INFLUENCE OF AMBIENT HUMIDITY ON MOISTURE ABSORPTION AND THE CALCULATION OF EVAPORATIVE HEAT TRANSFER IN WINTER CLOTHING

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INTRODUCTION

The partitional calorimetry method (1) is frequently used to determine heat balance and resulting clothing insulation in dressed persons. The method requires accurate measurements of body mass change to determine the skin evaporation rate. The measured loss of body mass, corrected for by the respiratory and metabolic weight **loss,** is commonly regarded as equal to the **skin** evaporative mass loss. However, in several conditions this is a simplification of the actual situation. Some part of the moisture that evaporates from the skin will be absorbed in the clothing system **(2).** Measurements of absorption **of** external moisture in winter clothing during experiments have not yet been reported. The heat contribution from the absorption processes to the total heat transfer in the clothing system has been analyzed only by a few authors (3,4).

The purpose of the present study was to investigate the influence of high ambient humidity on moisture absorption and the calculation of evaporative heat transfer in winter clothing during simulated human experiments by use of a thermal manikin.

METHODS

A thermal manikin (5,6) was used to simulate the human subject The manikin was attached at the top **of** the head to a strain gauge force transducer (HBM Z6, Hottinger Baldwin Messtechnik, Darmstadt, Germany) to measure weight change continuously. Three winter clothing ensembles (S1, S2, W) were iesied. The ensembles comprised tight-fitting underwear, a fibre pile suit and an outer overall and jacket (S1) or parka (S2, W). The total clothing insulation (IT) measured with the standing thermal manikin (5,6) was S1: **2.46** clo, S2: 3.12 clo and W3.20 clo, respectively. S1 and S2 ensembles were all manufactured from synthetic fibres, while the two inner layers in W were made of wool fibres [total mass S1: 3010g, S2: 3860g, W: 4110g (1620 g wool)]. The heated manikin (surface temperature: 34.0°C) was dressed and conditioned in the laboratory [air temperature (T_a): +25°C, air water vapour pressure (p_a): 0.9 kPa, relative humidity (rh): 30%]. At thermal and humidity equilibrium, the manikin was moved into a climatic chamber [T_a: +16°C, p_a: 1.4 kPa, rh: 78%]. The total mass change of the manikin and the clothing system was registered at one minute intervals. The experiment in the climatic chamber lasted for 170 minutes.

RESULTS AND DISCUSSION

Absorption occurred in all clothing systems during the climatic chamber test. The measured relative mass increase fitted an exponential curve (figure 1). The time constant differed between the experiments andranged from 38 to 131 min. The largest time constants were found in W. The time constants in our experiments were larger than in similar experiments by Tanabe (7). A time constant of 35 min of weight change was reported with wool clothing at lower clothing insulation (IT: 1.0 clo) at a relative humidity transient from 20 to 80 %. This difference was probably due to the larger mass of the clothing systems used in our experiments. In contrast to our results, absorption did not occur in synthetic fibre clothing experiments performed by Tanabe ***(7).*** The total of absorbed moisture in our experiments was 30 g, 31 g and **43** g in S1, S2 and W, respectively.

Heat balance in dressed subjects measured with the partitional calorimetry method does include some commonly known difficulties in the quantification of the different avenues of heat loss. For example, in determination of evaporative heat transfer it is difficult to quantify the latent heat originating from the absorption processes contributing to the total heat transfer in the clothing system. Subtracting the estimated absorbed moisture received in our new experiments from the body mass change values in earlier treadmill walking experiments with the same clothing ensembles, resulted in a reduction of I_T by 0.06 to 0.18 clo **(2** to ***6*** %).

The data presented in this study should, however, be interpreted with care. During experiments with subjects, skin temperature and sweat evaporation will affect relative humidity in the clothing system and alter the absorption capacity of the clothing fibres. Exercise might in some conditions enhance absorption by exposure of a larger surface area. Finally, in contrast to our thermal manikin measurements, experiments with subjects dressed in high-insulating winter clothing are probably performed in a lower ambient temperature with a rather low water vapour content, although the relative humidity is 100% or near. Accordingly, the absorption rate will be low.

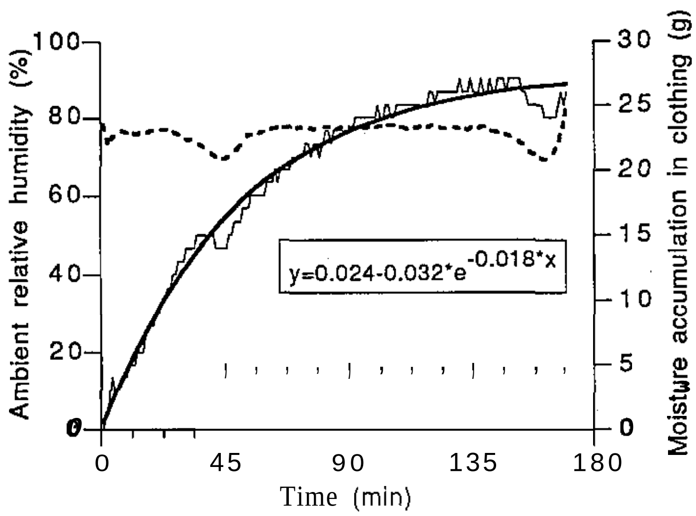

Figure 1. Ambient relative humidity (broken line) and moisture accumulation (solid line) in a three-layer winter clothing manufactured from polyamide and polyester fibres measured on a standing thermal manikin. Best fit exponential function curve is plotted.

CONCLUSIONS

Corrections of the skin evaporation rate during climatic chamber experiments by subtracting the rate of moisture absorption in the clothing may reduce the methodological errors of partitional calorimetry. The largest errors in the determination of the skin evaporative rate will be present at short lasting experiments (<60 min) and with clothing ensembles comprising fibres with high moisture regain. The corrections can most probably be based on regain properties of the fibres involved.

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