,	v :	1.48m/s	(0.10-4.88m/s)

The numbers of comfort sensation vote are as follows.

1 :	very uncomfortable	5
2 :	uncomfortable	24
3 :	slightly uncomfortable	46
4 :	neutral	70
5 :	slightly comfortable	115
6 :	comfortale	92
7 :	very comfortable	24

Comfortable sensations are voted more than uncomfortable ones in the environment of the naturally ventilated rooms. It is noticed that female subjects much more frequently change their vote than males do.

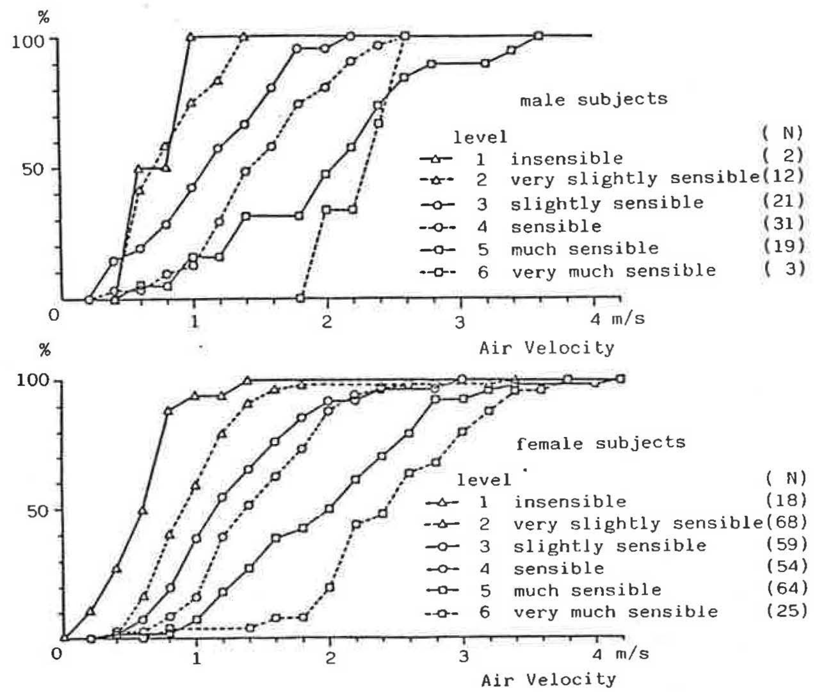

Fig. 1. Cumulative frequency distributions of air flow velocity for six levels of air flow sensation.

The cumulative frequency distributions of air flow velocity for six levels of air flow sensation are depicted in Fig. 1. There is no significant difference in median of velocity of each level between male and female. Medians of velocity are as follows.

1 : insensible	0.6 m/s
2 : very slightly sensible	0.9 m/s
3 : slightly sensible	1.1 m/s
4 : sensible	1.2 m/s
5 : much sensible	2.0 m/s
6 : very much sensible	2.4 m/s

The scatter diagrams of comfort sensation and air flow sensation are shown in Fig.2. There is high correlation between these two sensations, especially for female. The existence of air flow is useful to improve comfort sensation.

Fig.3 compares air flow sensation between whole body and local body. The figures of face and chest & abdomen are composed of the results of all subjects, but those of thighs and shanks are shown separately for male and female. The most sensitive part of the body is shank, which has high correlation with whole body. The reason is that shanks are exposed, facing air flow and peripherial parts of the body comparing with the others. Sensation of thighs is different between male and female, because the former in short pants exposed his thighs and the latter in skirts covered hers.

