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# Effects of Wettability of Cotton Shirts on Wear Comfort Sensation

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**ABSTRACT**

The samples included highly wettable, modestly wettable and non-wettable cotton shirts treated by surfactants and a finishing agent. When subjects wore these samples, the influence of the fabrics materials on physiological and psychological response was examined. The subjects marked a ballot to communicate their sense of sweating, soaking, thermal sensation and discomfort sensation at three minute intervals. The relationship between the wettedness on skin and fabric and subjective sensation was studied.

The results are as follows : Each subject experienced the equivalent exercise condition, but the vapor pressure, body weight loss, thermal sensation, sense of sweating, sense of soaking and discomfort sensation of the subject were different. The thermal sensation of subjects became warm by exercise and that corresponded with the temperature and humidity inside the fabrics.

There was hysteresis between each sensation and the wettedness. The hysteresis of each sensation was different.

Body weight loss and wettedness on the skin of the subject wearing non-wettable shirts were higher than those of the highly wettable shirts. The sense of soaking and discomfort sensation experienced by subjects who wore non-wettable cotton shirts were lower than those of the highly wettable cotton shirts.

## 1 Introduction

Wear comfort sensation of a subject is influenced by a complicated sensation including contact sensation with fabrics and thermal sensation. Microclimate between cloth and skin has a great influence on thermal sensation and comfort sensation.

The effects of fiber differences on wear comfort and microclimate between cloth and skin under exercise have been studied[1,2,3,4,5].

The previous paper[6] deals with the effects of wettability of cotton shirts on microclimate between clothes and skin under resting and exercise using knitted cotton undershirts treated by two surfactants and a finishing agent. The change of the skin and fabric wettedness was examined. The results indicated that wettedness and body weight loss of the subject wearing non-wettable shirts were greater than those of wettable shirts.

The subjects marked a ballot to communicate their sense of sweating, soaking, thermal sensation and comfort sensation during the wearing experiment. In this paper, the correlation between these subjective sensations and wettedness on skin and fabric was studied.

## 2 Experimental

All the fabrics used are highly moisture absorbant. However, the shirts treated by an anionic surfactant are highly wettable, and those treated by a cationic surfactant are modestly wettable. Those treated by a fluorine-containing finishing agent are not wettable.

Experiments were conducted in a climatic chamber under a temperature of 23°C, a relative humidity of 49% and an air movement of 10 cm/sec. Two subjects performed the wearing test during 84 minutes including 21 minutes of exercise. Exercise was conducted by an intensity of about 40 percent each subject's maximum aerobic capacity determined from a previous maximum exercise tolerance test. The velocity of the treadmill was 63.5 and 58.5 m/min with an 8.6 percent slope for subject S and I respectively. Local temperature and vapor pressures were measured at one minute intervals inside and outside the shirts on

both right and left sides of the back and in the environment. The subjects marked a ballot to communicate their sense of sweating, soaking, thermal sensation and discomfort sensation at three minute intervals. Table 1 shows a rating chart for subjective sensation. The details of the experiment are shown in the previous paper.[6]

## 3 Results and discussion

Fig. 1 shows evaporative heat transfer during the experiment. Since the two subjects have a similar physique, evaporative heat transfer shows a similar curve with body weight loss.

For example, the relationship between thermal sensation of subject and the wettedness on skin and fabric that were mentioned in the previous paper[6] are shown in Fig. 2 which shows the results of non-wettable shirts (Sample 8). At the start of exercise, the wettedness on skin and fabric was low. Along with increased wettedness on skin and fabric, the thermal sensation of the subject changed to a hot sensation.After the thermal sensation reached hot, the movement to cool showed hysteresis as it was different from the movement to hot sensation. In spite of the fact that the wettedness was the same, the movement to cool sensation slid into cool as compared with the movement to hot sensation. The thermal sensation felt by each subject showed hysteresis in Fig. 2. The hysteresis of the wettable shirt was lower than that of the non-wettable shirt. The hysteresis of the skin wettedness was less than that of the fabric wettedness, and the thermal sensation between the increase and decrease of the wettedness on skin was similar.

Fig. 3 shows the relationship between the sense of sweating and the wettedness on skin and fabric of non-wettable shirts (Sample 8). The sense of sweating increased along with the wettedness on skin and fabric. After that, the sense of sweating was low in spite of the same wettedness on skin and fabric. The sense of sweating had a big hysteresis.

