Effect of Pressure on Heating and Cooling Requirements for Thermal Protection of Wet-suited Divers

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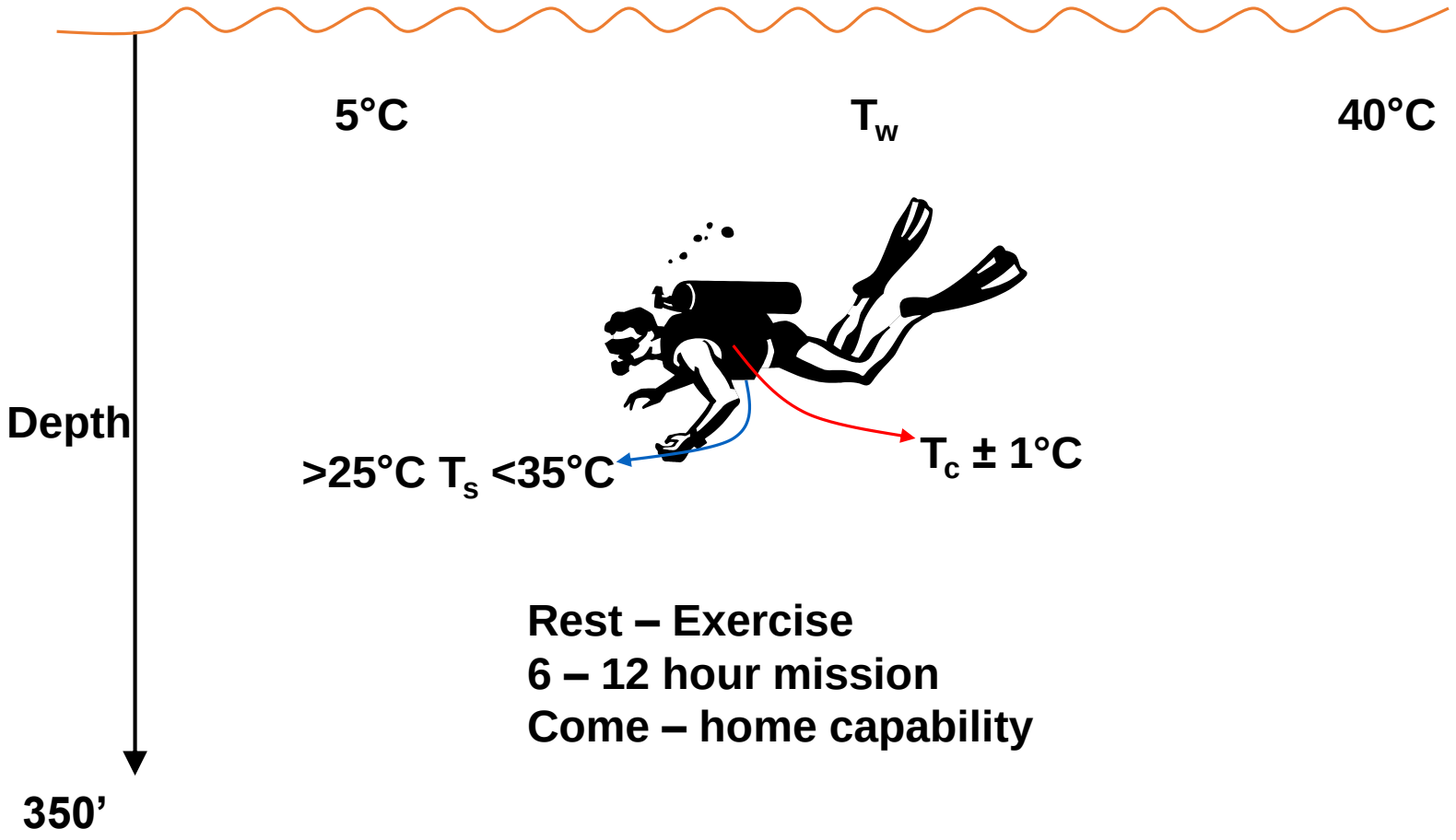
Project AIM: To minimize the impact of thermal issues in dive planning
PURPOSE: To engineer, build and test a Diver Thermal Protection System (DTPS). Also to develop its use as a total body and regional calorimeter

