*Sixth Int. Conf. on Envir. Ergon.* *Montebello, Canada, Sept. 25-30, 1994* *eds. J. Frim, M.B. Ducharme & P. Tikuisis*

# EFFECTS OF DIFFERENT LEVELS OF INSULATION OVER THE EXTREMITIES AND FACE ON THERMOREGULATION IN COLD AIR

Graeme Maidment
Environmental Sciences Division
Royal Air Force Institute of Aviation Medicine
Farnborough, Hants, UK, GU14 6SZ

## INTRODUCTION

A number of studies (1-6) have provided evidence that excess insulation over the hands and feet may impair the normal thermoregulatory responses to a cold challenge. Furthermore, studies have also revealed a significant effect of facial cooling on metabolic responses (7,8). This paper describes a study which was performed to determine the effects of different levels of insulation over the extremities and face on thermoregulatory responses to cold air exposure.

## METHOD

9 healthy male subjects (age 27 - 43, height 1.63 - 1.85 m, weight 61 - 91 kg) were dressed in a common clothing assembly consisting of a flying coverall and underwear, and one of the following assemblies which differed in the amount of insulation afforded to the extremities and face:

Assembly A - 2 pairs of woollen socks and "Mukluks," 3 pairs of gloves, woollen balaclava
Assembly B - 1 pair of socks and thin leather boots, 1 pair of thin knitted gloves, woollen balaclava.
Assembly C - As for Assembly B, but with no face coverage.

They were exposed at rest to air at -12.5 +/- 1°C (airflow 0.65 +/- $0.15 m.s^{-1}$) for up to 2 hours wearing each assembly. Continuous recordings were made of rectal and auditory canal temperature, skin temperature and heat flux at 14 sites, distal finger and toe temperatures, and metabolic rate by indirect calorimetry. At the end of the exposure, the subjects were rewarmed by immersion in water at 37-40°C.

## RESULTS

A large number of subjects withdrew from the study during the second hour of exposure while wearing Assemblies B and C, due to pain in the hands and feet; to reduce bias, data from the first 60 minutes of the exposure only are considered. There was no significant difference in the rates of fall of core temperatures between different clothing assemblies. Mean rectal and auditory canal temperatures fell by 0.32°C and 0.61°C respectively over the course of the first 60 minutes. Oxygen uptake rose in all conditions (Figure 1), the rate of increase being greater with Assembly C than with the other assemblies ($p < 0.05$). Net heat loss was calculated from area-weighted heat flux data, metabolic rate and respiratory heat loss data. Contrast analysis revealed that net heat loss fell linearly with time, as shown in Figure 2. The net heat loss for Assembly C decreased more rapidly than for the other 2 assemblies ($p < 0.05$). Mean regional skin temperatures at time 0 and 60 minutes are shown in Table 1. Temperature changes were only significant at the regions where the insulation varied between assemblies.

| | ASSEMBLY A | | ASSEMBLY B | | ASSEMBLY C | |
|---|---|---|---|---|---|---|
| | t = 0 | t = 60 | t = 0 | t = 60 | t = 0 | t = 60 |
| FOREHEAD | 34.0(0.7) | 30.9(0.6) | 34.9(0.5) | 31.5(0.4) | 32.4(0.5) | 26.9(1.0)*** |
| HAND | 33.7(0.4) | 27.5(0.3) | 32.1(0.5)* | 16.1(0.8)*** | 32.2(0.3)** | 16.0(0.7)*** |
| FOOT | 30.5(0.7) | 26.0(0.7) | 30.7(0.7) | 22.0(0.7)** | 30.7(0.6) | 22.4(0.4)*** |
| UPPER LIMB | 32.1(0.2) | 25.5(0.6) | 32.6(0.4) | 26.5(1.7) | 32.8(0.3) | 25.8(0.8) |
| TORSO | 32.5(0.2) | 26.4(0.7) | 32.2(0.5) | 27.8(1.0) | 32.0(0.4) | 27.3(0.6) |
| THIGH | 32.0(0.2) | 27.5(0.6) | 32.4(0.4) | 29.4(0.8) | 32.5(0.3) | 28.8(0.8) |

Table 1. Regional mean (SEM) skin temperatures ("C) at time 0 and 60 minutes. *, ** and *** denote significant differences from the Assembly A results, at the 5%, 1% and 0.1% levels respectively (unpaired t-test).

