環境温度変化時の二層構造編地の温熱生理学的研究

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Thermophysiological Studies of Double-face Knitted Fabrics Under Cyclic Ambient Temperatures

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ABSTRACT

The experiments were executed to elucidate the effects of three different kinds of T- shirt with double-face knitted fabrics on thermoregulatory responses and clothing humidity during cyclic ambient temperatures (neutral→warm→neutral). The double knitted fabrics used in the present experiments were composed of the inside layer of polyester and the outside layer of cotton (A: C/P), the inside layer of cotton and the outside layer of polyester (B: P/C), and the inside layer of cotton and the outside layer of cotton (C: C/C). Main results are summarized as follows: 1) The increasing rates of clothing humidity were the slowest in C in comparison with those in A and B under the influences of an increase in an ambient temperature (T_a) from 28°C to 37°C in 30 min. 2) The level of clothing humidity was the lowest in C at T_a of 37°C. 3) The decreasing rates of clothing

humidity were the quickest in C under the influences of T_a decrease from 37°C to 27°C in 30 min. 4) There did not exist any consistent differences in the amounts of sweating and the whole bodily weight loss due to evaporation through clothing among A, B and C. These findings are discussed in terms of thermal physiology and clothing sciences.

要　　旨

二層構造編地の三種類のTシャツの体温調節反応や衣服内湿度に対する効果を，周期的に変動する室温下で調べた．二層構造編地は皮膚側がポリエステル，表側が綿（A：C/P），皮膚側が綿，表側がポリエステル（B：P/C），皮膚側が綿，表側が綿（C：C/C）の三種類である．主要な結果は次のようにまとめられる．1）環境温（T_a）が28°C から 37°C へ30分かけて上昇する際の衣服内湿度の上昇速度はC着用時にもっとも遅かった．2）T_a：37°C 下での衣服内湿度のレベルはC着用時にもっとも低かった．3）T_a が 37°C から 27°C へ30分かけて下降する際の衣服内湿度の下降速度はC着用時にもっとも速かった．4）発汗量や衣服を通しての蒸発による体重減少量にはA，B，Cの間に差が存在しなかった．これらの知見について温熱生理学と被服学の立場から論じる．

Introduction

Umbach[1] assists that for sportswear or underwear for work clothes worn next to the skin double-face fabrics are advantageous under heavily sweating conditions, in which the inside layer worn on the skin is made from synthetic fibres and the outside layer from an absorbent fibre material like cotton. According to Tsuchida and Harada[2], however, multi-layer knitwear is beneficial under warm conditions, in which the inside layer worn on the skin should be made from textile materials with good moisture and water absorbancy properties, the middle layer from hydrophobic synthetic fibre and the outside layer from textile materials with much coarser texture than the skin side, and with greater surface area and high moisture discharge properties. Thus, there are some disagreement between two groups concerning the textile materials of the inside layer worn next to the skin. This suggests that further survey and experimentation in field and laboratory are needful to conclude these problems decisively. Therefore, we endeavoured to compare local sweating rate, clothing microclimate and whole bodily weight loss during cyclic ambient temperature (neutral→warm→neutral) among three different kinds of T-shirts : double-face fabrics with the inside layer of polyester and the outside layer of cotton (A : C/P), the inside layer of cotton and the outside layer of polyester (B : P/C) and the inside layer of cotton and the outside layer of cotton (C : C/C).

Materials and methods

Five female students, aged 19—21 yrs, volunteered as subjects. They were one kind

of T-shirt among clothing of A, B and C in the upper half of the body, cotton short pants in the lower half and sat quietly for 30 min on a stool at an ambient temperature (T_a) of 28°C and a relative humidity of 50%. After 45—60 min, T_a was increased gradually in 30 min to 37°C, kept at 37°C for 30 min, and then decreased to 28°C in 30 min. When T_a reached to 28°C, the experiment ended. Rectal and skin temperatures, clothing microclimate (temperature, humidity), local sweat rate and whole bodily weight loss were continuously measured during these cyclic changes of T_a. The physical properties of the fabrics used in present experiment are summarized in **Table 1**.