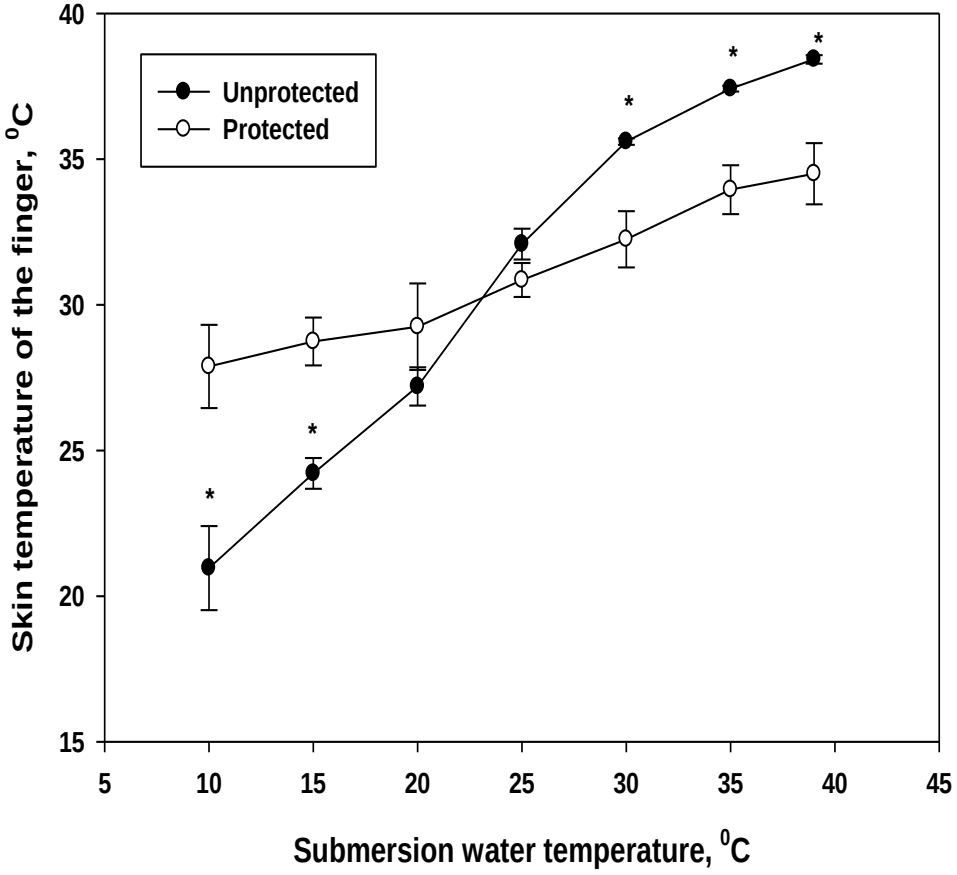


Diver Thermal Protection SystemDesign

Use as total body-regional calorimeter

Delta P (output – return T) times flow rate = power to protect the diver

Diver Thermal Protection with DTPS



- n = 8 male divers
- 6.5 mm wet suit
- Swimming
  - 2.0 l/min
  - 3.0 hrs
- Unprotected did not protect in either cold (hand/feet) or hot (core) water
- Protected maintained Tcore at 37°C and Tskin >25°C and <35°C