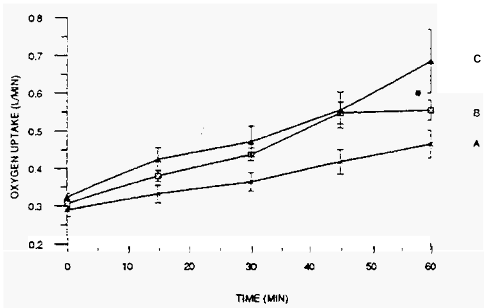

FIGURE 1. MEAN OXYGEN UPTAKE FOR ALL SUBJECTS, 3 CLOTHING ASSEMBLIES.

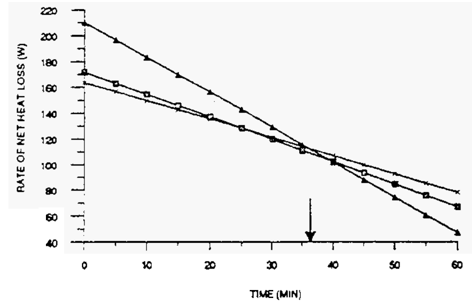

FIGURE 2. MEAN RATE OF NET HEAT LOSS FOR ALL SUBJECTS

## CONCLUSIONS

This study provides further evidence that insulating the peripheries or the face compared with more proximal areas of the body can alter the thermoregulatory responses to cold air exposure. The effect appears to be greater for the face than for the hands and feet and, in contrast to previous studies (1,2,5), seems to modulate metabolic rate to a greater degree than the vasoconstrictor response, as inferred from surface heat loss. Core temperature fell similarly during each condition. There was a high level of agreement between the *total* heat debt for Assemblies A and B. The rate of change of heat loss was greater when the face was exposed (Assembly C) and, using the linear prediction, the total heat loss would have been less for this assembly than for the others after approximately 37 minutes (Figure 2). However this linear representation is inappropriate for longer durations of exposure as the metabolic rate would not continue to increase linearly with time. This study used a more morphologically diverse group of subjects than those studies which have shown an effect on core temperature (2,4), and it is possible that the diversity of response would mask an effect which would be more apparent in consistently thin subjects. Although there appears to be a slight thermal disadvantage to having higher levels of insulation over the peripheries, this is not reflected in the core temperature, and the increased comfort afforded by the extra insulation almost certainly outweighs any small penalty in terms of heat balance. The importance of the face in thermoregulatory control in the cold is supported by these data.

## REFERENCES

1. Choi J. K., Park Y. S., Park Y. H., Kim J. S., Yeon D. S., Kang D. H., Rennie D. W. and Hong S. K. 1988, Effect of wearing gloves on the thermal balance of Korean women wet-suit divers in cold water. Undersea *Biomed. Res.* 15(3):155-164.

2. Jeong W. S. and Tokura H. 1988, Effects of wearing two different forms of garment on thermoregulation in men resting at 10°C. *Eur. J. Appl Physwl.* 57:627-631.

3. Jeong W. S. and Tokura H. 1989, Effects of wearing two different types of clothing on body temperatures during and after exercise. *Int. J. Bwmeteorol.* 33:77-81.

4. Jeong W. S. and Tokura H. 1993, Different thermal conditions of the extremities affect thermoregulation in clothed man. *Eur. J. Appl. Physwl.* 67:481-485.

5. Park Y. S., Kim J. S., and Choi J. K. 1992, Increase in heat loss by wearing gloves and boots in wet-suited subjects working in cold water. *Ann. Physiol. Anthrop.* 11(4):393-400.

6. Veghte J. H. 1962, Human physiological response to extremity and body cooling. *Aerospace Med.* 33:1081-1085.

7. Riggs C. E., Johnson D. J., Kilgour R. D. and Konopka B. J. 1983, Metabolic effects of facial cooling in exercise. *Aviat. Space and Environ. Med.* 54(1):22-26.

8. Stroud M. A. 1990, Effects on energy expenditure of facial cooling during exercise. RAF IAM Report No. 698.