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The Psycho-physiological Response of Polyethylene Terephthalate Irradiated by Ultra-Violet: Subjective Fabric Hand and Wear Comfort

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Abstract: The purpose of this study was to compare the subjective fabric hand evaluation and wear comfort of PET treated by Ultraviolet and to evaluate the subjective results from the investigation of microclimate temperature. The subjective hand evaluation was performed by 20 subjects (age: 20-25) with 5-point scale questionnaires to investigate the change of PET knit fabrics treated for different times, specifically, 0, 30 and 90 minutes. The questionnaires were composite with 8 questions; roughness, smoothness, wetness, stiffness, coolness, touch, preference, and comfort. In order to evaluate sensations of wear comfort, we made garments with UV treated fabric and five female students were tested. They walked at the speed of 6.7 km/hr for 15 minutes in an environment, which was controlled at 29 °C, 75 ± 5 % RH. Before and after exercising, the microclimate under clothing and subjective wear comfort was measured. The results of subjective evaluation of fabric hand were that untreated and treated for 30 minutes PET were recognized as similar and have a good evaluation on comfort, preference, and touch. According to the result of wear comfort, clothing treated by UV for 90 minutes had the lowest value on the thermal and humidity sensations. In addition, the value of tactile and comfort sensation was the highest on the clothing treated by UV for 90 minutes. In the case of objective evaluation, PET treated for 90 minutes was the lowest on microclimate humidity. PET irradiated by UV for 90 minutes was more 'cool' in thermal sensation and more 'dry' in wet sensation. Accordingly, it was consistent with the result of subjective wear comfort.

Keywords: Subjective fabric hand, Subjective wear comfort, PET, UV treatment

Introduction

As 'well-being' is a trend these days, it is an important issue that the requirements of consumers are satisfied with various functional fabrics. Because of this tendency, functional fabrics that are highly sensible, functional, and environmentally friendly have a competitive edge [1,2]. In the development of a new fabric, surface modification is the main concern from effective and competitive points of view [3]. Because of its simplicity, ultraviolet (UV) irradiation is considered one of the most important surface modification methods that add new functions to a fabric in a dry environment [4-6].

The 4-channel PET knit fabric (hyosung, korea) used in this study, is generally used in sport and leisurewear. The fabric has a clover-like cross section with 4 leaves. This technology makes it possible to pull sweat away from the body to the outer layer of the fabric by the capillary effect. However, the fabric still has a poor absorption property, which is related to the hydrophobic property, poor dyeability, low hygroscopicity, and high static charge. To resolve these problems, previous studies investigated the hydrophilic properties of 4-channel PET knit fabric, which was treated with UV irradiation.

In the previous study, we investigated the effects of UV irradiation on the moisture regain. We found an increased creation of the hydrophilic group with UV treatment. Furthermore, we found the water contact angle was decreased and the methyl ethylene contact angle was increased with increased UV irradiation. Therefore, we can conclude that the surface energy and hydrophilic property was increased. In addition, scanning electron microscopy (SEM) and physical properties were measured to confirm the relationship between the surface changes and physical properties mentioned above. The results indicate the surface modifications of PET such as etching, bubble, and crack were increased with increasing treatment time. The physical properties such as the decrease of static charge, tensile strength and elasticity, and an increase of yellowness were also changed slightly [7,8].

Changes due to UV irradiation had an effect on the mechanical property, tactile sensation, and hand value of the fabric. Seventeen mechanical properties and hand values were measured with a KES-FB instrument. The results show that bending and surface properties were changed. The values of B and 2HB were the highest in the fabric treated by UV for 30 minutes, and the value of MIU, MMD, and SMD was the highest in the fabric treated by UV for 90 minutes. The change of hand value derived from mechanical properties showed that 4-channel PET knit fabric treated by UV for 90 minutes was suitable for use as a summer fabric [9].

In this study, we evaluated the subjective sensibility of fabric irradiated for 0, 30, and 90 minutes. We then manufactured the cloth and investigated the wear comfort during exercise in a standard summer climate. This was followed by a comparison of the two subjective evaluations. Finally, a microclimate objective investigation was performed to judge the reliability of the subjective evaluations.

