LESSONS FROM HISTORY

Pugh and Edholm's "The Physiology of Channel Swimmers"—A Commentary

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The article titled "The Physiology of Channel Swimmers"¹ presents the results of 3 years of observations on a select group of individuals—English Channel swimmers—and the factors concerning the individuals' ability to endure a protracted bout of exercise in cold water. It is a classic article that compares "people showing unusual tolerance of cold . . . with people showing unusual intolerance."

The investigators attempted to answer several questions. However, due to methodological and logistical problems as well as a small sample of subjects, who varied morphologically and physiologically, the following partial questions and answers were provided:

Do Channel swimmers tolerate hypothermia better than others?

The investigators' answer is "yes," based on the alteration in the rectal temperature data of two individuals in comparison to another group of Channel swimmers. The investigators suggested that whereas one tall and lean subject (G.P.) could not sustain exercise in cold water at such a low rectal temperature, another "short and stocky" subject (J.Z.) could maintain his body temperature while exercising in cold water for a very long period of time. In addition, the research demonstrated that the rectal temperature of J.Z. declined only when he was fatigued and his expenditure of energy concomitantly decreased. These seminal findings have been replicated 50 years later. Most recently, Castellani² evaluated 48 hours of sustained operations (SUSOPS) and how this exercise stressor alters thermoregulation during cold exposure. The results indicated that sustained (84-hour) military operations lead to a greater decline in core temperature. In an earlier study, Castellani³ evaluated thermoregulation during cold exposure after several days of exhaustive exercise and suggested that susceptibility to hypothermia is increased by exertional fatigue.

The increased insulation and decreased rate of heat loss appear to be the primary factors enabling the Channel swimmers, who were overfat, to maintain body temperature in cold water for a prolonged period of time.¹

Other documented characteristics, such as the length of the limb and the volume of the limbs in relation to the trunk, were also considered. The investigators report that "a man with short limbs and a large trunk would cool less quickly than a man of the same surface area but with long slender limbs and a small trunk." This observation alludes to the contemporary concept of the surface area-to-mass ratio (SA:MA). The research in this area remains unclear because both Toner et al⁴ and Glickman-Weiss et al⁵ were unable to find differences with respect to core temperature or tissue insulation in men matched for subcutaneous fat and total fat but differing in body mass and morphology (SA:MA). Therefore, SA:MA may not affect thermoregulation compared with other factors such as percent fat, that is, the passive resistor to heat exchange, and peripheral vasoconstriction, the active resistor to heat exchange.⁶

The investigation of the Channel swimmers suggests that body fat provides an insulator to reduce heat loss. This factor is critical in the area of cold-water immersion and needs to be carefully controlled in future studies.

"Is the heat production of Channel swimmers exceptionally high, enabling them to maintain heat balance even in cold water?"

It is uncertain whether there is a clear answer to this question based on recent observations. An article published by *The New Yorker*⁷ featured data on a female distance swimmer, Lynne Cox. Barbara Drinkwater, an exercise physiologist, evaluated Cox's physiological response to 4 hours of swimming in cold water and found an increase in Lynne's body temperature from 97.6°F to 102°F. Drinkwater suggested that the swimmer was efficient in closing down blood flow to peripheral areas (ie, peripheral vasoconstriction) and was able to create more heat than she lost as a result of her large muscle mass and high exercise intensity. This ability coupled with the swimmer's even distribution of body fat acted as an "internal wetsuit."⁷

In contrast to Drinkwater's observations, the authors' data on the Channel swimmers did not indicate an in-

crease in overall heat production (with a concomitant increase in core temperature). The data on the Channel swimmers did, however, demonstrate a high total energy expenditure. The time required to cross the Channel was approximately 12 to 20 hours, and the rate of stroke was maintained approximately constant throughout the swim. This suggested that one of the swimmers (J.Z.) expended approximately 750 calories/h, or a total energy expenditure of 9000 to 15 000 calories. The investigators report that this would make Channel swimming the “greatest feat of endurance” in the world of sport.

The differential response that Pugh and Edholm¹ observed raises concern regarding the survival advice reported by Glaser⁸: “Fit men, who are in danger of immersion in cold water, might be advised to swim or struggle as hard as they can for as long as they can. If they try to preserve their strength by clinging to wreckage or floating on their lifebelts, they will die from cold. Perhaps more lives would have been saved in the past if this had been understood.” The survival advice to maintain temperature homeostasis is now well understood. Peter Steele⁹ provides an account of a shipwreck in cold water (6°C–7°C) in which only 1 individual survived, the woman (Jane) who huddled in a crouched position to reduce heat loss and avoided utilizing energy fruitlessly in attempting to swim. However, her male counterpart made a futile attempt to swim to keep warm. His inadequate clothing and low body fat all mitigated against his survival.

Pugh and Edholm’s results suggest that there is variability in the physiological responses to cold-water immersion based on overall body fat or tissue insulation.¹ The rate of body cooling for the “stocky” subject (J.Z.) was very low when he lay motionless in the cold bath and was virtually “nil” while he was swimming. The 2 tall and lean subjects cooled more rapidly while swimming than while lying still; the investigators speculated that they would almost certainly survive longer by refraining from swimming or struggling.

Do Channel swimmers lose heat less rapidly because of their physique?

The increased insulation and the decreased rate of heat loss appear to be the primary factors that enabled the Channel swimmers, who were all overfat, to maintain core temperature for a protracted period of time.

In summary, although the research investigation is dated, it appears to be consistent with current cold-water immersion studies. Investigators suggest that tolerance to cold water is related to the thickness of the subcuta-

neous fat^{6,10} and indicate that SA:MA ratio may also play a role in thermoregulation.⁴ Additionally, the authors state that human fat is a better insulator than human muscle (previously determined by Hatfield and Pugh¹¹). This may help explain the disparity between the subjects’ body heat loss during exercise in cold water in Pugh and Edholm’s investigation. The greater the percent body fat, the less thermal or metabolic strain the individual will sustain to maintain temperature homeostasis during acute cold exposure. This concept has been repeatedly and consistently confirmed in similar cold exposure protocols.^{6,12}

In this scenario, “To be fat is good.”

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