REGIONAL CUTANEOUS THERMOSENSITIVITY: ITS SIGNIFICANCE IN THE DESIGN OF THERMAL PROTECTIVE CLOTHING

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INTRODUCTION

The hyperpnea observed at the onset of cold water immersion, termed gasping (4), appears to be the result of a neurogenic drive from the cutaneous cold sensors. Thermoreceptors in the skin have been assigned a major role in autonomic thermoregulation in humans, but their population density over the body surface is not known. If thermoreceptors are distributed evenly, and if their sensititvity is equivalent, then a given thermal stimulus will elicit a similar response from all skin regions. Conversely, differential cutaneous thennosensitivity would suggest that the design of thermal protective suits should offer more insulation to regions with greater thermosensitivity, and thus a greater contribution to the gasping response.

Gasping at the onset of accidental cold water immersion increases the risk of aspirating water (1). Thermal protection offered by clothing will reduce the gasping response (2), and thus the risk of immersion drowning. Thermal protective suits for occupations at high risk of cold water immersion incorporate either the wet or dry suit principle: dry suit designs normally incorporate material with less insulative properties, and though such suits may be beneficial in reducing the gasping response, they may not provide as much thermal protection as a wet suit design (3).

METHODS

Differential cutaneous sensitivity to cooling was assessed by observing the gasp response, while separately exposing four discrete skin regions to 15°C water during head-out immersion. Seven male subjects, ranging in age from 20 to 33 yrs., in height from 177 to 184 cm., and in weight from 70 to 77 kg., participated in the present study. They were accepted on the basis of having physical dimensions within one standard deviation of a student population mean, as determined by the CANREF study (5). All subjects were familiarised with the test procedure and the possible risks associated with the trials. The experimental protocol utilised was approved by the Simon Fraser University Ethics Review Committee.

Subjects were requested to participate in a total of 10 head-out immersions: 5 immersions in 15°C water (COLD) and 5 matching immersions in 34°C water (CONTROL). During both COLD and CONTROL trials, subjects were immersed to the sternal notch in four conditions of partial exposure, plus one condition of whole body exposure. Partial exposure of the skin was achieved with a modified neoprene dry suit, allowing exposure to the water of either the arms, upper torso, lower torso, or legs, while keeping the unexposed skin regions thermoneutral.

Tha gasp response was quantified with the technique of mouth occlusion pressure described in detail elsewhere (2, 6). Briefly, the mouth pressure at 100 msec. (P0.1) following an occluded inspiration was recorded with a differential gas pressure transducer (Model 270, Hewlett Packard), connected to an AC carrier preamplifier (Model 17403A, Hewlett Packard), and the pressure signal filtered with a 1KHz low-pass filter (3rd order). The resultant signal was recorded on an oscillographic chart recorder (Model 7404A, Hewlett Packard). During the 5 minute rest and 5 minute immersion period, skin temperature was recorded from 19 sites with copper/constantan thermocouples. In addition, bath temperature was monitored with a YSI 701 thermistor (Yellow Springs Intruments Co.), and electrocardiograms were monitored for any irregularites.

The total skin area (SA) exposed during each trial was estimated by representing the body as a combination of geometrical shapes (7).

RESULTS

The differences between immersion and resting P0.1 values (ΔP0.1) were determined for every second inspiration. The integrated ΔP0.1 response during the first minute of immersion ($\int\Delta$P0.1) was considered indicative of the gasp response to the cold stimulation of the exposed skin surface area. Hydrostatic pressure effect was taken into account, by obtaining the difference in the $\int\Delta$P0.1 values between COLD and CONTROL immersions for each exposure condition. Finally, a thermosensitivity index (TSI) of each exposed area was determined by adjusting for the estimated exposed surface area and the decrease in average temperature of the exposed region **(AT).**

Results indicated that the highest PO.1 values were elicited from complete exposure, followed in descending order by the exposure **of** the upper torso, legs, lower torso, and arms. Correcting the PO.1 response for differences in SA and **AT** between regions, indicated that TSI for the upper torso was significantly higher than the indices for the arms, legs, but not significantly higher than the lower torso index. The TSI for bod the upper and lower torso were higher, albeit not significantly, than the TSI for the whole body exposure.

