PHYSIOLOGICAL EVALUATION OF A SEMIPERMEABLE MEMBRANE IN SLAUGHTERHOUSE WORK CLOTHING

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INTRODUCTION

Efficient, safe work performance depends on workers maintaining their thermal balance and comfort, and according to Ramsey (1) the temperature range for optimal work performance is rather narrow. Cold wind penetrating a clothing ensemble lowers the temperature in the ensemble and reduces skin temperature. If this causes a subjective sensation of discomfort it may be disadvantageous. In a slaughterhouse the indoor climate is regulated to optimize meat quality and production staff are exposed to moderately cold, windy conditions. In the work situation employees usually wear a non-windproof, single-layer cotton outer garment. Introducing a windproof lining in the clothing ensemble may increase thermal comfort. However, an extra layer in the ensemble may affect sweat transportation from the body, which is undesirable if the sweat accumulates in the underwear. To avoid this problem a semipermeable membrane lining could be introduced. The purpose of this study was to evaluate the effects of a windproof semipermeable membrane lining on thermoregulatory responses, thermal comfort and sensations of temperature and humidity. Work and rest periods were scheduled under moderate cold, windy conditions.

MATERIALS and METHODS

Work intensity for slaughterhouse employees was registered together with environmental conditions. These conditions were then simulated in a climatic chamber, in which room temperature was maintained at +2°C and wind velocity at 1.7 m/s. Six male subjects (age 25±4 years, weight 74±8 kg and height 178±7 cm) volunteered for the study, which comprised two bouts of 30 minutes of walking on a treadmill (35% of maximal aerobic work capacity), each followed by 15 minutes of rest. The subjects performed two experiments **(A** and **B)** in randomized order. In both they were dressed in long-armed pullover and longjohns underwear (Ullfrotté 200g), an outer garment (single-layer cotton), gloves and a cap. In experiment B a semipermeable membrane lining (jacket) was placed between the underwear and the outer garment. Wind penetration and water-vapour permeability of the membrane were 0.0 l/min/20cm^2 and 27.2 g/m^2/h, respectively. Skin temperatures were measured every minute and mean skin temperature (MST) was calculated using the equation $MST = (0.21 \times T_{forehead}) + (0.1 \times T_{chest}) + (0.11 \times T_{back}) + (0.17 \times T_{stomach}) + (0.12 \times T_{upper\ arm}) + (0.06 \times T_{lower\ arm}) + (0.15 \times T_{front\ thigh}) + (0.08 \times T_{front\ leg})$ (2,

modified). The relative humidity (rh) and temperature between underwear and membrane were measured at the chest by use of humidity and temperature sensors (3E GmbH, Entwicklung Elektronischer Einrichtungen, Miinchen, Germany). On the bases of these recordings water-vapour pressure (wvp) was calculated. Sweat production was determined from the total change in body weight. Clothing was weighed before and after each experiment in order to determine amount of moisture accumulated in each layer. Every **15** minutes during the experiments a questionnaire was used to obtain information about subjective ratings of thermal comfort and sensations of temperature and humidity **(3).**

The difference in response when wearing a semipermeable membrane lining or not was assessed by a one-way ANOVA for repeated measures (referred to as time) of changes in skin temperatures, MST, rh, wvp and subjective evaluation, for every **15** min (three-point moving average, minute **14-16** and so on). An ANOVA was calculated from the data of the naked body and clothing weight. **A** contrast test was used as a post hoc test to locate significant differences between means during the experimental period. All differences reported are significant at the $p<0.05$ level and results are presented as means ± s.d.

RESULTS

Skin temperatures: From minute **15** and throughout the remainder of the experimental period the MST of subjects who were using the clothing ensemble including the semipermeable membrane lining **(B)** was higher than that of subjects wearing the ensemble without such a lining **(A)** (Fig. 1). At the end of the experiment, MST was **1.2±0.7°C** lower during experiment A compared to B. Measurements started five minutes after entering the climatic chamber, and the overall fall in MST without the semipermeable membrane lining was **2.9±0.3°C** from start to end. The equivalent reduction using the semipermeable membrane lining was **2.0±0.4°C.** Upper and lower arm temperatures at the end of the experiment were **2.3±0.9°C and 1.8±1.1°C** lower when no semipermeable membrane lining was used. Temperatures at the chest and back did not differ using the two clothing ensembles.

