THERMAL RESPONSES OF SUBJECTS, BAREHEADED OR WITH HEADGEAR, TO A COLD AIR STREAM AT -10°C

D. Gavhed, **G.** Ohlsson and I. Holmér

National Institute for Working Life, Solna, Sweden

❦

INTRODUCTION

Wind is often present in the outdoor workplace. In combination with cold air temperatures, wind enhances cooling of the unprotected face and may constitute a **risk** for frostbite in healthy individuals. Moreover, cold wind may also be negative for individuals with cardiovascular diseases, since it increases blood pressure (1). The wind chill index (WCI) is used as a tool to predict the risk for frostbite in bare **skin** (2). However, even in conditions where combinations of air temperature and air speeds are not at the WCI risk levels for frostbite, a pronounced risk for frostbite and a marked increase in blood pressure have been reported in young males **(3).**

Although headgear is considered essential for work in a cold outdoor climate, people often do not wear such clothing. Reasons for not wearing headgear may include restriction of hearing and/or vision, discomfort or ignorance of the physiological effects of the actual weather conditions.

The aims of this study were to (1) investigate whether the risk for frostbite was higher bareheaded compared with wearing headgear and **(2)** examine the magnitude of the blood pressure response of middle-aged individuals to **cold** wind, **with and** without headgear.

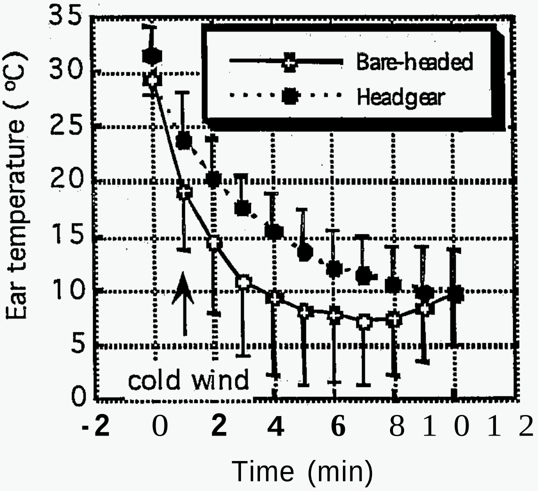

Figure 1. Average earlobe temperature in 4 seated subjects who were bareheaded (o) or wore headgear (•) during exposure to -10°C with an air stream of 6 m·s⁻¹ blown in the face. Bars show standard deviation.

MATERIALS AND METHODS

Nine healthy subjects, 1 female and 8 males, 45 to 54 years old ("resting" **SBP: 115** to **140** mmHg, **DBP:** 70 to **100** mmHg), were exposed twice **to an** ambient temperature of **-10°C and an equally cold air stream** of 6 m·s^{-1} **directed to the face.** **The subjects** wore warm

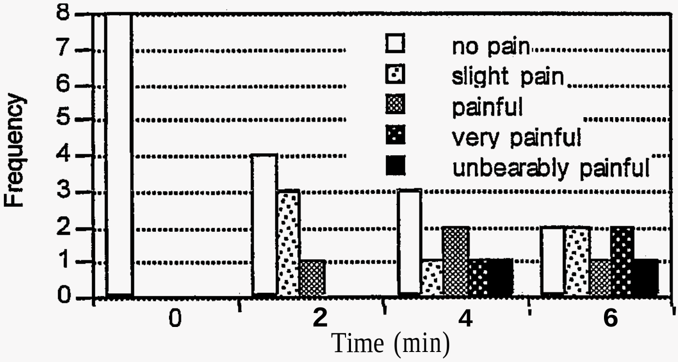

Figure 2. The frequency of pain sensation ratings from **8** bare-headed subjects during exposure to -10°C and *6* m·s^{-1} wind in the face.

winter clothing. Subjects performed 1 trial wearing a winter cap with earflaps (headgear) and 1 without a cap (bareheaded).

Skin temperatures of the forehead, chin, cheek, nose and earlobe were measured continuously with thermocouples (copper-constantan, diameter: ***0.2*** mm, time constant: 0.04 s), and the subjects rated their pain sensation at the measuring sites every **2** min. Systolic (SBP) and diastolic (DBP) blood pressures were measured while the subject was seated before exposure, every *2* min during exposure and after exposure. Heart rate was recorded by telemetry (Sporttester, Polar Electro KY; Finland) continuously.

The maximal exposure to wind was 10 min. Four experiments were interrupted before 10 min elapsed due to low **skin** temperatures (approx. **0°C).** In one experiment, the subject had repeated bouts of apnea with the onset of wind exposure, **thus** the exposure was discontinued after 1.5 min. Consequently, the results from this subject were excluded from the statistical analysis (ANOVA, t-test).