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Table 1. Characteristics of fabric

Specimen	Weave	Weight (g/m)	Thickness (mm)	Moisture regain (%)	Wicking (cm/10 min)	Surface energy (erg/cm^2)	Irradiation time (min)
A	Tuck stitch	15.0915	0.952	0.4251	6	0.0028	0
B		15.0745	0.928	0.6218	16.5	0.29	30
C		15.6450	0.898	0.7047	10.6	0.6	90

Experimental

Material

The fabric was washed with 2 g/*l* of $NaClO_2$, 2 g/*l* of HCOOH and 2 g/*l* of HNO_3 at 60 °C using a liquor ratio 50:1 for 60 minutes, neutralized with ammonia liquor, and rinsed in distilled water. Ultraviolet treatment was then done at a distance of 5 cm from the low pressure mercury lamps, for treatment times, of 0, 30, and 90 minutes. The characteristics of the fabric are shown in Table 1. UV treatment was done on a single side of clothes using a UV instrument that isolated the fabric from external light during the irradiation process [7].

Evaluation of Subjective Sensibilities on 4-channel PET Knit Fabric

The environmental conditions were controlled to be 29 °C, 75 ± 5 % R.H. (standard summer climate in Korea). The sensibilities of 4-channel PET knit fabric treated by UV were subjectively evaluated by 20 subjects (age: 20-25) with 5-point scale questionnaires. The questionnaires used two categories. One category is for sensibility evaluation: roughness, smoothness, wetness, stiffness, coolness, and touch, and the other is for total evaluation: preference and comfort. Subjects evaluated test samples in random order. Each subject was asked to assess three fabric specimens, each 20 × 20 cm, by using their hands and eyes [10].

Evaluation of Wear Comfort

Sport shirts were made as shown in Figure 1 with three fabrics that were irradiated for times of, 0, 30, and 90 minutes. To evaluate sensations of wear comfort, we made a garment with UV treated PET and chose five healthy female subjects in their twenties. Each subject wore the test suit and training short pant with 100 % cotton. They walked at the speed of 6.7 km/h for 15 minutes under conditions of 29 °C, 70 ± 5 % R.H. Before and after exercising, the subjective wear comfort and microclimate under the clothing was measured. The experimental schedule is shown in Figure 2. The test process was repeated twice per person and the mean was calculated [11,12].

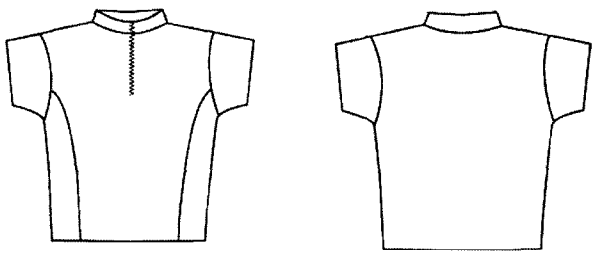

Figure 1. Design of garment for experiment.

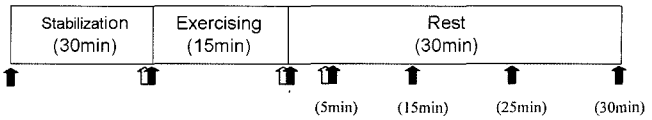

Figure 2. Time schedule of experiment; ⬆: measurement of microclimate under clothing, ⇧: measurement of subjective wear comfort.

Results and Discussion

Subjective Sensibilities of 4-channel PET Knit Fabric

Figure 3 shows the results of subjective sensibilities of 4-channel PET knit fabric that was irradiated by UV for times, of 0, 30, and 90 minutes. The results of subjective sensibility were that untreated and 30 minutes treated PET, were rated similar, but 90 minutes treated PET showed a different trend. The sensibilities of roughness (D1), and stiffness (D4), show the highest rating on PET treated for 90 minutes, while others show a low rating. In contrast to these results, smoothness (D2) shows the lowest rating on 90 minutes treated PET. In addition, the order of evaluation results, for sense of touch (D6), preference (D7), and comfort (D8) was untreated >

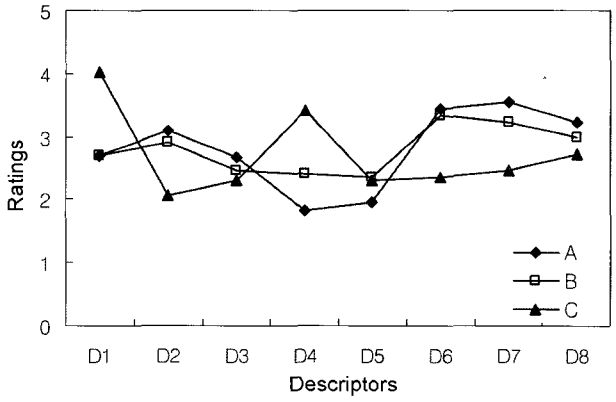

Figure 3. Positioning map of AEROCOOL irradiated by UV on sensibility; D1-roughness, D2-smoothness, D3-wetness, D4-stiffness, D5-coolness, D6-touch, D7-preference, D8-comfort.

