EFFECTS OF THERMAL PROTECTIVE AID ON BODY COOLING IN COLD AND WINDY WEATHER

R. Ilmarinen, E. Kähkönen & T. Seppälä
Institute of Occupational Health
Helsinki, Finland

INTRODUCTION

The fact that hypothermia is a major lethal risk, besides drowning, for a victim of maritime hazards while immersed in water is well accepted. However, it may still be a serious problem after the victim has managed to enter a lifeboat or craft, especially if his clothes are wet. The international regulations of SOLAS-74 from November 1984 introduce the requirements for ***life-saving appliances* (1).** A passenger ship shall carry for each lifeboat on the ship a thermal protective aid for every person to be accommodated and not provided with an immersion suit. There are no specific tests for the thermal protective qualities of thermal protective aids. It should only be demonstrated by the fabric test that the material has a thermal conductivity of not more than 0.25 W/(mK) and a thermal aid shall be so constructed that when used to enclose a person, it shall reduce both the convective and evaporative heat loss from the wearer's body. However, the information about the effects of any thermal protective aid on body cooling and potential survival time in accidental cold exposure is scanty.

The objective of the study was to evaluate the effects of a thermal aid, approved for survival crafts in Finland, on body cooling in cold and windy conditions.

METHOD

A mummy-shaped thermal aid (TA), made of wind- and waterproof non-woven olefin fabric, TWEK, with a metallized, heat reflective inside was selected for testing and studied in conjunction with standard test clothing (C) with a thermal insulation I_{cl} of 1 clo.

Four medically screened men and two women volunteered (Table I) as subjects after being fully informed of the experimental protocol and associated risks. The experiments were conducted in a climatic chamber according to the principles of the Declaration of Helsinki, which governs ethical human experimentation. Each subject was studied in random order once in each of the test configurations **i.e.,** Cdry+TA, Cwet+TA, Cdry, and Cwet at an air temperature of -14°C **(±0.5°C)** with a turbulent air velocity of 6 to 10 m/s. Two subjects were exposed simultaneously and they were instructed to sit as still as possible on a thin disposable paper blanket placed on the floor of the chamber. The exposure time was 2 hours, except for the control trial Cwet, which was scheduled for 1 hour. The minimun time interval between the trials for a given subject was one week in order to minimize the acclimation effect.

The continuous monitoring included ECG, heart rate, rectal temperature (Tr) at a depth of 10 cm, and skin temperatures (Tsk) at nine sites. Subjective evaluations of thermal sensation and comfort as well as perceived exertion (RPE) were requested every 30 minutes. The termination criteria were Tr **35°C,** any Tsk <10°C for more than 30 min, severe muscle cramps, irregularities in cardiac function, the subject's own request, and the supervisor's decision.

Table I. Characteristics of the subjects

Sex	N	Age (yrs)	Height (cm)	Weight (kg)	A_{Du} (m^2)	Body Fat (%)	$\dot{V}O_2$ ($ml \cdot kg^{-1} min^{-1}$)
Female	2	14–39	164–166	54–63	1.58–1.66	22.0–25.0	39.6-46.5
Male	4	34–49	168–187	57–78	1.66–2.03	9.6–12.9	47.7–63.0

RESULTS

None of the exposures was terminated prematurely. The lowest individual Tr value of 35.5°C was registered in a trial of Cwet. In this particular case ***after drop*** during the recovery resulted in a Tr drop to 34.6°C. The mean drop in Tr was 0.65°C for Cwet, 0.35°C for Cwet+TA, 0.30°C for Cdry, and 0.15°C for Cdry+TA during the first 60 min. In 2 hours Tr decreased 1°C in Cwet+TA, **0.9°C** in Cdry, and **0.6°C** in Cdry+TA on average.

The mean skin temperature ($\bar{T}sk$) decreased by 7.0°C in Cwet, 4.0°C in Cwet+TA, 3.5°C in Cdry and 2.0°C in Cdry+TA on average during *the* first hour, and the changes in 2 hours were 6.7°C for Cwet+TA, 4.0°C for Cdry, and 3.0°C for Cdry+TA. The lowest skin temperatures were measured in the extremities, even as low as 3 to 4°C for the toes at the end of exposure. In Cwet and Cdry also the Tsk of the upper arm, thigh and calf fell rapidly to about 15 to 20°C. The Tsk for the lower back, shoulder, and abdomen was more affected by postural temperature regulation (cramped sitting and leaning on each others).