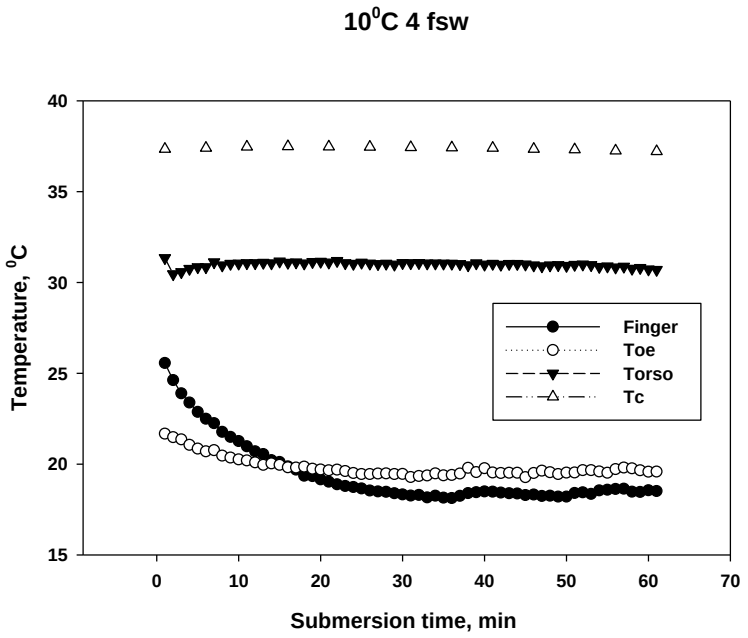
Introduction

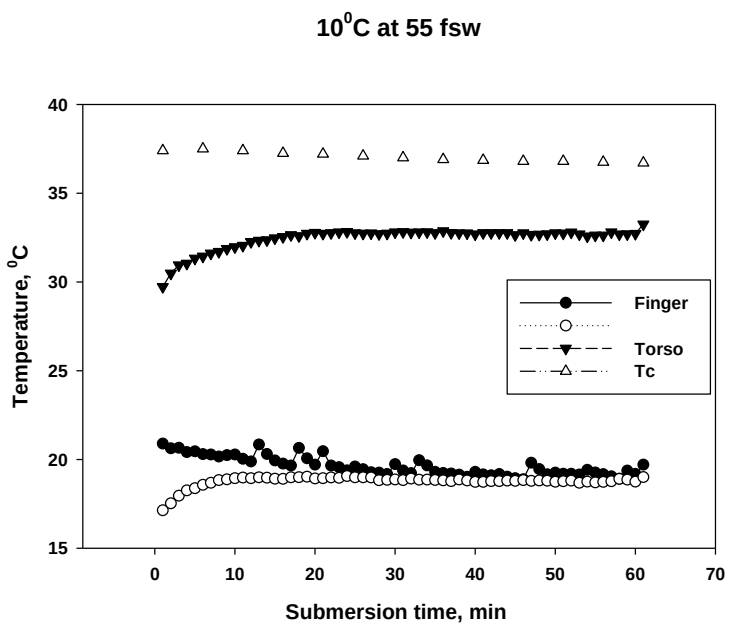
- Diving is often carried our in water temperatures above and below the temperature that is thermally neutral. Insulation plays an important role in thermal regulation, particularly in water where heat loss due to convection is very high. For diving, foam neoprene is the insulation currently used in the construction of wetsuits. Foam neoprene is a closed cell elastomeric foam.
- The rubber component of the foam is typically neoprene rubber, or polychloroprene (thermal conductivity, k_r = 0.100-0.192 W/(m-K), [1-5]) and the gas component is nitrogen or air (k_g= 0.026 W/(m-K), [6]). The entrapped nominally stagnant gas within the neoprene rubber results in a lowered thermal conductivity of the rubber. Convection in the cells is typically insignificant due their small size.
- When a diver submerges, the gas cells compress with increasing depth, which increases the thermal conductivity and thermal resistance as a function of depth.
- Previous studies have directly measure the thermal properties of foam neoprene insulation under hydrostatic pressure using a custom built thermal conductivity meter placed inside a spherical hyperbaric chamber.
- The purpose of the present study was to determine the effect of hydrostatic compression of a 6.5 mm wet suit on the power required to maintain thermal balance of divers down to a depth of 120 fsw in a hyperbaric chamber.