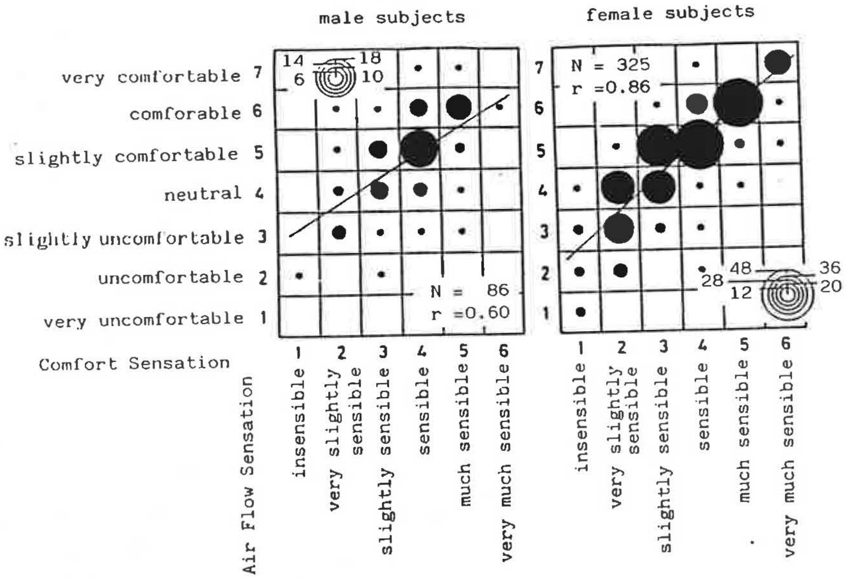

Fig. 2. Scatter diagrams of comfort sensation and air flow sensation

6	very much sensible	3	slightly sensible
5	much sensible	2	very slightly sensible
4	sensible	1	insensible

