



ACCLIMATIZATION TO DIVING IN COLD WATER

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Who gets cold when diving in cold water, and why?
Is cold something you can get used to? How?

BRIEF OVERVIEW OF SUSCEPTIBILITY TO COLD

Just as the "dose" of nitrogen or oxygen, meaning partial pressure and time exposed, are main factors in decompression sickness and oxygen toxicity respectively, major factors in cold stress are temperature and length of exposure. As with dosage of any drug or substance, several interacting and competing mechanisms, in addition to the dosage, determine if you will be affected, and by how much.

You generate heat in many ways, lose heat in many ways, and have various anatomical structures and physiologic schemes to block heat loss and gain. Thermal scientists can put all the figures for heat generation, heat loss, and resistance to heat loss into mathematical models to estimate what your final temperature might be. But it is more involved than just saying that young or old, or big or small people have any one characteristic and therefore greater susceptibility.

Losing body heat, by itself, does not mean that you are chilling. You lose heat all the time. Your body generates heat in the process of being alive. If you didn't lose heat, your body would cook (sometimes it does, and that will be covered in another article on overheating).

Losing heat doesn't necessarily mean you are in danger of hypothermia or any other injury from cold. You need to lose some heat. Whether you stay comfortable or get cold depends on how much heat you keep and how much you lose.

You lose heat in several ways. You also generate heat and store heat. No one variable such as gender or skin surface area makes anyone more susceptible to chilling or hypothermia than anyone else.

Losing body heat, by itself, does not mean that you are chilling.

FACTORS IN SUSCEPTIBILITY

SURFACE AREA TO MASS RATIO. Much is made of the "surface area to mass ratio." What is it? Your heat production roughly proportional to your body mass. On the other hand, radiation of heat from your body to the environment is in proportion to the area of your skin that covers you. The proportion of how much external surface area you have compared to how much internal mass is your ratio.

Car and home heat-redistributors are built to have long thin shapes. Their high surface area-to-mass ratio gives off, or radiates, lots of heat. Imaginatively, they are called radiators. Long, thin spaghetti cools rapidly. Short, round, bulky, baked potatoes stay hot longer. Like spaghetti, your fingers and ears are long and thin with much exposed surface. Fingers and ears chill faster than your torso. Fingers have less total surface than your torso, but a higher ratio. Your torso, very much like a potato, has more internal mass compared to its outer surface of skin, giving it a lower ratio of surface area-to-mass.

Bodies, and body parts, that have a large surface area compared to their mass, can radiate more heat than those with smaller surface area-to-mass ratios. Although a higher ratio does allow more relative heat loss, it is not the main determinant of chilling. Someone with a larger ratio can lose more heat through that particular pathway yet still not be at greater risk of chilling, because of all their other heat-conserving and generating mechanisms. Moreover, a larger person has more total surface area and loses more total heat than a smaller person. For example, a large male has more total surface area, and so loses more total heat than a smaller man or woman, but is not more susceptible to chilling for that one reason.

AGE. Young children are less able to thermoregulate in the cold than adults for a variety of reasons including size, active heat generation, vasomotor control, and other factors. Risk of chilling also generally increases with aging, although changes in physical fitness and body composition that accompany aging, is often confused for aging itself.

BEHAVIOR. Is the person who gets out of the water first, really the cold one? A thermal stress workshop held at the Institute for Naval Medicine in England by the Diving Medical Advisory Committee discussed what they called the non-responder to cold. They stated, "It is still not known what

the differences are between the man who responds to and complains of the cold, and another man who cools and is unaware that he is cooling. Presumably this latter type of diver is a potential hypothermic casualty."

MEDICATIONS. Medications called beta blockers are commonly prescribed for migraine headache. They are also sometimes taken for high blood pressure, although other medications have gained greater acceptance as anti-hypertensives. People taking beta blockers sometimes report reduced cold tolerance. A possible reason is that beta blockers, particularly a class called non-selective beta blockers, were found in some studies to block non-shivering thermogenesis, which is one small means of heat production.