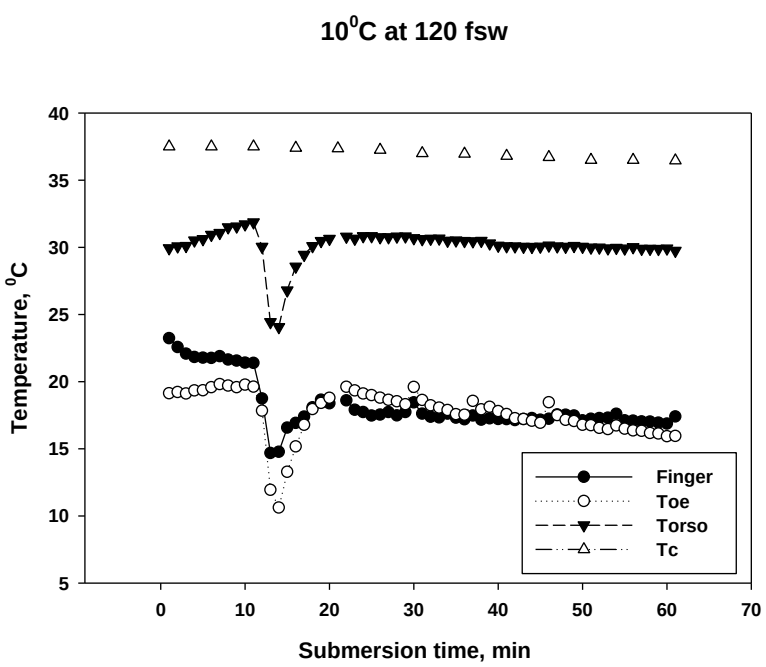
Methods

- 8 experience male divers completed experiments at 4, 55 and 120 fsw in a hyperbaric chamber submersed in water with temperatures from 10 to 39 degrees C.
- Subjects were submersed while resting and then fin swam for one hour (50% VO2 max.).
- Subjects breathed air from a simulated scuba set-up with -15 cm static lung load.
- Skin and the inlet and outlet temperatures of the DTPS were measured continuously (thermistor), as was core temperature (Ingestible pill).
- Data were collected via BioPac and analyzed by computer.
- Statistics were compared by ANOVA for repeated measures

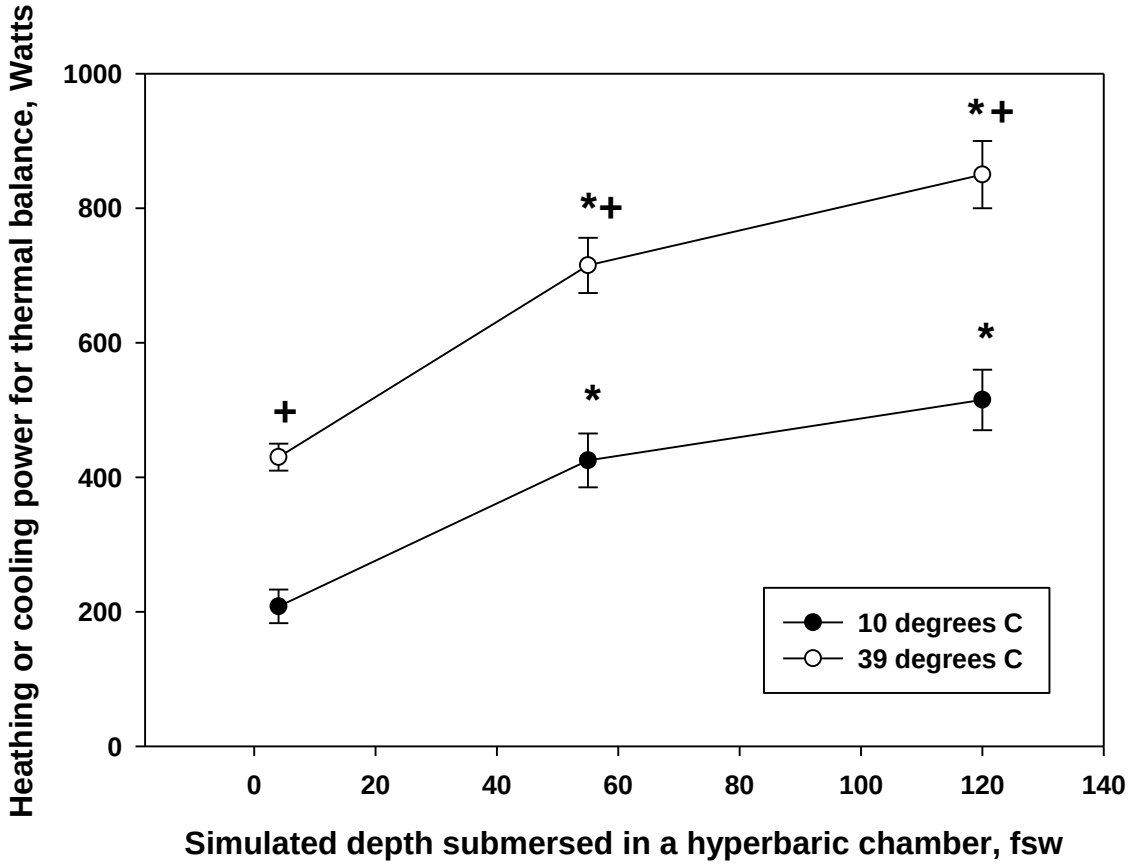
Results: Diver Thermal Protection at Depth







