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Venue

Tower Hall Funabori
Tokyo, Japan

Program

Monday, June 11

1:00 PM–5:00 PM	The Fiber Society Governing Council Meeting, Bunka-Gakuen University
3:00 PM–7:30 PM	Pre-registration and Welcome Reception, Bunka-Gakuen University

Development of a New Outdoor Sport Shirt Using a Thermal Manikin Under Different Climatic Conditions

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INTRODUCTION

Humans are endothermic organisms and have much higher basal energy consumption, which is mainly necessary to keep their body temperature constant within a wide range of different environmental temperatures. The human body temperature is around 37 °C in the body core such as cranial, thoracic, abdominal cavities and in the extremities, the temperature is lower (28-36°C) [1]. Especially in active sports, the muscles produce heat from metabolic activity and this causes greatest thermal stress during exercise. In order to provide heat balance, the heat is lost from the body through four independent processes; evaporation, convection, conduction and radiation [2].

The clothing is one of the parameters that affects heat balance of the athlete during exercise. Combining clothing functions with wear comfort is a growing market trend, and for all active sports, it is one of the vital factors for achieving high level of performance. Functional requirement of high active sportswear depends on the nature of sport, climatic conditions and amount of physical activity. As Bhatia and Malhotra (2016) concluded in their overview research about thermo-physiological wear comfort of clothing, heat and moisture transmission mechanism through clothing, need to be analysed together with material properties and other influencing parameters [3].

In the present research, the mostly used fabrics in outdoor sports were determined and evaluated by using thermal manikin. Outdoor rowing was chosen as outdoor sport and since it is a water sport, a water repellent finishing was applied to all fabrics. In order to achieve the optimum shirt design, which enhances the comfort and performance of the user, the environmental conditions were analysed first. Moreover, the thermal responses of human body was investigated as well by literature research. With respect to thermal manikin test results and literature review, suggestions were done for outdoor rowing clothing.

MATERIALS AND METHODS

The mostly used fabrics for outdoor rowing were determined and tested. The fibres and the knitting structures were presented in Table I. The fabrics were evaluated by using thermal manikin (PT-Teknik/Denmark). In order to perform thermal manikin tests, three long sleeve basic shirts were produced from each fabric and were treated with a water-repellent finishing (5% of a fluorocarbon-based product).

Code	Composition	Knitting Structures
F1	60% Polyamide 35% Polyester 5% Elastane	False Rib 1
F2		Single Jersey jacquard 1
F3	60% Polyamide 35% Polypropylene 5% Elastane	Single Jersey jacquard 2

Table I. The composition, knitting structures and the codes of shirts.

Two test series were conducted in order to evaluate the effect of air temperature and humidity change on thermal insulation properties of the shirts. The test series were set with respect to “ISO 9920:2007: Ergonomics of the thermal environment—Estimation of thermal insulation and water vapour resistance of a clothing ensemble.” The specimens were dressed up to the thermal manikin and the manikin was kept in a stationary standing position. The skin temperature was set and during the test periods maintained at 33 ±0,2°C. The values of skin temperature and heat loss were recorded every minute during the test time (60 minutes). The tests were conducted in different climatic conditions in a climatic chamber at constant ambient temperature and relative humidity. "Test Series 1" were performed at constant of 24,5±1°C temperature and 60±5% relative humidity, "Test series 2" were conducted at of 19±1°C temperature and of 77±2% relative humidity, in which colder climatic condition was simulated.

RESULTS AND DISCUSSION

The heat loss values of Test Series 1 and Test Series 2 for eight body parts were graphically evaluated and compared (Figure 1). According to obtained data, F3 had the greatest heat flow in all body parts than other structures in Test Series 1. In Test Series 2, all fabrics showed similar heat flow values. In addition, it can be seen in the graph that, at the chest, all fabrics had the least heat flux values.

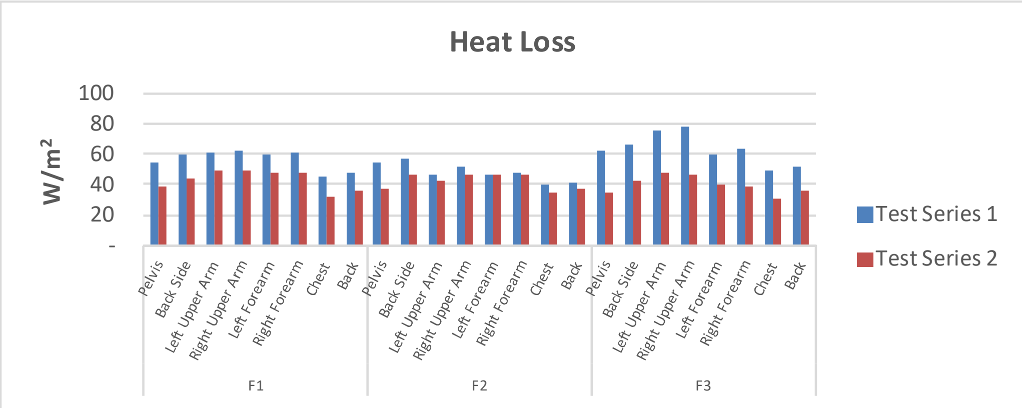

Figure 1. The heat loss values of structures for body parts according to test series.