RESULTS

The face cooled quickly in the first few minutes (Fig. 1); the average rate during the whole experiment was 2 to 3°C min^{-1}. The face skin temperature did not differ between conditions. As expected, the temperature of the earlobe (Fig. 1) was significantly lower without the cap than with the

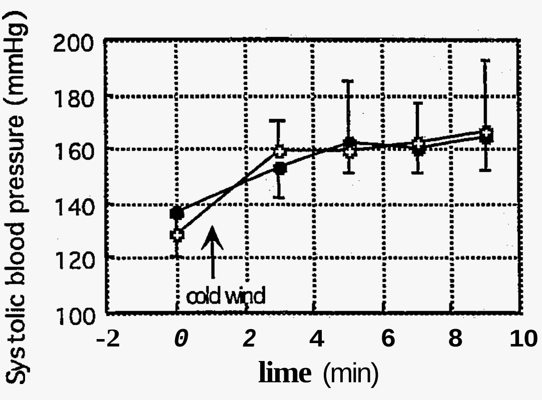

Figure 3. Systolic blood pressure in 4 seated sub-jects bareheaded (o) and with headgear (•) during exposure to -10°C and a 6 m·s^{-1} air stream blown in the face.

cap during the first 5 min of exposure. An increase in earlobe temperature in bareheaded subjects was observed at the end of the experiment (Fig. 1), most probably due to cold-induced vasodilatation (CND).

As the experiment proceeded, pain sensations were reported more frequently (Fig. 2); similar responses were observed even with headgear.

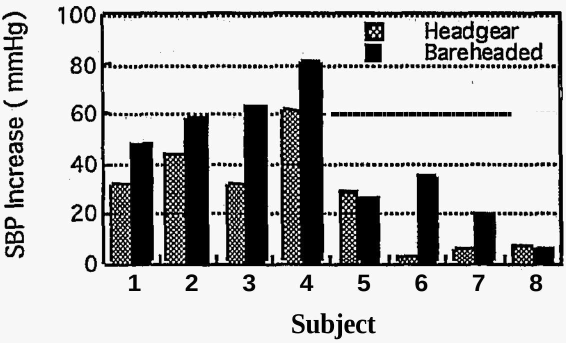

Figure 4. Increase in systolic blood pressure from pre-exposure to peak pressure in 8 seated subjects, bare-headed and with headgear, during exposure to -10°C and an air stream with a speed of 6 m·s^{-1} blown in the face.

Blood pressures increased immediately in response to cold wind and tended to increase further to a peak value after about 8 min (Fig. 3). The mean increase in SBP from the initial value to the peak value in cold wind (Fig. 4) was less with headgear than without (headgear: 26 mmHg, range 3 to 61; bareheaded 42 mmHg, range 6 to 81). DBP increased in cold wind by 4 to 30 mmHg in all but one of the experiments. SBP and DBP were not significantly different between conditions. Heart rates were not affected by the use of headgear. In half of the subjects (n = 4), heart rates decreased in the cold wind by 14 to 41 bpm, both bareheaded and with headgear.

DISCUSSION

At -10°C and 6 m·s^{-1}, WCI is 1450 W·m^{-2} and the "equivalent" temperature is 24°C. This is reported to correspond to "bitterly cold," but these conditions do not indicate risk for frostbite at any duration of exposure. The results of this study showed that skin temperatures at some spots reached almost 0°C in 25% of the cases. The earlobe was the critical local site in three experiments. Surprisingly, in one experiment the forehead was the first measured site on the head to reach 0°C. In this particular experiment, convective heat loss increased, possibly due to greater turbulence near the edge of the cap. This turbulence may have been due to a slightly different position of the cap or the head, relative to the wind.

The increase of earlobe temperature in bareheaded subjects at the end of the exposure was probably caused by CIVD. This response was initiated at temperatures below 10°C after fast cooling. However, the CIVD response was not observed in all experiments with fast cooling.

The individual blood pressure responses varied and were divided into four patterns (Fig. 4): (1) significant response with and without headgear, but stronger without (Subjects 1-4); (2) marked response in both conditions (Subject 5); (3) no response with headgear, but a marked response without (Subjects 6-7) and (4) no response in either condition (Subject 8). To investigate whether these response patterns are correlated with external factors, such as hair insulation and experience in the cold, a larger sample is needed.

CONCLUSIONS

Wearing headgear with ear protection reduced the cooling of the ears and pain sensations. However, there is a risk for developing cold injuries on the face or ears with a short-term exposure to 10°C and moderate air velocities ($6 m \cdot s^{-1}$), even with headgear. The systolic blood pressure response to cold wind was significantly reduced with headgear. Hence, wearing headgear may decrease the incidence of heart ischemia during the cold season.

REFERENCES

1. Stroud, M.A. 1991, Effects on energy expenditure of facial cooling during exercise, *European Journal of Applied Physiology*, **63, 376-380.**
2. Siple, P. A. and Passel, C. F. 1945, Measurements of dry atmospheric cooling in subfreezing temperatures, ***Proceedings of the American Philosophical Society*, 89, 177-199.**
3. Gavhed, D., Mäkinen, T., Holmér, I. and Rintamäki, H. 1997, Cardiovascular and thermal effects of cold wind in pre-cooled and thermoneutral subjects wearing cold-protective clothing, in Proceedings of the Symposium on Thermal Physiology. (Copenhagen: The August Krogh Institute), 183-186.