Fig. 4 shows the relationship between the sense of soaking and the wettedness on skin and fabric of non-wettable shirts (Sample 8). The sense of soaking increased along with the wettedness on skin and fabric. In spite of the fact that the wettedness was the same, the sense of soaking decreased to dampness and was kept damp. As the sense of soaking was less sensible, the hysteresis of the soaking sensation of the subject wearing each sample was different.

Fig. 5 shows the relationship between discomfort sensation and the wettedness on skin and fabric of non-wettable shirts (Sample 8). Although discomfort sensation increased along with the wettedness on skin and fabric, in this sample discomfort sensation did not decrease soon in spite of the decrease of the wettedness. But, in another sample of non-wettable shirts, discomfort sensation decreased. Discomfort sensation of wettable shirts was higher than that of non-wettable shirts.

The hysteresis of each sensation was a little different as mentioned above.

**Table 1** Subjective sensation rating chart

| Sample | Thermal sensation | Discomfort sensation | Sense of sweating | Sense of soaking |
|---|---|---|---|---|
| 4 | Very hot | ——— | ——— | Soaking wet |
| 3 | Hot | Intolerable | Much | Wet |
| 2 | Warm | Uncomfortable | Moderate | Slightly wet |
| 1 | Slightly warm | Slightly uncomfortable | A little | Damp |
| 0 | Neutral | Comfortable | Not at all | Dry |
| − 1 | Slightly cool | | | |
| − 2 | Cool | | | |
| − 3 | Cold | | | |
| − 4 | Very cold | | | |

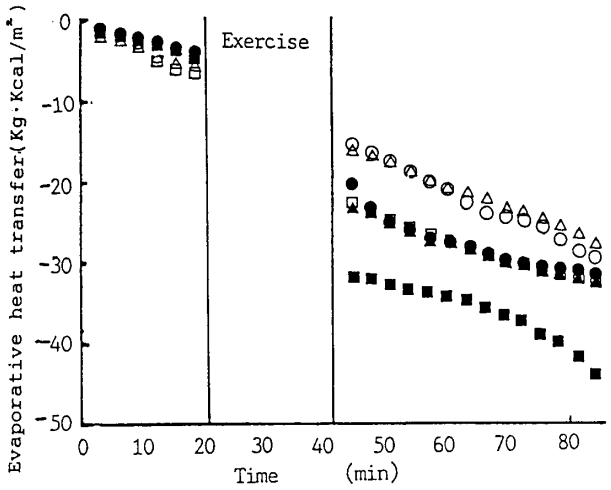


Fig. 1 Evaporative heat transfer during experiment.
Subject S ● Sample 1, 2 ▲ Sample 4, 5
■ Sample 7, 8 (Mean value)
Subject I ○ Sample 3 △ Sample 6
□ Sample 9

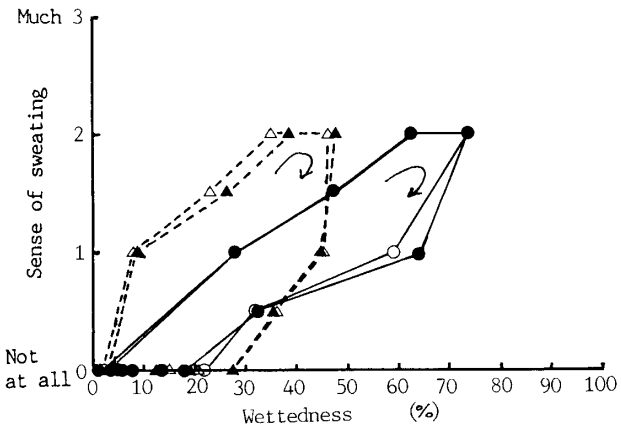


Fig. 3 Relationship between sense of sweating and the wettedness. (Sample 8)
—● Skin wettedness at the right side of the back
—○ Skin wettedness at the left side of the back
--▲ Fabric wettedness at the right side of the back
--△ Fabric wettedness at the left side of the back

