SIMULATION OF ROUGH SEAS IN A WATER IMMERSION FACILITY: PART II - COMPARISON OF LABORATORY TO FIELD DATA

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INTRODUCTION. To examine the effects of rough compared to calm seas on human thermal responses to cold water immersion, two unique field evaluations were previously conducted by the U.S. Coast Guard (1, 2). Testing was conducted in a river in the Northwestern U.S., when water temperatures averaged 6-11°C. In these studies, body cooling rates with wet suit garments were L5 to 2.0 times faster in rough compared to calm seas. To Simulate the cooling effect of rough seas in the laboratory, the Navy Clothing and Textile Research Facility has evaluated a number of techniques utilizing compressed air and water surface current to create turbulence in a water immersion tank. Initial work was conducted on a thermal manikin to compare eight methods of water agitation for their effectiveness in reducing the thermal insulation (clo) of an anti-exposure garment. A diffuse compressed air methodology was found to be both effective in reducing thermal insulation and practical for routine laboratory use. To evaluate the validity of this technique, human testing was then conducted both in the laboratory and during a rough seas field evaluation.

METHODS. Eight male subjects (age, 25 yr; ht, 175 cm; wt, 68 kg; body surface area, 1.8 m^2; body fat as determined by hydrostatic weighing, =%) underwent a total of nine, 90-minute cold water immersions. Three immersions were conducted in an Atlantic Ocean inlet, with the subjects wearing a) a closed-cell foam jacket with beaver tail (loosely-fitted, wet suit concept), b) a closed-cell foam coverall (also loosely-fitted, wet suit concept), and c) the coverall over a tightly-fitted, shorty wet suit. Both water and air temperatures averaged 10°C; wind averaged 4 m/s wind. The subjects were tethered via a safety harness to a nearby pier. A Coast Guard vessel was used to create a 1.2-m breaking wave over the subjects approximately once every 50-60 seconds. Following the field testing, the same subjects participated in six immersions in the laboratory immersion tank. The environmental conditions measured during the field testing were duplicated in the laboratory. To create water turbulence, compressed air was released from Lines located at the bottom of the pool. During the six laboratory immersions, the amount of compressed air and the subject's position in the water were varied. Two garments - the beaver-tail jacket and the coverall - were evaluated. For both field and laboratory evaluations, exposures were terminated when rectal temperature decreased to 35°C or the subject or medical monitor requested termination because of severe cold discomfort.

RESULTS. Field Testing. After the first 20 minutes of water immersion, the decrease in rectal temperature was greater with both the jacket and the coverall than with the coverall/shorty wet suit combination ($p<0.05$). By 40 minutes of immersion, the decrease in rectal temperature with the jacket was also greater than with the coverall ($p<0.05$). The decrease in rectal temperature after 50 minutes averaged 0.6, 1.3, and 1.9°C with the coverall plus shorty wet suit, coverall, and jacket, respectively. (Note: Because of the significantly reduced tolerance time when the jacket was worn, physiological responses for all three ensembles were statistically analyzed only up until 50 minutes of exposure.)

Laboratory Testing. During the first hour of water immersion, there were no significant differences in the rectal temperature response between the coverall and the jacket ($p>0.05$). From 70 minutes on, the decrease in temperature was greater with the jacket than with the coverall ($p<0.05$). After 90 minutes, the decrease in temperature averaged 1.2°C with the coverall and 1.6°C with the jacket. Comparison of Field and Laboratory Data. With one exception, *the* methods used to simulate rough seas in the laboratory resulted in slower body cooling **rates** than those obtained during field testing. When the beaver-tail jacket was worn, the decrease in rectal temperature after 60 minutes of immersion averaged 1.1°C in the laboratory compared to 2.6°C in the field. When the coverall was worn, the decrease in rectal temperature after 80 minutes averaged 1.0°C in the laboratory and 1.9°C in the field. The one laboratory technique which reproduced the field results utilized the maximum amount *of* compressed air and created a geyser effect **about** the subject's head. Because *this* technique caused an unacceptable risk of water aspiration, it was not considered feasible for continued use.

RESULTS OF FURTHER TESTING. Modifications were made to the rough sea simulator and further thermal manikin and human testing was conducted The modified methodology combined compressed air with a water surface current. The cooling rates that resulted using this technique, however, were generally lower than desired. In addition, duplicate ***tests*** demonstrated that reproducibility of the data was poor. When the **test** with the coverall was repeated, the decrease in rectal temperature after 50 minutes of immersion averaged only 0.6°C, compared to 1.3°C for the previous immersion. It was hypothesized that the subjects learned after the first exposure to **reduce** the flushing of water through the neck seal by holding **the** back ***of*** their necks more tightly against the life jacket

CONCLUSIONS. While using water surface current and/or compressed air to agitate **the** water in a laboratory immersion tank results in a faster cooling *rate* than *calm* water testing, these techniques may not duplicate the **cooling** effects of **actual** rough ***seas.*** This may be because actual waves **cause** a *greater* degree ***of* flushing *of*** water through the garments' *seals* and/or a greater heat loss from the head. To simulate the cooling effect of actual waves and *currents*, a laboratory technique which involves periodically dunking the subject may be required.

REFERENCES

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