Table 1 Physical properties of the fabrics used in the experiment

		A (C/P)	B (P/C)	C (C/C)
Density (no./inch)	Wale	34	34	33
	Course	33	38	37
Thickness (mm)		0.95	0.90	0.80
Weight (g/m^2)		249.7	244.1	231.8
Liquid Water absorbancy	Wale	13.8	14.8	16.0
(cm/10 min)	Course	10.8	11.2	13.0
Vapour permeability ($g/m^2/24h$) at T_a of 37°C, 60% RH		2,548	2,733	2,910
Water absorption (%)		21.4	34.0	49.5
Air permeability ($m^3/m^2 \cdot min$)		49.8	46.8	34.8
Moisture regain (%) at T_a of 37°C, 60% RH		2.3	3.9	5.3

C/P means the double face fabrics with the inside layer of polyester and the outside layer of cotton, P/C those with the inside layer of cotton and the outside layer of polyester and C/C those with the inside layer of cotton and the outside layer of cotton.

Results

Clothing humidity and local sweat rates were compared individually among three kinds of clothing under cyclic ambient temperatures in **Fig. 1**. Clothing humidity began to increase nearly simultaneously when T_a began to increase gradually from 28°C to 37°C. It is noteworthy to notice that clothing humidity started to rise before the beginning of the sweating. Close observations indicate that the increasing rates of clothing humidity were the slowest in C under the influences of T_a increase from 28°C to 37°C. Although the level of clothing humidity was the lowest in C at T_a of 37°C, there did not exist consistent difference in the level of clothing humidity between A and B. When T_a began to decrease, the decreasing rates of the clothing humidity were the quickest in C. Furthermore, we could not find any significant differences among A, B and C in onset time of sweating, and the amounts of local sweating which were estimated from area of sweating waves.

In **Fig. 2** whole bodily weight loss during the latter 60 min was compared individually among A, B and C. As seen in the figure, we could not detect any systematic differences in the body weight loss.