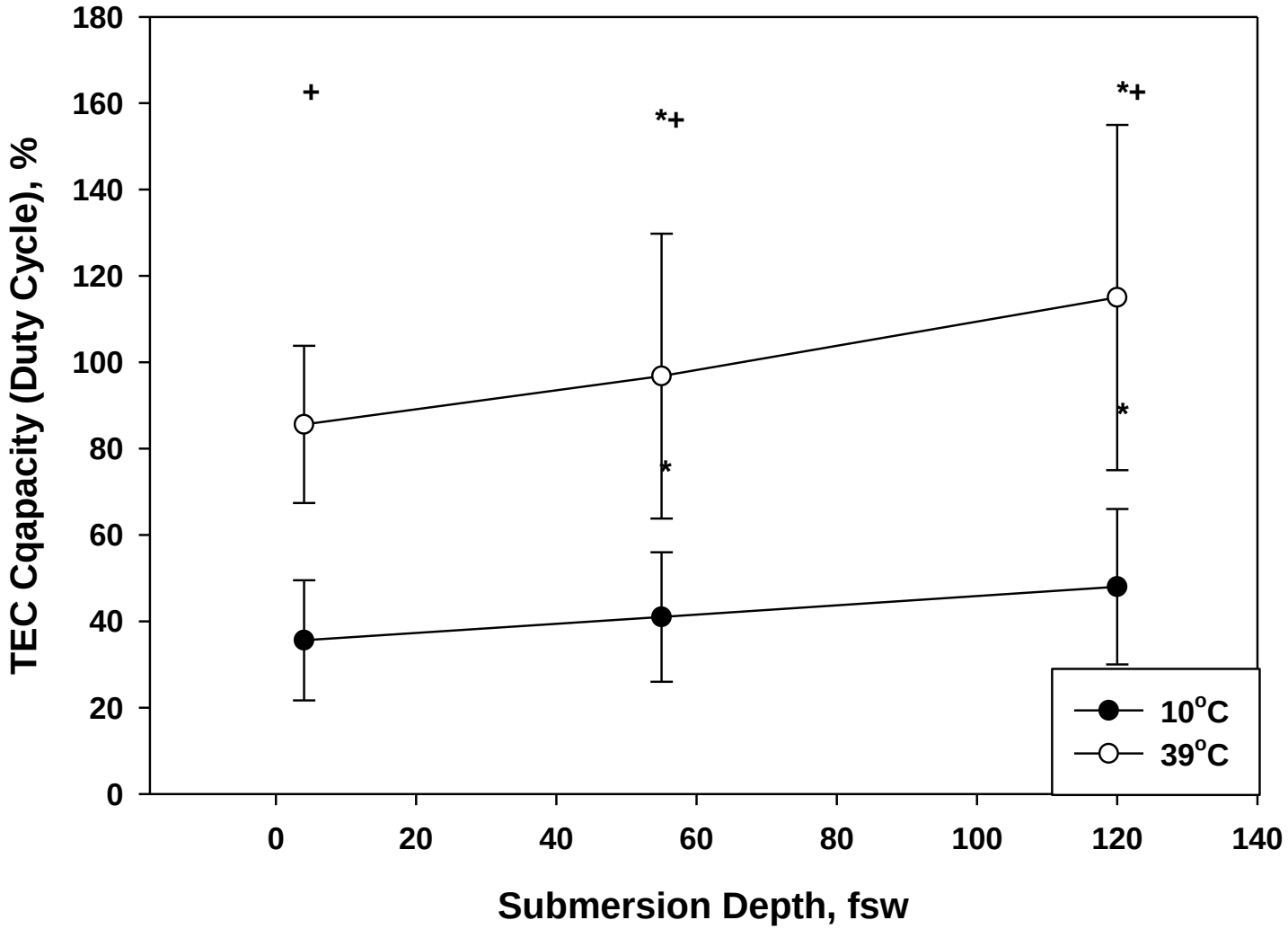
Effect of submersed depth on power to maintain thermal balance