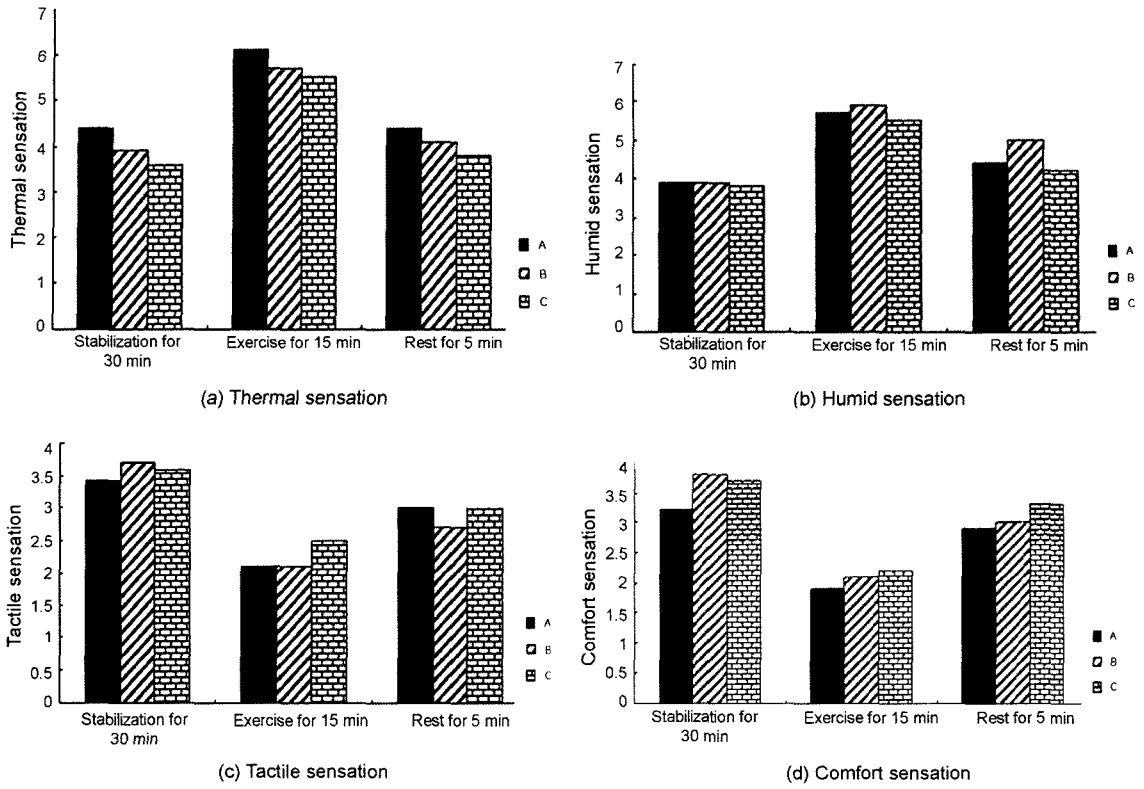

Figure 4. Comparison of mean of subjective sensation.

treated for 30 minutes > treated for 90 minutes. These results indicate that untreated PET was evaluated as the best on sense of touch, preference, and comfort and that longer irradiation resulted in poor evaluation for these characteristics.

This finding was not in agreement with the results of total hand value measured by KES-FB in our previous study. It was considered that hand sensitivity was mainly dependent on the smoothness of the materials, even though we mentioned that it is for summer sports.

Evaluation of Wear Comfort

Figure 4 shows the subjective sensation with wearing the manufactured clothes on three points before running, right after running, and after a 5 minute rest. Thermal and humid sensations are evaluated high right after running for 15 minutes. In contrast, touch and comfort was the lowest at the same point. From these results, we can conclude that high thermal and humid sensation affected touch and comfort. Coolness of thermal sensation was directly proportional to irradiation time. Comparing the three cloths, the cloth treated 90 minutes appeared to have the lowest rate on humid sensation. In the sensibility of touch and comfort, the cloth treated 30 minutes shows a high rate before exercising, but the cloth treated 90 minutes was the highest rate during exercising and the rest term, which was the sweatiest period. At the time of right after running and after a 5 minute rest, comfort, general sensibility evaluation, was 0 minutes < 30 minutes < 90 minutes.

