CLOTHING PERFORMANCE IN THE COLD

Assessing the lower temperature limit for comfort in footwear

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Introduction

When selecting clothing and equipment for use in the cold, consumers often receive only limited guidance from product information provided by manufacturers. In the area of sleeping bags the introduction of standards for their climatic range assessment, though often heavily debated by manufacturers, has undoubtedly provided consumers with guidance. Currently no such standards exist for outdoor footwear. Many manufacturers of footwear do claim certain lower temperature limits, going to -40ºC in some cases. No information is however provided on how this is tested and what criteria are applied. Kuklane et al. (1999) did several studies on the relation between footwear insulation and comfort range, but so far this has to our knowledge not led to the development of a standard. In the present study, following up on work by Kuklane, an attempt was made to collect physiological data that may be used in setting criteria for the lower temperature range of footwear.

Methods

Dressed in suitable winter clothing, identical socks and 7 different walking shoes (5 identical models with thermal resistance increasing stepwise in 5 steps, +2 other models) six participants (3 males, 3 females) volunteered to take part. Ethical approval was obtained for the testing. Participants were exposed to five environmental conditions; 0°C, -7°C, -14°C, -20°C and -30°C. Air velocity was 0.4 $m.s^{-1}$. During exposure, participants completed a rest-exercise protocol of 10 minutes walking (331 W), 10 minutes stepping (313W) and 10 minutes rest, for 120 minutes. Four skin temperatures (Grant thermistors), at the arch, medial heel, lateral foot and base of 4th metatarsal, were averaged every 5 minutes. Local thermal comfort and foot acceptability were rated every 5 minutes.

Results

A relation of mean foot T_{sk} with ambient temperature (negative) and boot insulation (positive) was observed, with drops in foot temperature of more than 20°C in extreme cases. A clear pattern was observed, with the toe having the coldest T_{sk} followed by the lateral foot, mid-arch and the heel having the highest T_{sk}. Moderate to strong correlations existed between foot thermal comfort and thermal sensation and mean foot T_{sk} (r^2>0.55, r^2>0.77, respectively). Threshold for 'uncomfortable' and a 'cool' local thermal sensation occurred at a mean foot T_{sk} of 23°C.

Discussion

It is well established that the extremities are at great risk of cold injuries, but this study also revealed that the lateral foot was more susceptible than the medial aspect. Protective footwear should account for the uneven foot temperature distribution with the toe having the lowest T_{sk} followed by the lateral foot. Footwear should aim to protect mean foot temperature from dropping below 23°C. This limit value can be used to assess how well cold footwear protects the

foot in cold climates. A time limit and a metabolic rate definition are essential components of such an assessment however.

References

1. Kuklane, K; **Footwear for cold environments Thermal properties, performance and testing**, *Arbete och Haelsa*; 1999. 23