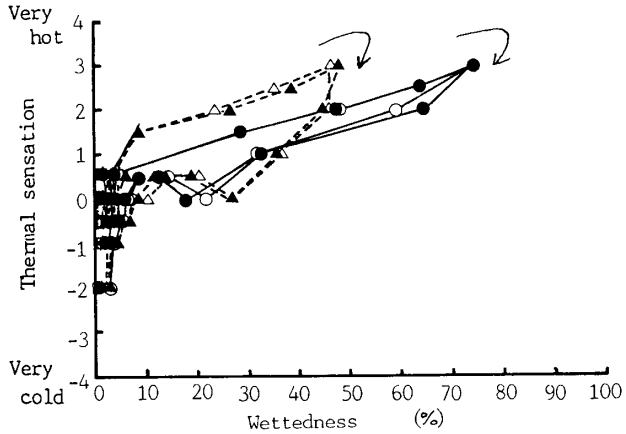


Fig. 2 Relationship between thermal sensation and the wettedness. (Sample 8)
—● Skin wettedness at the right side of the back
—○ Skin wettedness at the left side of the back
--▲ Fabric wettedness at the right side of the back
--△ Fabric wettedness at the left side of the back

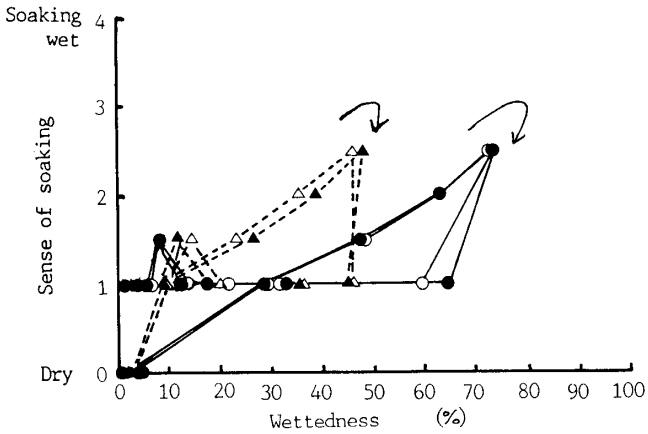


Fig. 4 Relationship between sense of soaking and the wettedness. (Sample 8)
—● Skin wettedness at the right side of the back
—○ Skin wettedness at the left side of the back
--▲ Fabric wettedness at the right side of the back
--△ Fabric wettedness at the left side of the back

Fig. 6 shows the thermal sensation experienced by subjects during the experiment. The value of subject S was the mean. The thermal sensation indicated by Gagge[7] was 7 grades, but in this paper we used 9 grades, adding very hot and very cold. A few minutes after the start of the exercise, the thermal sensation of the subject wearing each sample increased gradually. When the exercise was stopped, the thermal sensation of the subject reached a peak and then decreased rapidly. This result was similar to the change of temperature inside the shirt by evaporative heat regulation caused by sweating. But, the mean skin temperature of the subject was different from this thermal sensation. After 60 minutes, subject I did not feel so cool, but subject S felt cool because of much sweating. The subject wearing the non-wettable

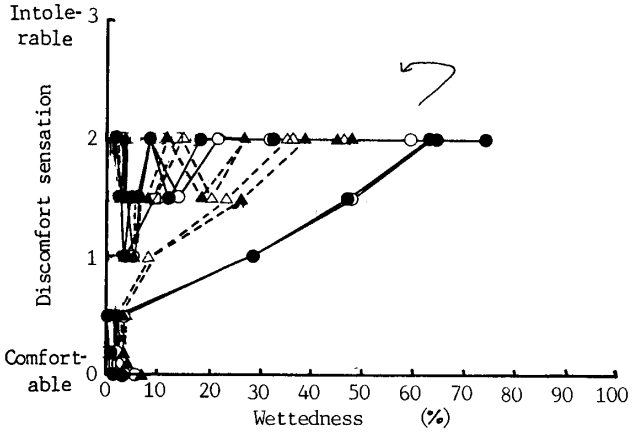


Fig. 5 Relationship between discomfort sensation and the wettedness. (Sample 8)
—● Skin wettedness at the right side of the back
—○ Skin wettedness at the left side of the back
--▲ Fabric wettedness at the right side of the back
--△ Fabric wettedness at the left side of the back