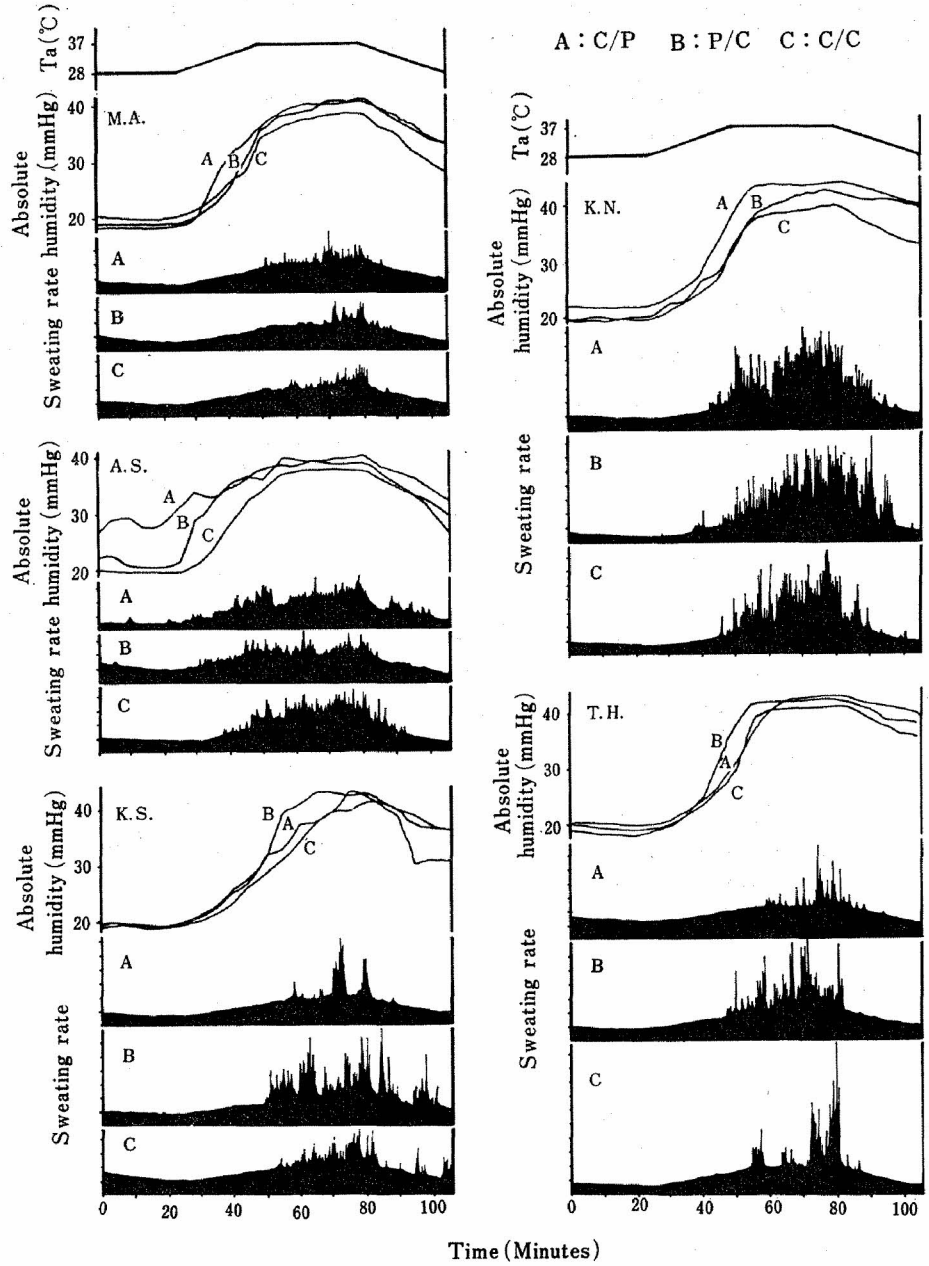

Fig. 1 A comparison of temporal changes in clothing humidity and local sweating rates from forearm in 5 sedentary subjects during cyclic ambient temperature changes among A, B and C.

Any consistent differences were not found in the level of rectal and mean skin temperatures, and clothing climate temperatures among A, B and C throughout the whole experimental period.

Discussion

Main results are summarized as follows : 1) The increasing rates of clothing humidity were the slowest in C in comparison with those in A and B under the influences of T_a increase from 28°C to 37°C. 2) The level of clothing humidity was the lowest in C at T_a of 37°C. 3) The decreasing rates of clothing humidity was the quickest in C under the influences of T_a

