Journal of Fiber Bioengineering and Informatics 8:2 (2015) 221–228
doi:10.3993/jfbim00088

# A Study on Material of Manikin Skin for Measuring Clothing Evaporative Resistance

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**Abstract**

Evaporative resistance is an important parameter of clothing in its thermal comfort. The sweating thermal manikin developed for evaporative resistance test needs a textile skin covering its surface to simulate sweating. To investigate the effect of skin material on the measurement, three knitted fabrics (cotton, blend of cotton and polyester, polyester) were made into skins for the sweating thermal manikin Newton. The evaporative resistances of boundary air layer and four clothing ensembles were measured under an isothermal condition. It was found that the evaporative resistances measured with cotton skin were smaller than those measured with the other two skins. The large evaporative area and strong water absorbing ability of thick, dense and hydrophilic cotton skin result in more evaporative heat loss and consequently lower evaporative resistance values.

*Keywords*: Evaporative Resistance; Fabric Skin; Sweating Thermal Manikin; Heat Loss; Skin Temperature

## 1 Introduction

Evaporative resistance is one of the clothing's most important parameters in evaluating the thermal comfort and heat stress of wearers [1]. Previous studies have demonstrated that thermal manikin is the most ideal instrument for measuring clothing evaporative resistance [2]. The calculation of evaporative resistance needs the sweating skin surface temperature and evaporative heat losses from sweating skin [3]. However, the set point of nude manikin surface temperature (i.e., 34 °C) is usually used instead because of the difficulty of sensory measurement of sweating skin surface temperature. To enhance the calculation accuracy on evaporative resistance, Wang et al. developed a universal empirical equation upon evaporative heat loss to predict the sweating skin surface temperature [4–6]. Now the only factor that influences the calculation of evaporative resistance becomes the evaporative heat loss from sweating skin. Whereas, skins made of different textile materials have different water absorbing and evaporating abilities, which leads to different evaporative heat losses from the sweating skin. Therefore, the evaporative resistance of the same clothing measured with different skins may obtain different evaporative resistance values. Given

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June 2015

the fact that no standard skin is addressed in the only standard for measuring clothing evaporative resistance using a sweating thermal manikin ASTM F2370, it is of great importance to study the effect of skin materials on measuring clothing evaporative resistance. To quantify the local moisture transfer property of clothing, the local evaporative resistance of clothing should be reported [7–9].

In this paper, three knitted fabrics (cotton, blend of cotton and polyester, polyester) were made into skins for a 34-zone sweating thermal manikin Newton respectively to measure the total and local evaporative resistances of boundary air layer (code: A) and four different clothing ensembles. The effect of skin materials on measuring clothing evaporative resistance was investigated through analyzing the total and local evaporative heat losses and evaporative resistances.

# 2 Methodology

## 2.1 Skins and Clothing Ensembles Tested

Three knitted fabrics (cotton, blend of cotton and polyester, polyester) were made into skins for sweating thermal manikin Newton. Skins are denoted as C, CP and P respectively. Four clothing ensembles: an ensemble of tight-fit cotton sportswear, a dust-proof coverall, a fire-protecting coverall and an ensemble of down clothing (clothing codes: CS, DPC, FPC and DC) were tested in combination with three skins. Three skins all fit the nude manikin very well and vary only in textile materials. Three skins and four clothing ensembles are shown in Fig. 1. The parameters of skin fabrics are presented in Table 1.

## 2.2 Test Procedures

A 34-zone Newton type sweating thermal manikin (MTNW, Seattle, WA, USA) was used in this study. All tests were conducted in a climatic chamber, where a so-called isothermal condition

Fig. 1: Skin C, CP, P and clothing CS, DPC, FPC, DC