

EVALUATION OF THE EFFECTIVENESS OF OUTER GARMENT CLOTHING AT THREE DIFFERENT TEMPERATURES

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INTRODUCTION

During a work situation the outer garment is supposed to protect the body against the effects of water and wind, and at the same time, allow produced sweat to diffuse from the body to the surroundings. Some of the sweat will accumulate in the clothing ensemble and may result in thermal discomfort. The textile materials in the outer garment may influence sweat accumulation in a clothing ensemble with regard to amount and location of sweat. Textile material with GORE-TEX® is often preferred as outer garment due to the low air permeability, waterproofness and a high water vapor permeability. However, the ambient temperature may influence the transportation of water vapor through the textile materials.

The purpose of the present study was to investigate the effect of three different outer garments on sweat accumulation, temperature under the outer garment, skin temperatures (T_{skin}), rectal temperature (T_{re}) and subjective thermal sensation at three different ambient temperatures. The chosen garments are the most common outer garments available on the Norwegian market.

METHODS

Six male subjects (26 ± 2 year) participated in the experiments which comprised twice repeated bouts of 40 minutes cycle exercise (40% of maximal aerobic work capacity) followed by 20 minutes rest. The experiments were conducted in a climatic chamber, the ambient temperature (T_a) being controlled at $+10^\circ\text{C}$, -10°C and -25°C .

A 3-layer clothing ensemble was used and the subjects were dressed in the same underwear and middle layer at all experimental conditions. The underwear was manufactured of double-layer wool and the middle layer was a cotton pullover. At -25°C the subjects also used a thick woollen pullover and an extra pair of polyamid/polyester trousers. Three different outer garments were used: A) 100% Cotton, B) 3-layer polyester GORE-TEX® and C) 100% polyester Microfiber (table 1). Weight, air permeability and water vapor permeability of the outer garments were measured according to respectively ISO 3801, DIN 53887 and BS 7209.

Table 1. Weight, air permeability and water vapor permeability of three outer garments.

Outer garment	Weight (g/m^2)	Air permeability ($1/\text{m}^2/\text{s}$)	Water vapor permeability ($\text{g}/\text{m}^2/\text{h}$)
A) 100% Cotton	279	18.6	23.6
B) 3-layer polyester GORE-TEX®	182	< 0.03	38.1
C) 100% polyester Microfiber	131	62.5	38.2

The clothes were weighted individually before and after each experiment in order to determine the amount of moisture accumulated in the different layers in the clothing ensemble. Temperature under the garment (chest), T_{re} and 13 skin temperatures were measured every minute and all the skin temperatures were used for calculating the mean skin temperature. Subjective evaluation of thermal comfort and sensation on temperature and humidity were collected every ten minutes during the experiment.

RESULTS AND DISCUSSION

The results showed that the textile materials of the outer garments had a significant influence on sweat accumulation. At $+10^\circ\text{C}$ the proportion of the produced sweat accumulated in the whole clothing ensemble was

larger using A (35%) than B (25%) and C (28%). Due to the thicker fabric and lower water vapor permeability the amount of sweat accumulated in the outer garment was higher at +10°C with A (10%) compared to B (3%) and C (2%) (figure 1). This resulted in an increased resistance to water vapor transport out of the garment and an increased accumulation of sweat in the clothing ensemble.

No differences in sweat accumulation in the whole clothing ensemble or in the outer garment were measured at -10°C (average 12% in the outer garment) or at -25°C (average 19% in the outer garment). At -10°C the temperature measured under the outer garments varied between +5°C and +10°C. At -25°C the temperature under the outer garments was as low as -10°C. Under such conditions the capability of the air to contain water vapor is low, the air saturates quickly and the water vapor will condense (+5°C to +10°C) and freeze (-10°C). Condensed and frozen water vapor can not dissipate through the outer garment and an increased accumulation of sweat inside the garment will occur.

Skin temperatures decreased significantly with decreasing T_a . Because of the thicker fabric T_{skin} was higher using A at -10°C and -25°C. Use of different outer garments did not result in differences in rectal temperatures. Subjective thermal comfort and sensation of temperature and humidity showed no differences between the clothing ensembles.

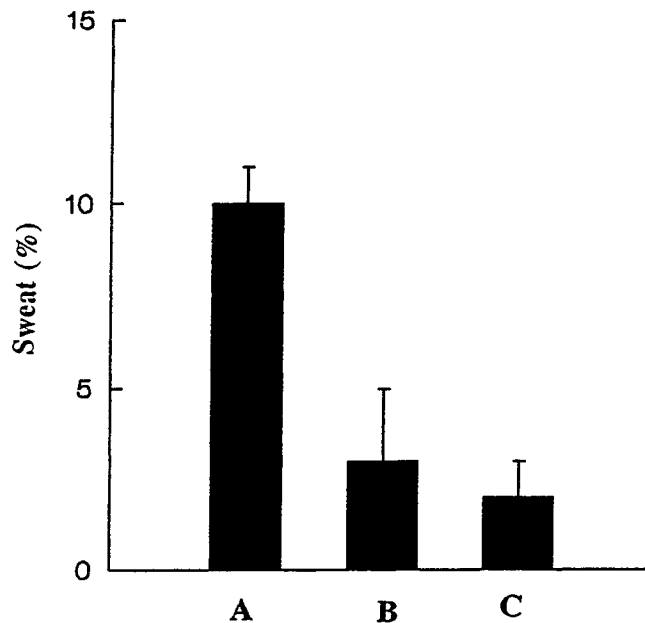


Figure 1. The amount of sweat in proportion to total sweat production in three different outer garments (A: 100% Cotton, B: Three-layer polyester GORE-TEX® and C: 100% polyester Microfiber) at +10°C (n=6).

CONCLUSION

3-layer polyester GORE-TEX® (B) and 100% polyester Microfiber (C) are to be preferred at +10°C because of the high water vapor permeability of the garments that allow more sweat to evaporate from the clothing ensemble. However, at -10°C and -25°C no differences were measured between the outer garments. At subfreezing conditions under the outer garment water vapor can no longer dissipate through the garment to the surroundings.

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