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Stanford researchers' cooling glove 'better than steroids'

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(Medical Xpress)—The temperature-regulation research of Stanford biologists H. Craig Heller and Dennis Grahn has led to a device that rapidly cools body temperature, greatly improves exercise recovery, and could help explain why muscles get tired.

"Equal to or substantially better than steroids … and it's not illegal."

This is the sort of claim you see in spam email subject lines, not in discussions of mammalian thermoregulation. Even the man making the statement, Stanford biology researcher Dennis Grahn, seems bemused. "We really stumbled on this by accident," he said. "We wanted to get a model for studying heat dissipation."

But for more than a decade now, Grahn and biology Professor H. Craig Heller have been pursuing a serendipitous find: by taking advantage of specialized heat-transfer veins in the palms of hands, they can rapidly cool athletes' core temperatures – and dramatically improve exercise recovery and performance.

The team is finally nearing a commercial version of their specialized heat extraction device, known as "the glove," and they've seen their share of media coverage. But what hasn't been discussed is why the glove works the way it does, and what that tells us about why our muscles become fatigued.

Nature's radiator

For Heller and Grahn, the story starts, improbably, with a longstanding question about bears.

Black bears are extremely well-insulated animals, equipped with a heavy coat of fur and a thick layer of subcutaneous fat that help them maintain their body temperature as they hibernate through winter. But once spring arrives and temperatures rise, these same bears face a greater risk of overheating than of hypothermia. How do they dump heat without changing insulation layers?

Heller and Grahn discovered that bears and, in fact, nearly all mammals have built-in radiators: hairless areas of the body that feature extensive networks of veins very close to the surface of the skin.

Rabbits have them in their ears, rats have them in their tails, dogs have them in their tongues. Heat transfer with the environment overwhelmingly occurs on these relatively small patches of skin. When you look at a thermal scan of a bear, the animal is mostly indistinguishable from the background. But the pads of the bear's feet and the tip of the nose look like they're on fire.

These networks of veins, known as AVAs (arteriovenous anastomoses) seem exclusively devoted to rapid temperature management. They don't supply nutrition to the skin, and they have highly variable blood flow, ranging from negligible in cold weather to as much as 60 percent of total cardiac output during hot weather or exercise.

Coolers and vacuums

In humans, AVAs show up in several places, including the face and feet, but the researchers' glove targets our most prominent radiator structures – in the palms of our hands.

The newest version of the device is a rigid plastic mitt, attached by a hose to what looks like a portable cooler. When Grahn sticks his hand in the airtight glove, the device creates a slight vacuum. The veins in the palm expand, drawing blood into the AVAs, where it is rapidly cooled by water circulating through the glove's plastic lining.

The method is more convenient than, say, full-body submersion in ice water, and avoids the pitfalls of other rapid palm-cooling strategies. Because blood flow to the AVAs can be nearly shut off in cold weather, making the hand too cold will have almost no effect on core temperature. Cooling, Grahn says, is therefore a delicate balance.

"You have to stay above the local vasoconstriction threshold," said Grahn. "And what do you get if you go under? You get a cold hand."

Even in prototype form, the researchers' device proved enormously efficient at altering body temperature. The glove's early successes were actually in increasing the core temperature of surgery patients recovering from anesthesia.

"We built a silly device, took it over to the recovery room and, lo and behold, it worked beyond our wildest imaginations," Heller explained. "Whereas it was taking them hours to re-warm patients coming into the recovery room, we were doing it in eight, nine minutes."

But the glove's effects on athletic performance didn't become apparent until the researchers began using the glove to cool a member of the lab – the confessed "gym rat" and frequent coauthor Vinh Cao – between sets of pull-ups. The glove seemed to nearly erase his muscle fatigue; after multiple rounds, cooling allowed him to do just as many pull-ups as he did the first time around. So the researchers started cooling him after every other set of pull-ups.

"Then in the next six weeks he went from doing 180 pull-ups total to over 620," said Heller. "That was a rate of physical performance improvement that was just unprecedented."

The researchers applied the cooling method to other types of exercise – bench press, running, cycling. In every case, rates of gain in recovery were dramatic, without any evidence of the body being damaged by overwork – hence the "better than steroids" claim. Versions of the glove have since been adopted by the Stanford football and track and field teams, as well as other college athletics programs, the San Francisco 49ers, the Oakland Raiders and Manchester United soccer club.

The elegant muscle

But what does overheating have to do with fatigue in the first place?

Much of the lab's recent research can be summed up with Grahn's statement that "temperature is a primary limiting factor for performance." But the researchers were at a loss to understand why until recently.

In 2009, it was discovered that muscle pyruvate kinase, or MPK, an enzyme that muscles need in order to generate chemical energy, was highly temperature- sensitive. At normal body temperature, the enzyme is active – but as temperatures rise, some of the enzyme begins to deform into the inactive state. By the time muscle temperatures near 104 degrees Fahrenheit, MPK activity completely shuts down.

There's a very good biological reason for this shutdown. As a muscle cell increases its activity, it heats up. But if this process continues for too long, the cell will self-destruct. By shutting itself down below a critical temperature threshold, MPK serves as an elegant self-regulation system for the muscle.

"Your muscle cells are saying, "You can't work that hard anymore, because if you do you're going to cook and die,'" Grahn said.

When you cool the muscle cell, you return the enzyme to the active state, essentially resetting the muscle's state of fatigue.

The version of the device that will be made available commercially is still being tweaked, but the researchers see applications for heat extraction in areas more important than a simple performance boost. Hyperthermia and heat stress don't just lead to fatigue – they can become medical emergencies.

"And every year we hear stories about high school athletes beginning football practice in August in hot places in the country, and there are deaths due to hyperthermia," said Heller. "There's no reason why that should occur."

More information: H. Craig Heller and Dennis A. Grahn. *Disruptive Science and Technology*. 2012, 1(1): 11-19. doi:10.1089/dst.2012.0004.

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