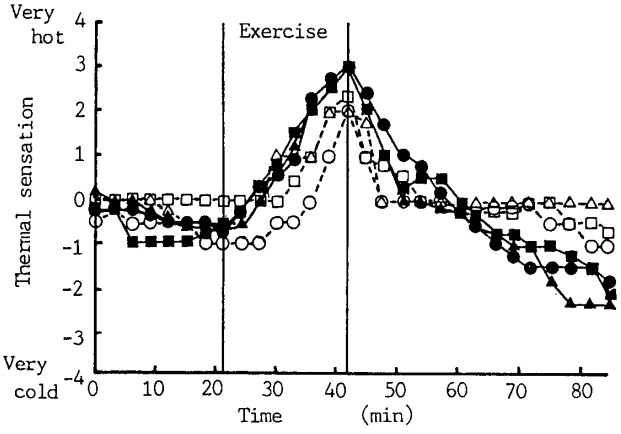


Fig. 6 Thermal sensation during experiment.
Subject S ●Sample 1, 2 ▲Sample 4, 5
■Sample 7, 8 (Mean value)
Subject I ○Sample 3 △Sample 6
□Sample 9

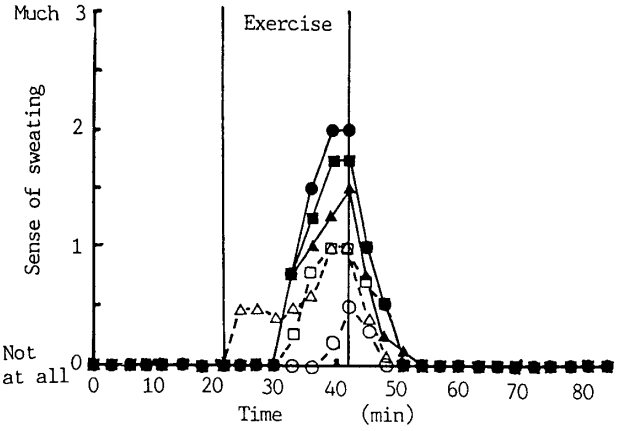


Fig. 7 Sense of sweating during experiment.
Subject S ●Sample 1, 2 ▲Sample 4, 5
■Sample 7, 8 (Mean value)
Subject I ○Sample 3 △Sample 6
□Sample 9

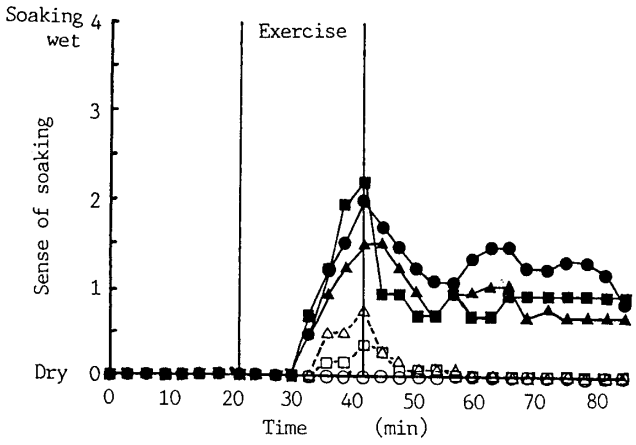


Fig. 8 Sense of soaking during experiment.
Subject S ●Sample 1, 2 ▲Sample 4, 5
■Sample 7, 8 (Mean value)
Subject I ○Sample 3 △Sample 6
□Sample 9

shirt felt warmer than the one wearing the wettable shirt.

Fig 7 shows the sense of sweating of the subjects during the experiment. Thermal sweating is important for body heat loss. That had partial and personal difference. Subject I showed a difference in the start of the sweating sensation. Subject S felt sweating 11 minutes after starting the exercise. These result corresponded to the temperature and humidity increase inside the fabric. Resent studies on sweating under exercise has shown a correlation with core and skin temperature[8,9]. Subject S felt sweating sensitively. When subject S felt sweating, the thermal sensation was grade 1, "slightly warm". The sense of sweating increased rapidly, took a peak at the end of the exercise, and then fell down rapidly. The peak of the