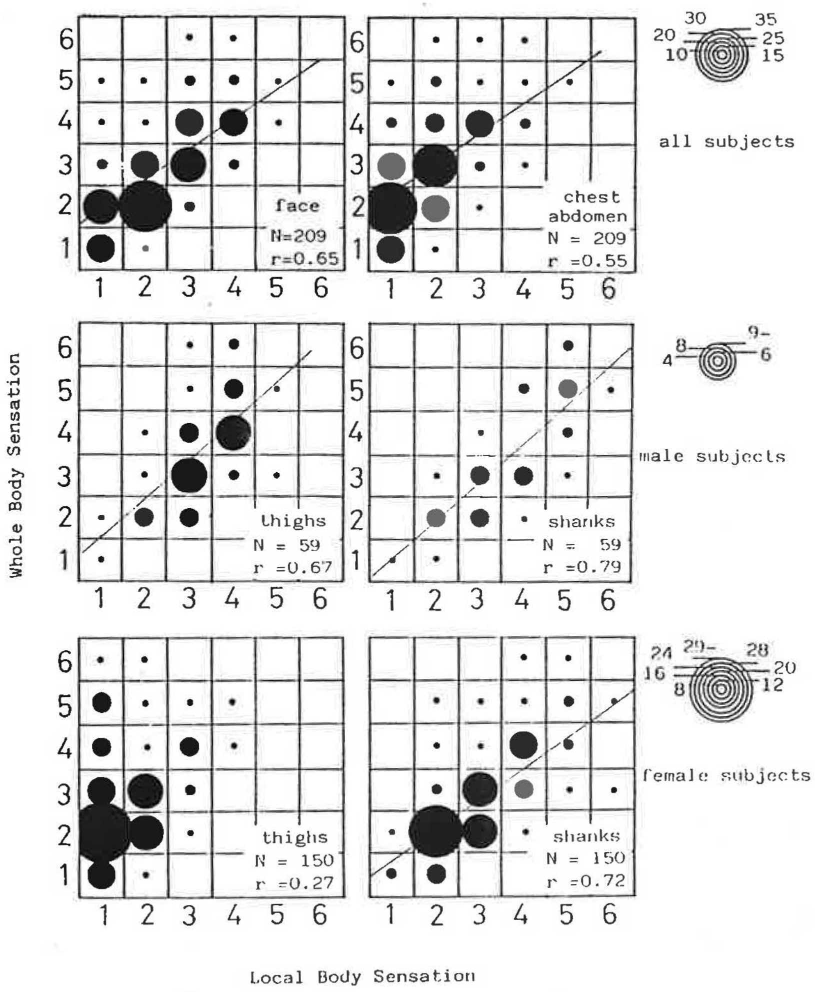

Fig. 3. Scatter diagrams of air flow sensations of whole and local bodies

Correlation matrix between air flow sensation and six kinds of feeling of air flow is given in Table 1, with high correlations shaded. Regularity feeling ranges only within irregular zone, as in naturally ventilated rooms, and so has little relation with others. Speed, strength and fluctuation feelings of air flow are highly related with air flow sensation of whole body and each other, with correlation coefficients larger than 0.75. It is considered that these three feelings, characterizing natural air flow, influence air flow sensation and comfort sensation, as the similar relation between comfort sensation and feelings of air flow are obtained.

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Table 1 : Correlation matrix between air flow sensation and feeling of air flow.

	Air Flow Sensation	Feeling of Air Flow: Temperature	Wetness	Speed	Fluctuation	Regularity	Strength
Air Flow Sensation		0.44	0.44	0.82	0.78	0.33	0.79
Feeling of Air Flow: Temper.	0.36		0.44	0.41	0.41	0.05	0.40
Wetness	0.42	0.59		0.41	0.44	0.11	0.48
Speed	0.76	0.27	0.41		0.82	0.30	0.85
Fluctu.	0.77	0.24	0.34	0.75		0.40	0.83
Regu.	-0.03	-0.32	-0.34	-0.14	-0.00		0.29
Streng.	0.76	0.37	0.44	0.84	0.80	-0.15	

male subjects (below diagonal); female subjects (above diagonal)

OCCUPANT ACCEPTANCE OF AIR MOTION AND ASYMMETRIC RADIATION IN NEUTRAL AND COOL ENVIRONMENTS

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Abstract

Subjective responses were studied from 50 subjects wearing winter clothing (0.86 clo) to two-hour-long exposures of winter indoor conditions that included air speeds between 0.05 m/s and 0.5 m/s and radiant temperature asymmetries from a cold wall of 0 to 20 K. The experimentally determined preferred temperatures increased with air speed. The low mean radiant temperatures from the cold wall were compensated for by increased air temperatures that maintained the operative temperature constant at a given air speed. It was found that radiant temperature asymmetries of 10 K or less did not affect acceptability. Increasing radiant temperature asymmetry to 18 K at neutral conditions decreased thermal acceptability by 7%. The level of acceptance of the environment at preferred temperatures was unaffected by air speeds of 0.25 m/s or less.

Introduction

Thermal nonuniformities in an otherwise thermally comfortable space can cause discomfort and detract from the environment. This study was undertaken to quantify the separate and additive effects of air speed and asymmetric radiation on sedentary people in neutral and cool environments (1). Air motion and drafts increase the local convective heat transfer on windward surfaces. Thus, skin temperature on the draft side may decrease causing discomfort. Radiation to cold surface can produce similar differences in skin temperature.

Facilities and methods

The testing was conducted in a climate chamber (2) where the air temperature (Ta), mean radiant temperature (Tr), and humidity are uniform and precisely controlled. A windbox with two 91-cm-diameter four bladed propellers driven by a quiet variable speed electric motor was located along the center of one wall.

The chamber was modified for this study with two partition walls extended from the windbox (Figure 1). One wall, capable of being cold, simulated the inside surface of a poorly insulated perimeter wall in winter and provided the required radiant temperature asymmetries (RTA). The other was a passive white cloth partition, whose temperature was close to the air temperature in the test zone. The cold wall was constructed from copper panels that were painted flat white and cooled with a refrigerated ethylene glycol water solution that flowed through the parallel tubes of the panels at a high rate.

The test subjects sat in low-backed chairs without arm rests at the locations shown in Figure 1. The chairs were arranged so subjects had radiation shape factors relative to the wall of 0.2 and 0.3.

Radiant temperature asymmetry, the difference in mean radiant temperatures seen by a plane element looking in opposite directions, was