Thermal and humid sensations have similar trends with coolness and wetness of subjective fabric hand. However, the consequences of touch and comfort were not in agreement with the result of the total evaluation in the subjective fabric hand test. Untreated and 30 minute treated PET was rated high on the touch, preference, and comfort from the results of hand sensitivity. On the contrary, the cloth treated 90 minutes shows a low rate on thermal and humidity sensitivity, in the case of wearing a cloth, and a high rate on tactile and humidity.

Evaluation of Microclimate Temperature

Because of a difference between the evaluation of fabric hand sensitivity and wear comfort, we measured the microclimate temperature to confirm these results.

A running program was performed on the actual summer environment of 29 °C, 70 ± 5 % R.H. Figure 5 shows the microclimate temperature increase during a stabilization period of 30 minutes. It is considered that the test environment was too high temperature compared with the outside temperature. There was not a significant difference before and after exercise. During the rest of the time, the microclimate temperature decreased slowly. There was a difference among the three materials, but the difference was inconsistent during the test.

In the microclimate humidity (Figure 6) the humidity

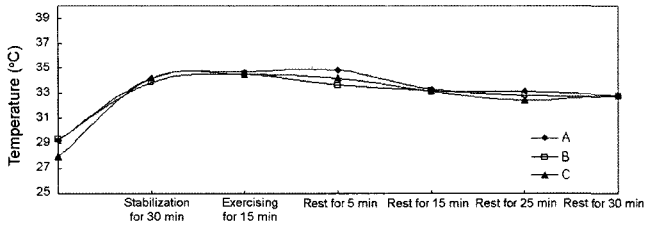

Figure 5. Change of mean temperature under cloth.

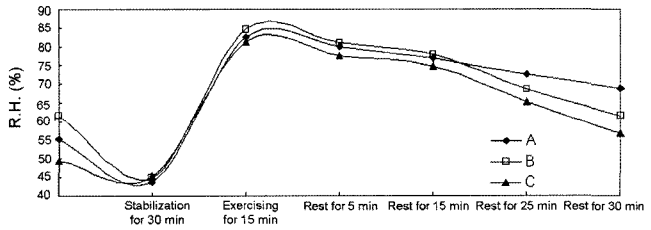

Figure 6. Change of mean humidity under cloth.

decreased during the stabilization period in spite of the high humidity environment. After running for 15 minutes, the microclimate humidity was significantly increasing. During the rest of the time, the microclimate humidity was decreasing and there was an obvious difference among the three materials. The cloth treated for 90 minutes by UV was consistently the lowest in humidity.

In addition, the microclimate humidity was decreased with rest time, but the slope of microclimate humidity was different. The cloths treated for 30 minutes and 90 minutes show a rapid decline in humidity. However, the untreated cloths show a gentle decline on the graph. We found the hydrophilic property was increased with an increase in UV treatment time, and that the absorption of sweat was increased with an increase in UV treatment time.

Conclusion

This study compared the subjective fabric hand evaluation and wear comfort of treated PET to determine the usefulness of the methodologies, using an evaluation of the microclimate as an objective evaluation. Specifically, in a 29 °C, 70 ± 5 %R.H. environment, the subjective sensibility of fabric irradiated by UV for irradiation times of 0, 30, and 90 minutes, wear comfort, and microclimate temperature were investigated.

The results were as follows: In the subjective fabric hand evaluation, subjects perceived that fabrics untreated and treated for 30 minutes were similar to each other; They gave untreated and treated for 30 minutes high marks on touch, preference, and comfort; They rated the fabric treated for 90 minutes as rougher, stiffer, and cooler. In the evaluation of wear comfort, we found that subjects are able to distinguish among three cloths irradiated by UV. Comparing the three cloths, the cloth treated 90 minutes appeared to have the lowest rate on thermal and humidity sensation. At the time of right after running and a 5 minute rest, the cloth treated 90 minutes showed the highest value in the sensibility of tactile and comfort. The comparison of hand evaluation with wear comfort in the high temperature and humidity environment showed there was a difference between the tactile comfort of a fabric and the actual comfort of wearing the clothing.

The evaluation of the microclimate showed: The mean temperature under cloth increased during stabilization and exercising in a 29 °C, 70 ± 5 %R.H.; the mean humidity under cloth decreased with time. The cloth irradiated 90 minutes showed the lowest level on the microclimate humidity. This may be due to an increase of the hydrophilic property of 4-channel PET knit fabric. From these results, we could establish that the cloth treated for 90 minutes presents a more comfortable environment to the wearer. Therefore, we confirm that the investigation of wear comfort is necessary to evaluate the comfort level of various fabrics.

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