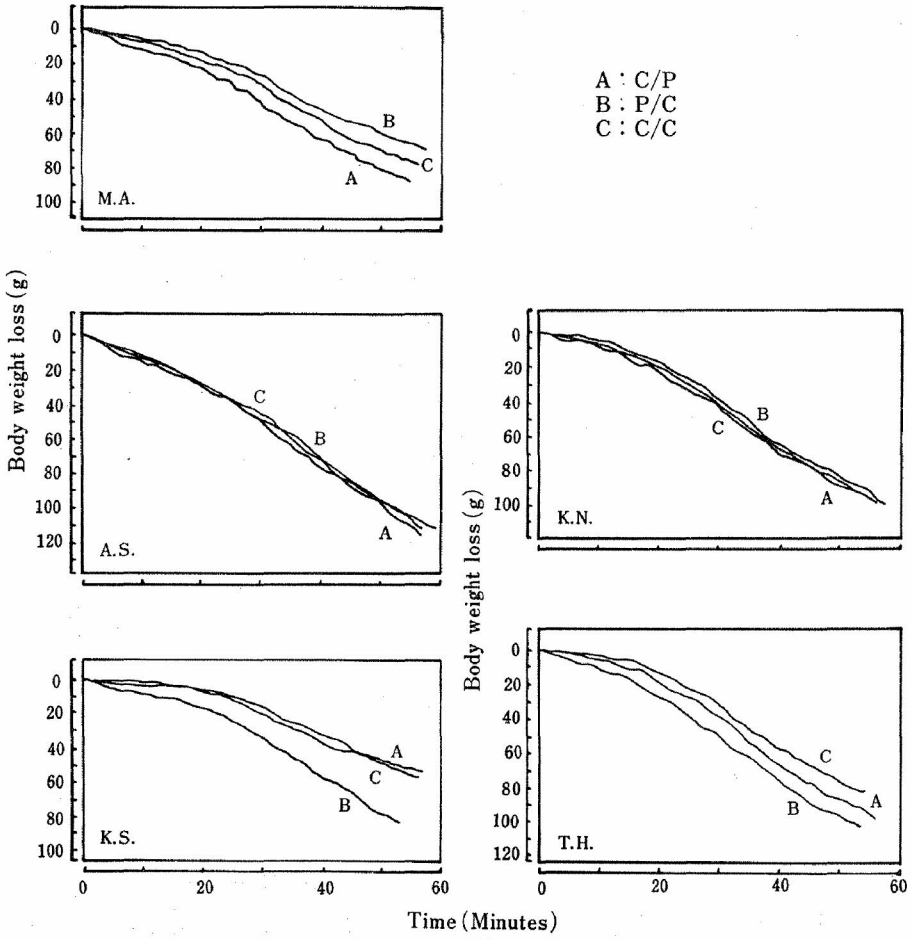

Fig. 2 A comparison of temporal changes in bodily weight loss in 5 sedentary subjects during the latter 60min among A, B and C.

decrease from 37°C to 28°C. 4) There did not exist any consistent differences in the amounts of sweating and the whole bodily weight loss due to evaporation through clothing among A, B and C.

Our present results that the level of clothing humidity was the lowest in C contradict the assertion by Umbach[1] and Tsuchida and Harada[2]. According to Umbach[1], the liquid moisture transport speed from inside to outside layer was quickest in double face fabrics in which the inside layer worn on the skin is made from synthetic fibres and outside layer from absorbent fibres material (PPmod/Co). This was demonstrated using a simple plate equipment. Even if the liquid moisture transport speed from inside to outside layer was the quickest in PPmod/Co, it remains to be known, to our understanding, whether the bodily weight loss due to evaporation through clothing to surroundings could take place most effectively in PPmod/Co. Furthermore, he claimed that the level of clothing humidity measured at chest was lower in PP/Co (inside : synthetic, outside : cotton) than in single layer cotton fabric at T_a of 28°C during 120 min walking on treadmill. This should be validated on the assumption that the amounts of sweating were identical between two kinds of clothing. The amounts of sweating, however, were not measured in Umbach's experiment. As sweating centers excite differently between different vapour absorbancies of fabrics[3], it should be carefully studied whether the amounts of sweating are really equal between two kinds of clothing with different materials.

Although Tsuchida and Harada[2] demonstrated that the clothing humidity was the lowest in multi-layer knitwear mentioned above (see Introduction) using specially constructed plate equipment in which the evaporation rate from the plate was controlled equally, the close observations to their data indicate that such tendencies occurred only during first restricted period, and later there did not exist any significant differences in the level of clothing humidity between the multi-layer and conventional cotton fibre.

In our present experiment we measured the local sweating rates quantitatively and the whole bodily weight loss due to evaporation through clothing to surroundings. These values were not significantly different among A, B and C. However, the level of clothing humidity was the lowest in C at T_a of 37°C and the increasing rates of clothing humidity were the slowest in C. These suggest that different behavior of clothing humidity in C compared with that of A and B is highly correlated with double-face knitted fabrics of the inside layer of cotton and the outside layer of cotton. Our present data were collected from sweating and sedentary subjects. The problem is whether these might be valid also in exercising subjects. Although there were not differences in the level of rectal temperature among A, B and C, the findings that the level of clothing humidity was higher in A and B than in C, might induce to produce hyperthermia more easily in clothing conditions of A and B under some circumstances.

References

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