THERMAL BALANCE OF DIVERS DURING SIMULATED COLD WATER DIVES IN AN ATMOSPHERIC DIVING SUIT

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INTRODUCTION

Atmospheric diving suits (ADS) have been developed to eliminate the hazards associated with exposure of divers to hyperbaric environments. The ADS manufactured by International Hard Suits (North Vancouver, British Columbia, Canada), and commonly known as the "Newtsuit", is made of cast aluminium and has frictionless swivel joints. The operational depth of the suit is 300 meters and the normal operating time of divers is 6 hours. The ambient pressure within the suit is maintained at 1 ATA, though negligible changes (±1 psi) in cabin pressure may occur due to the imbalance of oxygen consumption and delivery, and/or carbon dioxide production and scrubbing.

Although the suits have been deployed in Arctic waters and are being considered for routine service in the North Sea, extensive evaluation of divers' thermal balance has only been conducted for dives in 20°-30°C water (1,2). The present study investigated the effect of simulated cold water dives (4° - 6°C) on the thermal balance of Newtsuit divers.

METHODS

Four subjects participated in the study, having given their voluntary informed consent. The study was approved by the Institutional Ethics Review Committee.

Subjects were familiarised with the operation of the Newtsuit (International Hard Suits, North Vancouver, British Columbia, Canada). They were instrumented with thermocouples, placed at the arm, chest, thigh and calf, for the measurement of skin temperature. Mean skin temperature was derived from the unweighted average of these measurements. Core temperature was assessed with a YSI 701 rectal thermistor inserted 15cm.

Once instrumented, the subjects donned appropriate apparel. They wore long underwear (50% polyester, 25% cotton and 25% wool) and a model RF 45 worksuit (manufactured by Ocean Bottoms-Mountain Tops). The latter consisted of a Chinilla® liner, Texolite® and Thinsulate® insdative layers, with a Supplex® outer shell. A Goretex® coverall (M.E.T.A. Research, Vancouver, Canada) was donned over the garment assembly, and synthetic gaitors were added to the arms and legs. to prevent possible deterioration of the Goretex® due to potential leakage of oil from the swivel joints.

Subjects were assisted into the suit, suspended on a platform above a rank of water. Upon completion of the regular pre-dive checks. the suit was sealed and immersed in the water maintained at 4°-6°C.

RESULTS

All subjects reported some thermal discomfort, predominantly in the extremities. In all trials, cabin temperature decreased rapidly to levels slightly above the water temperature. Relative humidity increased to 90% within 5 minutes of the immersion.

A representative response of skin and rectal temperature for one subject is presented in Figure 1. Tsk was maintained at approximately 32°C, whereas Tre decreased to 36.74°C from 37.03°C. The magnitude of core cooling experienced by all subjects did not exceed 1.0°C (Table 1).

Table 1: Subjects' physical characteristics and decrease in Tre (ATre) and Tsk (ATsk) during the 6 hour immersion with the ADS in 4° - 6°C water.

Subject	Mass (kg.)	Sum of 4 skinfolds† (mm)	ATre (°C)	ATsk (°C)
1	71.8	31.0	0.29	1.7
2	70.0	41.0	1.00	7.2
3	70.0	42.0	0.00	1.2
4	58.8	39.5	0.29	4.8

† Triceps. subscapular. supraspinale, calf

DISCUSSION

The Newtsuit ADS is used for a variety of tasks. Consequently, the activity level of divers may vary from resting, for simple surveillance and inspection, to moderately heavy work for other tasks where active diver intervention is necessary. The present study simulated the condition of a diver conducting inspection type activity in cold water operations. In terms of thermal balance, this condition would not be considered the most optimal, due to low levels of metabolic heat production.

The results depicted in Fig. 1 indicate that the cold and high humid environment of the ADS's microenvironment. coupled with the high thermal conductivity of the cast aluminium shell establishes a

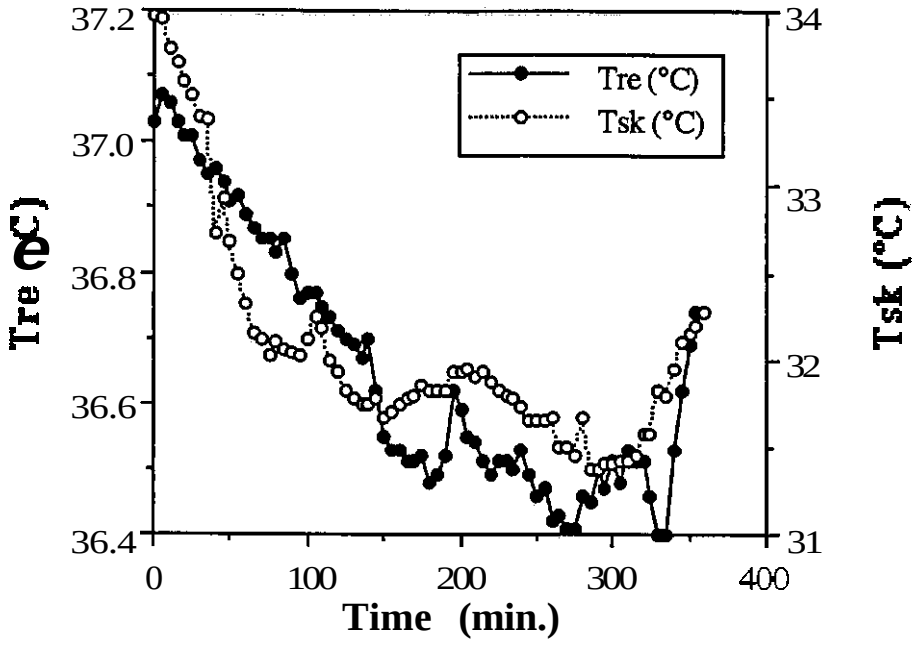

Fig. 1: Tre and Tsk responses of subject 1 during a simulated 6 hour dive in 4 - 6°C water.

high heat loss inducing environment, resulting in substantial core cooling of the diver. Though heat flux from the skin snrface was not measured, the high levels of skin temperature would suggest a high heat flux.

The Tre response varied for the subjects, exhibiting a return towards pre-immersion levels in some. It is probable that in such circumstances, shivering thermogenesis was initiated, although subjects did not report any significant shivering tremor during the immersion. It may be concluded, that in the circumstances of the present study, and particularly with the garment assembly used, the microenvironment within the snit did not cause cooling of the divers to levels which would be considered potentially hazardous. However, the ability to maintain thermal balance may be compromised, if the diver's activity level is sufficiently high to instigate sweating and consequently reduce the insulative value of the garment layers.

In conclusion, for cold water dives in which divers' activity levels are near resting, the magnitude of core cooling over a six hour period is below levels considered potentially harmful. Thermal balance in such situations appears to be attainable, especially with an appropriate garment assembly providing adequate insulation and a water vapour banier.

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