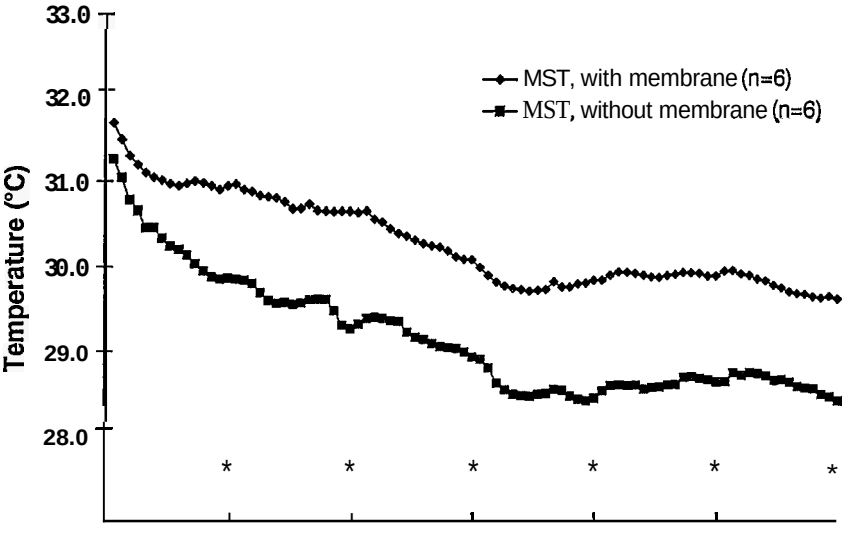
Moisture accumulation/transportation: Work intensity during the two periods was equivalent to **35%** of the subject's maximal aerobic work capacity and resulted in an average sweat production of **258±78** g. No differences in sweat accumulation were registered in individual clothing layers of the two groups. Total sweat accumulation in the clothing ensemble expressed as a percentage of produced sweat was **15.31t5.5% (41±22** g). The amounts of sweat in the outer garment and underwear were **3.7±1.2 % (923** g) and **1.6±1.2 % (5±4** g), respectively. The remaining sweat was in the socks, shoes, gloves and cap. Wvp measured at the chest, outside the underwear, increased during the working periods and from minute **15** and

throughout the experimental period it was higher using the semipermeable membrane lining. At the end of the two working periods wvp was **4-5** mbar higher using the semipermeable membrane lining (11.7-12.2 mbar) compared to using no such lining (6.7-8.2 mbar). Rh increased during the working periods, and average values at the end of the periods were about 50%. However, there were no differences between the two experimental conditions. Temperature measured at the same location as wvp and rh was lower when no semipermeable membrane lining was used. At the end of the experiment the temperature was 4.5 °C lower without such a lining in the clothing ensemble.

subjective evaluation: Subjective sensations of skin wetness did not differ between conditions and the subjects stated that these were close to "normal dry" throughout the experiments. The subjects reported the clothing ensemble as being almost completely windproof using the semipermeable membrane lining. Without the lining, the clothing ensemble was reported as being less windproof. The sensation of temperature in the clothing ensemble with the semipermeable membrane lining was reported as "neutral or warmer" during the work periods. Without the lining the subjects reported "neutral or colder". Thermal comfort was not affected by including the semipermeablemembrane lining in the clothing ensemble.

DISCUSSION

Neither during the first working period (min 0 to 30), nor the second (min **45** to 75), was heat production great enough to compensate for the initial decrease in MST. However, including a semipermeable membrane lining in the clothing ensemble reduced the decrease in MST during the experimental period and demonstrated the insulating/windproof effect of the membrane. Using the lining increased the wvp, a result that may be explained by increased resistance to water-vapour transportation through the extra layer in the clothing ensemble. However, some of the increase may be explained by a decrease in wind penetration through the clothing ensemble (shown by the increased clothing temperature) because the movement of air through the clothing ensemble contributes to moisture transportation ("pumping effect"). **On** the basis of the wvp results in this study, with only 1.5 hour exposure periods and low work loads it is possible that a longer experimental period (a normal working day is 7-8 hours) or an increased work load would have resulted in differences in sweat accumulation in the underwear between the two conditions. Increased sweat accumulation may affect the subjective evaluations of thermal comfort and sensations of temperature and humidity in the clothing ensemble. Further studies are therefore needed to determine the effects of higher work loads and longer experimental periods on the response of the membrane to moisture transportation.



CONCLUSIONS

Using a semipermeable membrane lining had a positive effect on skin temperatures and did not affect sweat accumulation in the underwear. The higher mean skin temperatures and the subjective reports of windproofness demonstrate that the semipermeable membrane lining provided a thermal aid which may **be** beneficial for workers exposed to moderately cold and windy conditions.

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