EXERCISE. Contrary to popular belief, you won't always get colder by exercising in cold water. Both heat loss and heat production increase when exercising in cold water. Whether you get cold or warm depends which you have more of. Often the exercise can generate enough heat to overheat you, as USNavy divers found out during Desert Storm operations in the Gulf.

FITNESS. Your thermal tolerance can improve with physical fitness, although cold tolerance better increases with exercise in cold conditions than from exercise alone. In other words, to get used to the cold, you need to be out in it. Often.

PROTECTIVE CLOTHING. Clothing studies yield interesting results. Subjects' core temperatures are sometimes lower with protective garments than without. Lack of input from cold receptors in their hands, decreased the body's ability to make the needed blood flow changes necessary for cold protection. Sensory information from cold receptors in the extremities seems of high importance in thermoregulation. Still, protective clothing is important, and makes a life-and-death difference in extreme cold air and water. Protective clothing protects you from losing more heat than you can replace.

GENDER. Women are not more susceptible to hypothermia than men, as commonly thought. To the contrary, several studies show women are often less susceptible. On average, women have better ability to limit heat loss. They may generate less (and sometimes more) total heat than men depending on work load, fitness, body size, and other variables. Men, on average, usually lose more total heat from higher skin temperatures due to their lesser vasoconstrictor response (evidenced by often warmer hands), and from their larger total skin surface area, and for that reason, must counter with increased heat production from typically greater mass and metabolism. It takes more calories and metabolic work to keep up such heat production, making a very extreme survival situation more problematic for males - they may be more likely to starve and freeze. Evidence is strong that women protect their core temperature in the cold as well or more than men.

What about the warmer hands issue? That doesn't mean that men fare better in the cold. It indicates that women are losing less heat through their periphery. Men's warm hands pour heat out into the environment. Your skin temperature is not 98.6F (37C). That familiar number is the average temperature of your core. Skin temperature is far cooler than core temperature. One of the ways your body resists heat loss through your periphery is by reducing warm blood flowing to your skin surface. In the cold, your

skin temperature quickly drops to that of (or close to) the surrounding air or water. If skin surface temperature is close to surrounding temperature, the gradient is small, so heat loss is small. (Heat travels down gradients from high to low, just as with nitrogen load.) People with cooler skin in the cold have a smaller skin-to-environment gradient to lose heat. An analogy is if you stand outside your house in cold weather, touch the exterior wall and find it warm, you would notice the expensive loss of heat and know your home needed better insulation. You may even wonder who designed such an inefficient structure.

BODY SIZE AND SHAPE. A large person can produce and store more heat than a smaller person. Adaptations in body shape and size, hypothesized to aid survival as a species in cold climates, is summarized in Bergman's rule. Bergman's rule is a generalization that peoples originally native to cold climates are larger than those from warmer climates.

Now imagine a long, tall, slender person. With large body size, arm and leg length often increase. More heat is lost through these areas of high surface-to-mass ratio, and comparatively little fat insulation. Another generalization, called Allen's rule, takes limb length into account. The short arms and legs of large people from cooler regions, for example Eskimos, helps reduce heat loss.

Body size and shape contribute to susceptibility to cold, but, like any other individual factor, do not determine it.

FACTORS IN SUSCEPTIBILITY TO COLD

- + Water and air temperature
- + Duration of exposure
- + Skin temperature
- + Body composition
- + Very young and very old age
- + Certain medications
- + Protective garments
- + Physical work load
- + Body size
- + State of acclimatization
- + Fatigue
- + Hydration
- + Nutritional status

WHAT IS ACCLIMATIZATION?

Cold acclimatization is a well-documented process of gradually increasing your resistance to cold injury through regular cold exposure. Following the recommendation of the International Union of Physiological Sciences, the term acclimatization is distinguished from acclimation. Acclimatization means change from seasonal or geographical exposure; acclimation is change produced in a laboratory.

WHO ACCLIMATIZES TO COLD?

Major examples of geographic acclimatization to cold are the indigenous people of the African Kalahari, the Australian desert, and Tierra del Fuego in Southern Chile. Many sleep outdoors nearly naked in freezing temperatures. Seasonal acclimatization occurs in people working outdoors year round and fishermen who dunk their hands in cold water all winter to tend their nets. Divers continuing to work late into the winter season, or year round in cold waters, gradually increase their cold tolerance. Extent varies among individuals and with exposure.

