Muskrat Winter Olympics: endurance under the ice

by Ted Bailey

I noticed while watching the 20th Winter Olympics at Turin, Italy that the winning times of speed skating events were separated by mere hundredths of seconds. For example, only 0.09 seconds separated Gold Medal winner Enrico Fabris from Silver Medal winner Shani Davis in the 1500-meter event.

An interesting article entitled "Endurance in Speed Skating: The Development of World Records" by Gerard H. Kuper and Elmer Sterken was published in the *European Journal of Operational Research* in 2003 (Volume 148: 293–301). The authors developed a model that predicted a maximum skating speed of 37.9 feet per second for men and that in the foreseeable future the world record would only increase by about 30 seconds for the 10,000-meter speed skating event. Their model's prediction and the actual Olympic world record for that event at Salt Lake in 2002 differed by only 0.0025 seconds!

One reason that such records do not decrease indefinitely is because of physiological limits set by the human body. Sprint events like the 500-meter speed skating event are dominated by the body's anaerobic metabolism, while the endurance events like the 10,000-meter event is dominated by aerobic metabolism. Anaerobic metabolism means "without oxygen;" it occurs when the body's demand for oxygen exceeds the rate of supply and the body relies on stored reserves. Anaerobic metabolism produces toxic waste products like lactic acid that can painfully accumulate in the muscles and blood.

Aerobic metabolism, on the other hand, is metabolism that uses oxygen already stored in the blood or oxygen taken up by breathing; aerobic metabolism does not produce painful lactic acid. So what does all of this have to do with muskrats?

When I walk on the ice of peninsula lakes in the winter I sometimes realize that air-breathing muskrats may be swimming under the ice and that our northern muskrats must forage for food under the ice each day throughout the long and dark winters that may last up to six months or more. The same physiological factors that limit a human speed skater's endurance on top the ice limit muskrat endurance under the ice. Researchers have discovered that most mammalian and avian divers maintain aerobic dive schedules in order to avoid build-up of painful and toxic lactic acid in their muscles and blood. This means that the distance muskrats can forage for food underwater may be primarily constrained by their aerobic endurance, not by their anaerobic endurance.

Dr. Robert A. MacArthur with the University of Manitoba, Canada is probably the world's expert on muskrat diving endurance. In his numerous studies of muskrats in laboratory experiments and in the wild, he determined that the average under-ice swimming speed of muskrats was 2.5 feet per second with a maximum of 4.2 feet per second. Interestingly this speed is similar to the submerged swimming speeds of diving ducks. Muskrats store most of the oxygen they utilize during submerged swimming in their blood. Both the density of red blood cells per unit volume and the size of red blood cells increased from summer to winter, giving them a 17-second winter advantage or 42.6 feet gain for under-ice foraging distance.

MacArthur also determined that the maximum aerobic dive limits for muskrats was about 57.9 seconds. But because their lungs are only about 50% inflated during dives and only about 80% of the oxygen in their blood is actually utilized, their practical dive limit is reduced to 49 seconds. Using 49 seconds one could calculate that muskrats could forage for food a maximum 123 to 206 feet underneath the ice from the air-filled chambers of their bank dens or lodges, without beginning a painful build-up of lactic acid. If, however, they have to return to their den while still holding their breath, these distances would be cut in half for a foraging radius of about 62 to 103 feet.

To extend their foraging distances, muskrats in some habitats gnaw holes through the ice and push up submerged vegetation through the holes to form a little protective shelter, or a "push up", where they can sit, breathe air and feed in safety from predators. MacArthur measured the distances between muskrat dens and pushups on top the ice. Pushups located offshore from island bank dens averaged 104 feet from the nearest shelter while those within stands of emergent vegetation averaged only 49.5 feet. Because these measured distances were within the aerobic-dive

limit endurance of muskrats, it demonstrates that most muskrats are limited to forage distances under the ice that are determined by their body's oxygen storage capacity.

Nevertheless, muskrats are capable of and have occasionally been measured exceeding their aerobic dive limits by remaining submerged longer or by travelling greater distances under the ice. One way muskrats can extend their foraging range if they cannot build "pushups" is to scavenge oxygen from previously expelled air from bubbles trapped underneath the ice. Muskrats therefore adapt physiologically and behaviourally to increase their endurance under the ice, not to win winter Olympic medals but to find enough food to survive the long northern winters.

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