

**THERMAL PROPERTIES  
OF THE NORDIC CROSS-COUNTRY SKI ENSEMBLE  
IN WINDY AND CALM COLD**

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**INTRODUCTION**

Skiing is affected by wind produced by the movement of the body through the air in addition to any external wind. In Nordic countries experienced skiers as well as touring skiers and even small children wear light, close-fitting clothing even in very cold weather, despite the fact that its thermal properties may be insufficient. It may reduce physical performance during dynamic exercise, and there may also be a risk of hypothermia (1).

The aim of this study was to compare body cooling of a subject dressed in a typical cross-country ski clothing ensemble during submaximal exercise in windy and calm cold.

**METHOD**

Five, physically trained men volunteered for the study (Table 1). The experiments were conducted in a climatic chamber under controlled cold ( $T_a$   $-15^{\circ}\text{C}$ ) conditions with and without fan-generated turbulent wind ( $v_a$  6 m/s and 0.3 m/s). The wind chill index was estimated as  $-30^{\circ}\text{C}$  and  $-15^{\circ}\text{C}$ . The subjects performed a 60-min submaximal work bout on a treadmill (10 km/h, incline  $5^{\circ}$ ), in random order once in both of the test configuration. The cardiovascular workload was about 70-80 % of the maximum estimated by the heart rate. The subjects wore cotton pants, long underwear (polypropylen fishnet) and a hooded ski overall (lycra), gloves, head band (WO), socks, and training shoes. Thermal insulation  $I_{cl}$  was 0.6 clo. HR, rectal temperature ( $T_r$ ) and skin temperatures ( $T_{sk}$ ) were monitored continuously.  $T_r$  was measured at a depth of 10 cm and skin thermistors were placed on the skin at nine sites. Sweat production was determined from the changes in body weight corrected for fluid intake and accounting for the amount of sweat absorbed into the clothing. The absorption of sweat by the clothing was assessed by weighing the garments before and after each exercise period. Subjective evaluations of perceived exertion (RPE), thermal sensations in general, and local discomfort votes were requested every 15 minutes.

**Table I.** Characteristics of the subjects

Age (yrs)	Height (cm)	Weight (kg)	Body Fat (%)	ADu ( $\text{m}^2$ )	$\dot{V}\text{O}_2$ ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ )
19-28	175-180	63-76	9.7-10.9	177-191	47-72

**RESULTS**

No differences occurred in mean  $T_r$  between windy and calm conditions.  $T_r$  was  $38.9^{\circ}\text{C}$  at the end of exercise in both conditions. Final mean body temperature ( $\bar{T}_b$ ) were  $2^{\circ}\text{C}$  and mean skin temperature ( $\bar{T}_{sk}$ )  $5.5^{\circ}\text{C}$  lower when the subjects exercised in wind (Figure 1). The skin temperatures for each of the body segments were lower in windy condition. The lowest individual local  $T_{sk}$  values were registered at the front of the body (chest  $17.8$ , abdomen  $11.1$ , thigh  $13.5^{\circ}\text{C}$ ). In windless condition the local  $T_{sk}$  values did not fall under  $20^{\circ}\text{C}$  in any exposure. Windy condition resulted in a mean heat debt of  $14.5 \text{ W}/\text{m}^2$ , while in calm cold the heat accumulation was  $16.2 \text{ W}/\text{m}^2$  (Figure 2).

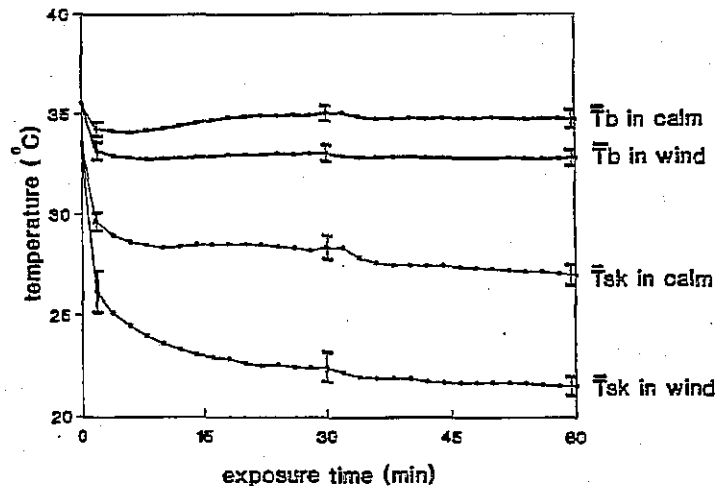


Fig. 1. Mean body and mean skin temperatures in windy and calm conditions (mean,  $\pm$ SEM)

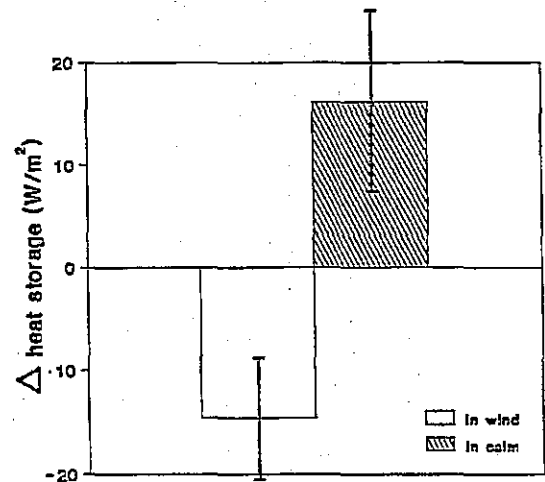


Fig. 2. The rate of change in heat storage (mean,  $\pm$ SEM)

The average sweat production for windy condition was 685g and for windless condition 1044g. About 80 % of the produced sweat evaporated effectively in wind, and 60 % in calm, on average. The amount of sweat absorbed into the clothes was 125g (SEM $\pm$ 8.8) in wind, on average. The garments were moist and a moisture triangle appeared on the upper back. In calm cold 384g (SEM $\pm$ 54.5) of sweat was absorbed into the clothing, on average, and the wetness of the clothing was visible. Slight individual differences were found in the amounts of absorbed sweat in windy cold (range 91-144g). In calm condition the differences were notable (range 186-567g).

Both conditions were perceived equally strenuous, light at the beginning and hard at the end of exposure, on average. There was a tendency to grade windy cold as somewhat more uncomfortable. The final mean thermal comfort sensation was uncomfortable in wind and slightly comfortable in calm. The mean thermal sensation in general varied between slightly cool and cool in wind, while it was rated as slightly cool to warm in calm. Local thermal discomfort correlated with low skin temperatures. No one reported intolerable discomfort.

## CONCLUSIONS

When the subjects exercised in a  $-15^{\circ}C$  temperature without wind, the body heat created by the high metabolic demands of the exercise could compensate for the cooling effects of the environment. The thermal properties of the given ski clothing seems to be sufficient in calm and moderate cold, while they do not protect enough against body cooling and local cold injuries at  $-15^{\circ}C$  with 6m/s wind. The negative value for heat storage suggests that the body was not in thermal equilibrium in spite of high  $T_r$ . This agrees with the drop in  $T_b$  and the low mean and local  $T_{sk}$  values. The temperature of working muscles may drop in long-lasting exercise to  $35-36^{\circ}C$  (2), which may reduce physical performance during prolonged exercise. The demands for a functional ski suit are the opposite; water vapour permeability and wind resistance of a light, aerodynamic bodysuit.

## REFERENCES

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