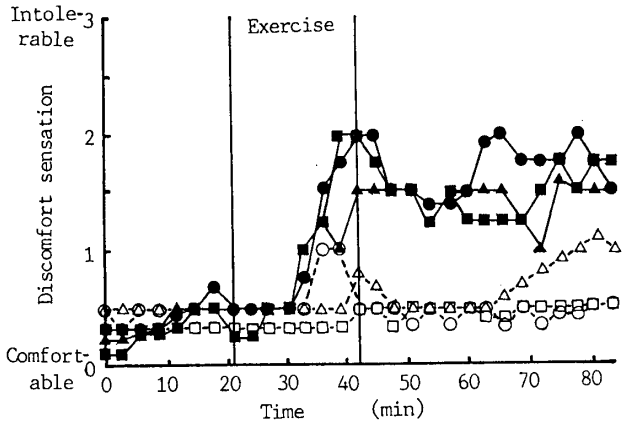


**Fig. 9** Discomfort sensation during experiment.
Subject S ● Sample 1, 2 ▲Sample 4, 5
■ Sample 7, 8 (Mean value)
Subject I ○ Sample 3 △Sample 6
□ Sample 9

sweating sensation of subject S wearing the wettable shirt was greater than that of the subject wearing non-wettable shirts.

Fig. 8 shows the sense of soaking of the subjects during the experiment. The soaking sensation of subject S was higher than subject I on a whole. This soaking sensation had a relationship to thermal and sweating sensation. Subject S felt soaking at the same time of sweating. After subject S finished the exercise, her sense of soaking was about grade 1 "damp". The sense of soaking of subject S wearing wettable shirts was higher than non-wettable shirts.

Fig. 9 shows changes in discomfort sensation in subjects during the experiment. The discomfort of subject I was little on a whole. After 65 minutes, subject I, wearing a modestly wettable shirt, felt slightly uncomfortable. The discomfort sensation of subject S increased at the same time of sweating. After finishing the exercise, the discomfort sensation decreased a little. Although the temperature inside the fabric and the skin wettedness of subject S decreased, this subject felt uncomfortable until the end of the experiment. The discomfort sensation of subject S wearing wettable shirts was greater than when wearing non-wettable shirts. As the sweating, soaking and discomfort sensation of subject I was little, the sense of soaking did not correlate with discomfort sensation. The discomfort sensation correlated highly with the sense of soaking in subject S.

From the results of these two subjects, although the humidity inside the fabric and the skin wettedness worn by the subjects decreased, discomfort sensation remained the same. The discomfort sensation and sense of soaking in subjects wearing wettable cotton shirts was greater than non-wettable cotton shirts.

## 4 Conclusion

The sample included highly wettable, modestly wettable and non-wettable cotton shirts treated by surfactants and a finishing agent. When subjects wore these samples, the influence of the fabrics materials on physiological and psychological response was examined. The subjects marked a ballot to communicate their sense of sweating, soaking, thermal sensation and discomfort sensation at three minute intervals. The relationship between the wettedness on skin and fabric and subjective sensation was studied.

The results are as follows :

1) Each subject experienced the equivalent exercise condition, but the vapor pressure, body weight loss, thermal sensation, sense of sweating, sense of soaking and discomfort sensation of subject I were lower than those of subject S.
2) The thermal sensation experienced by the subjects became warmer by exercise and that corresponded with the temperature and humidity inside the fabrics.
3) Discomfort sensation correlated high with that of the sense of soaking.
4) There was hysteresis between each sensation and the wettedness. The hysteresis of each sensation was different.
5) Body weight loss and wettedness on the skin of the subject wearing non-wettable shirts were higher than those of the highly wettable shirts. On the other hand, the sensation of discomfort and soaking of the subject wearing non-wettable shirts were lower than those of the highly wettable shirts.

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# 着用快適感に及ぼす綿シャツ地の吸水性能の影響

三ツ井紀子

着用快適感に及ぼす綿シャツ地の吸水性能の影響について検討した。吸水性，透湿性のある綿シャツ地に，高吸水性処理，中間的吸水性処理，撥水性処理を施し，試料とした。着用実験を行い，温冷感覚，発汗感覚，シャツの濡れ感・湿り感，不快感など，被験者の主観的感覚について検討した。また，皮膚上，衣服上の局所濡れ面積率と，各種主観的感覚との相関について検討した。

その結果，運動強度は同程度としたが，水蒸気圧，体重減少量，被験者の主観的感覚には，被験者間で差がみられた。温冷感覚は，衣服下の温度・湿度とよく対応していた。また，濡れ面積率と4つの主観的感覚には履歴がみられ，その履歴は，各主観的価格により異なっていた。撥水性試料着用時は，吸水性試料着用時より，濡れ面積率や体重減少量は大きかったが，発汗後の濡れ感・湿り感は小さく，不快感も小さかった。