CONCLUSIONS

Gasping at the onset of cold water immersion appears to be a valid indicator of regional cutaneous thermosensitivity to cooling, because stimulation of select skin regions elicited a measurable response. Present results are in agreement with the findings of Keatinge and Nadel (8), who reported that the upper torso is more sensitive to cooling than either the arms or legs. The ventilatory measurements **of** Tipton and Golden (9) observed during exposure of either the limbs or torso may underestimate the gasp response (2), and may explain the disparity between their observations and the present findings. Namely, their **findings of** equivalency in themosensitivity of the torso and limbs is in disagreement with the ranking predicted by averaging d e indices of the subregions, in both the present study and the earlier report of Keatinge and Nadel.

The equivalency of the sum of the regional responses to the whole body exposure responses suggests that regional thermoafferent signals interact in an additive manner, which agrees **with** the concept that, the *sensitivity* **of** a thermoregulatory response is *equivalent* to the *sum* of *peripheral* and central thermosensitivities **(10).**

Any method which retards the immediate cooling of the skin, will likely enhance survival by reducing respiratory distress. Present findings suggest that for those individuals at risk, who are unable to use complete survival suits, or to enter the water slowly, the most efficient protection against cold water immersion drowning may be a close fitting suit or life-jacket designed to provide not only flotation, but also thermal insulation of the torso. Conversely, there was–a tendency for the TSI of the arms and legs to be lower *than* that of the whole body.

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REFERENCES

1. Keatinge, W.R., Prys-Roberts, C., Cooper, K.E., Honour, **A.J.** and Haight, J., Sudden failure of swimming in cold water. Brit. Med. J., 1: 480 - 483,1969.
2. Mekjavic, I.B.. La Prairie, A., Burke, W. and Lindborg, **B.,** Respiratory drive during sudden cold water immersion. Respir. Physiol., 70: 121 - 130, 1987.
3. Mekjavic, **I.B.** and Sullivan, P.J., Constant wear thermal protection garments for helicopter personnel. In Environmental Ergonomics, edited by I.B. Mekjavic, E.W Banister and J.B. Morrison, pp 240 - 263, London: Taylor and Francis, 1988.
4. Cooper, K.E., Martin, S. and Riben P., Respiratory **and** other responses in subjects immersed in cold water. J. Appl. Physiol., 40: 903 - 910, 1976.
5. Ross, W.D. and Marfell-Jones, M.J., Kinanthropometry. In Physiological Testing of the Elite Athlete, edited by J.D. MacDougall, **E A.** Wenger and H.J. Green, pp 75 - 117, Ottawa: Mutual, 1982.
6. Lind, F.G., Truve, A.B., and Lindborg, B.P.O., Microcomputer-assisted on-line measurement of breathing pattern and occlusion pressure. J. Appl. Physiol., 56: 235 - 239,1984.
7. Katch, **V.,** Weltman **A.** and **Gold,** E., **Validity** of anthropometric measurements and the segment-zone method for estimating segmental and total body volume. Med. Sci. Sports, 6: 271 - 276,1974.
8. Keatinge, W.R., and Nadel, J.A., Immediate respiratory response to sudden cooling of the *skin.* J. Appl. Physiol., 20: 65- 69, 1965.
9. Tipton, M.J. and Golden, F.St.C., The influence of regional insulation on the initial response to cold immersion. Aviat. Space Environ. Med., 58: 1192 - 1196,1987.
10. Simon, E., Pierau, F.-K. and Taylor, D.C.M., Central and peripheral thermal control of effectors in homeothermic temperature re–dation. Physiol. Rev., 66: 235 - 300, 1986.