WHAT CHANGES OCCUR IN TRUE ACCLIMATIZATION?

True cold acclimatization involves at least three adaptations. Cold-acclimatized people begin shivering at lower body temperatures, because they generate more heat without shivering. A big hallmark of cold-acclimatized people is improved ability to sleep in the cold. Cold acclimatization may involve either increased or decreased skin temperatures, depending on circumstances. In some cases, skin blood flow increases to keep extremities warm and to resist cold injury. In other cases it decreases to reduce heat loss. For example, skin temperatures of Australian Aborigines were lower while sleeping than those of the unacclimatized European investigators.

ACCLIMATIZATION TO COLD

- + Shivering occurs at a lower body temperature
- + Ability to sleep in the cold
- + Changes in peripheral blood flow distribution

LOSING YOUR EDGE

When chronic exposure to cold environments ends, you gradually lose your cold adaptation. When acclimatized Korean divers switched from bathing suits to wet suits, their thermal advantage decreased. Loss of acclimatization was also documented in the Ama divers of Japan when they began wearing cotton suit insulation and wet suits.

ACCLIMATIZATION IS NOT ALL THERE IS TO DIVING WARM IN THE COLD

To truly acclimate to cold weather, you need to expose yourself to cold conditions on a regular basis, and to exercise in the cold. You will reduce or eliminate your acclimatization potential if you keep yourself in a tropical micro-climate of warm clothing and indoor heating.

How practical is it to live a cold life in order to acclimatize to cold? Up to a point, it helps greatly. Below critical environmental temperatures, obviously, acclimatization is not all there is to diving warm in the cold. Cold affects many of your body systems as they make adjustments to increase heat production and decrease heat loss. Extreme cold exposures overwhelm your protective systems, with chilly effects.

One important way to conserve heat and tolerate cold water immersions is to wear good thermal protection. Various animals dive in Arctic waters using both wet suit and dry suit technology. The fur of seals and polar bears, for example, is an effective wet suit. It adds exterior insulation to their thick fat layer by trapping a two to ten millimeter water layer near their skin. The feather pelt of penguins, on the other hand, works like a dry suit, maintaining an insulating layer of air. Humans who have no feathers or fur should wear exposure suits that include head covering when they dive in cold water.

Some divers ask if pouring warm water in your wet suit, or warming up between dives in a heated car or boat cabin, will cause you to sweat and vasodilate your peripheral blood vessels, increasing heat loss, thereby making you colder than before. It's unlikely that you will overheat to such an extent. The additional heat you gain back is important for rewarming. You will be warmer than before and will build back a heat reserve. Rewarming is an important part of cold water diving.

YOU CAN DO SEVERAL THINGS TO CONSERVE HEAT WHILE DIVING IN COOL AND COLD WATER:

- + Wear good exposure garments, suitable for conditions
- + Get the weather report and make site condition checks
- + Allow wider diving safety margins with colder conditions
- + Stay well nourished, rested, and hydrated
- + Pre-wet your face and hands
- + Get in slowly
- + After diving, dry off, get changed, and get out of the cold
- + Rewarm well between dives
- + Keep in good muscular and aerobic shape to improve your heat-conserving and heat-producing systems
- + If you are cold, do something about it

DON'T JUST SIT THERE

Diving safely in the cold is a matter of not losing more heat than you produce. Divers rarely get clinical

hypothermia from diving, but often get cold and uncomfortable, which can affect fun and safety.

If you are cold, do something about it. Safety in the cold requires action and thought by the diver before, during, and after diving. You can dive safely in cold water when you properly prepare.

For more information on cold and other diving physiology topics, see the fun book, **DIVING PHYSIOLOGY IN PLAIN ENGLISH**. This book covers decompression theory, tables, computers, effects of immersion, DCS, O2 toxicity, lung injuries, heat and cold, swimmer's ear, marine stings, exercise and nutrition, headaches, why you have to 'pee' when you get in the water, and many other topics. Fifth revised printing 2003.

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