Moreover, the comparisons were performed for each test series by calculating the effective thermal clothing insulation I_{cle}. The temperature difference of fabrics in two different conditions were evaluated regarding to the body parts (Figure 2). With respect to obtained data, it can be clearly seen that, in Test Series 2, F3 had the greatest effective clothing insulation. In addition, the fabrics showed similar effective clothing insulation properties in Test Series 1. Test Series 2 simulates colder environment and therefore it can be concluded that F3 was able to adapt effective clothing insulation properties in different conditions.

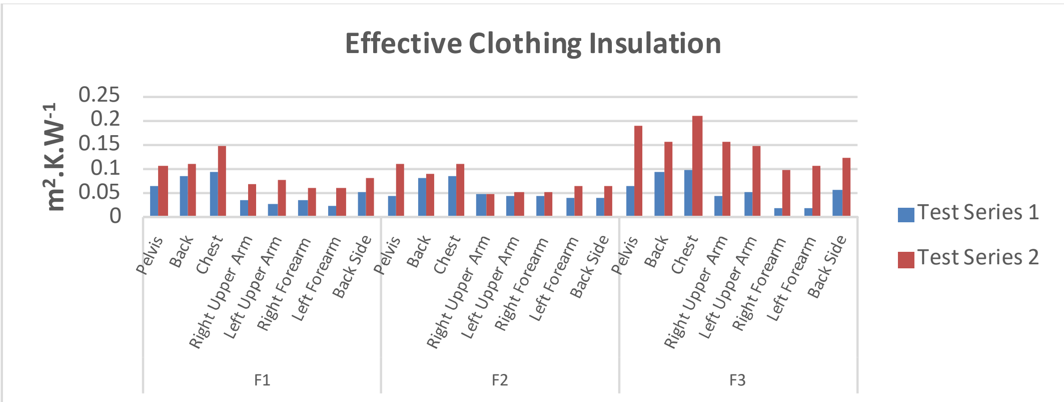

Figure 2. The effective clothing insulation values of structures for body parts according to test series.

CONCLUSIONS

The air temperature, water temperature and wind are the factors that affect the performance of the rowing as well as the safety rowing. Some clubs have the rules, which are, if the sum of the water temperature and air temperature is below 18˚C [4] or the air temperature is below 5˚C [5], the conditions are not considered "safe" for rowing. Moreover, in some clubs the wind conditions are defined critical above 5.1 m/s [4] whereas others allow going out only very experienced crews in the wind above 14 m/s [6]. In this wide range of climatic conditions, the garment needs to assist the active body, support the performance of the wearer and provide thermoregulation. In order to achieve the garment, which matches these needs, the thermal and sweating responses of human body need to be considered together with environmental conditions and thermal and physical properties of fabrics.

The thermal response of a thermal manikin in different temperatures dressed with 100% Cotton long sleeved shirt was studied as a previous study [7] and the infrared images taken in this study were presented here as examples (Figure 3).

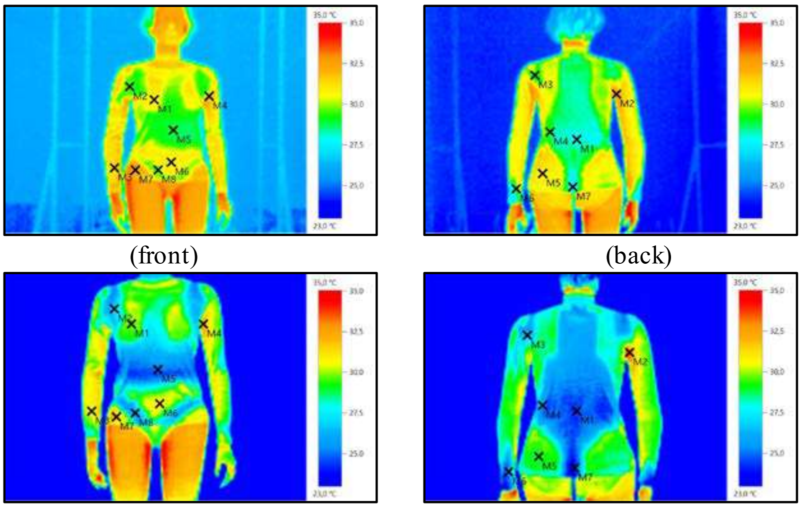

Figure 3. IR images at 24,5˚C (top) and at 19˚C (bottom).

With respect to all obtained data, it can be said that, a shirt for outdoor rowing can be produced with only F3. However, combining the evaluated fabrics may provide better thermoregulation for human body. Therefore, in the chest and back, which have lower skin temperatures, F3 was suggested to be put on for both in cooler and warmer air conditions. Moreover, F2 was suggested to be put on the sides of the garment and F1 on armpits due to higher heat loss and lower thermal effective thermal insulation values.

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