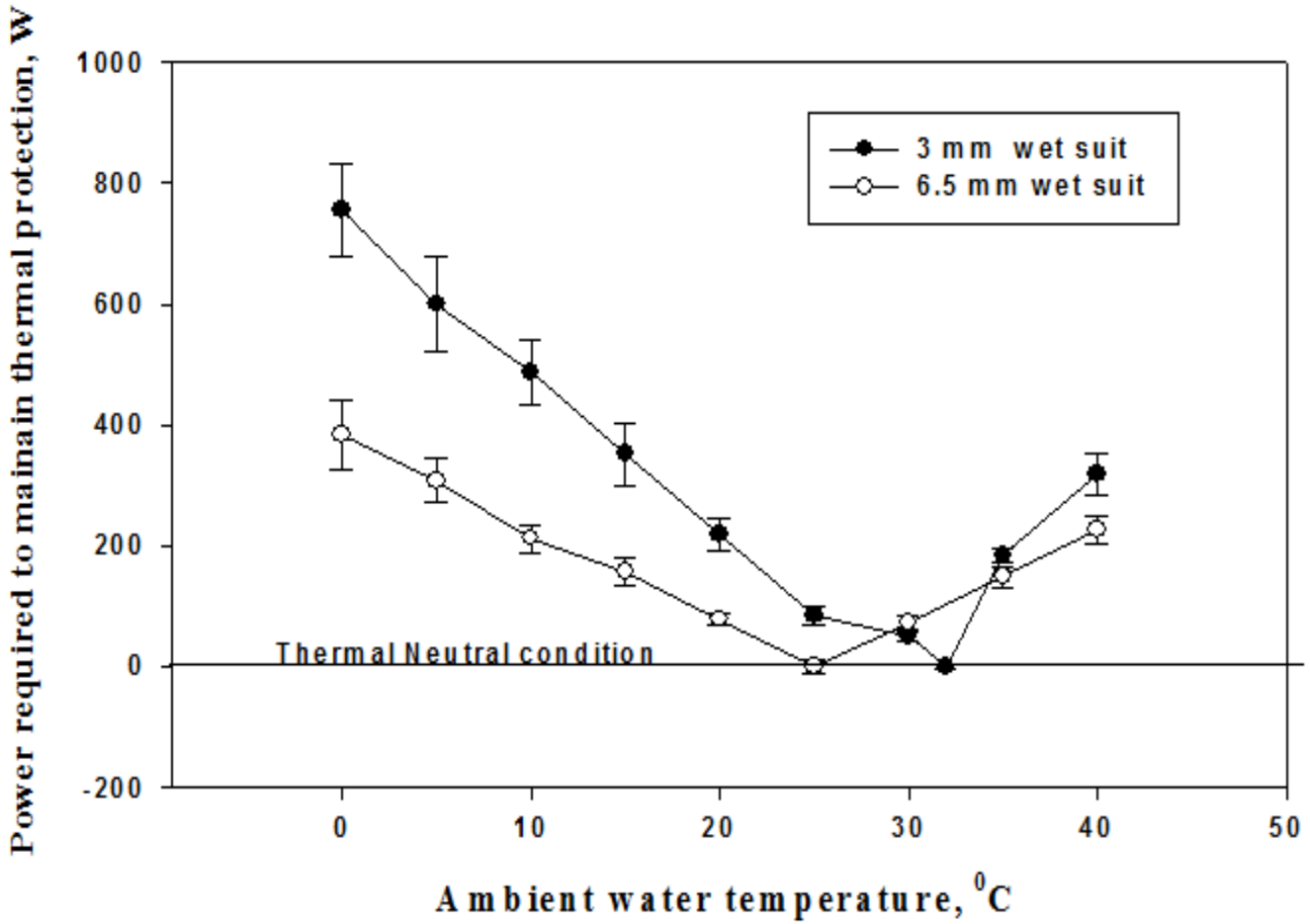
- **The regional power:**

  Head = 7.6 ± 2.2, Torso = 21.2 ± 10.3, Arm = 20.7 ± 4.4, Hand = 12.4 ± 6.1, Leg = 32.7 ± 14.7, Foot = 14.3 ± 7.2%

Results: Effect of Depth on TEC Capacity, duty cycle



Effect of Insulation on Heating/cooling power required to keep diver thermal neutral



Conclusion

- The DTPS provided thermal protection at all depths and water temperatures and provided calorimeter data.
- The reduction in insulation of the suit results in divers not being protected at depth.
- In the cold waters, the DTPS had reserves, however at 29 degrees C it was operating at full capacity.
- As expected, due to the compression of the foam neoprene wet suit, the power requirement in cold and warm water was greater at 55 and 120 fsw, with the most significant change between 4 and 55 fsw.
- The heat/cooling of the six zones were not different at depth than was observed near the surface.
- The reduction in insulation of the suit requires great heating/cooling power by an active system.