Mean body temperature ($\bar{T}b$) drop was about the same for Cdry and Cwet+TA in two hours (3.9°C) and for Cwet (3.8°C) in one hour. In Cdry $\bar{T}b$ decreased slower, 2.9°C in 2 hours (Fig. 1). The greatest heat loss (Wm^{-2}) in first 60 minutes on average was measured for Cwet, in which the individual responses differed the most. The individual rates of change in heat storage varied from 67 to 236 Wm^{-2}. Also in Cdry mean body heat loss was greater (107 WM^{-2}) than in Cwet+TA and in Cdry+TA, which resulted in about the same (80 Wm^{-2}) heat loss on average.

There were no differences between Cdry and Cwet+TA in the average ratings of thermal sensations. Both conditions were perceived *slightly cool* at the beginning and cold at the end of exposure. Cdry+TA was perceived the warmest and least uncomfortable condition. Individual variation in thermal votes was great, but all the subjects rated Cwet as the coldest and the most uncomfortable condition. In a few Cwet trials some subjects reported their condition as *intolerable* at the end of the exposures.

Cdry+TA was perceived the least strenuous condition on average (Fig. 2). Cdry and Cwet+TA were rated more strenuous, but the differenses in mean votes for those two conditions were small. Violent shivering and painful feelings of cold resulted in the perception of Cwet to be the most strenous condition.

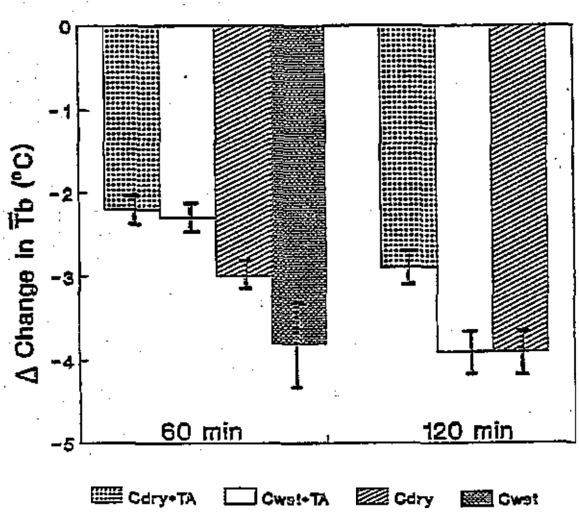

Fig. 1. Mean body temperature change in 60 and 120 minutes (X±SEM)

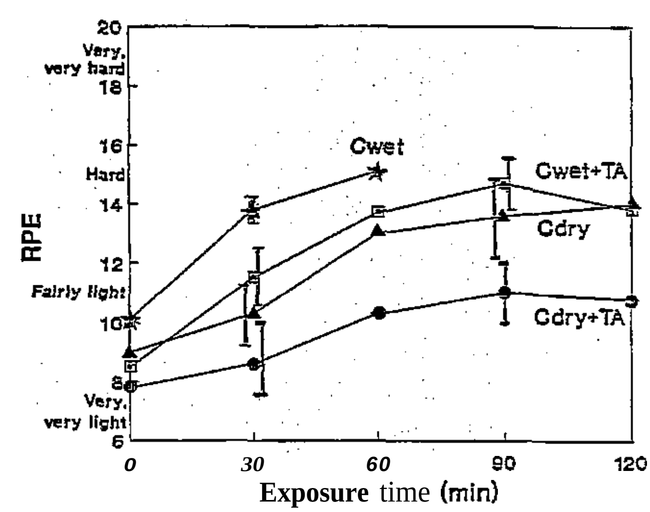

Fig. 2. Repeated perceived exertion (RPE) for each test configurations (X±SEM).

CONCLUSIONS

The results indicate that the wind- and waterproof thermal protective aid with a heat reflective inside is not sufficient to maintain the thermal balance of a lightly clad victim in cold and windy conditions. However, it provides protection which could extend survival time significantly in accidental exposure to cold and windy weather. The protective effects are most notable for persons in wet clothes.

REFERENCES

1. International Maritime Organisation (IMO): International Convention for the Safety of Life at Sea. IMO, The Bath Press, London, 1986.