When it comes to sweat, second time's the charm

ASU professor shares new insights on how salty skin helps the body survive extreme heat

By Roger Ndayisaba, ASU News
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Around the world, sweat is seen as gross. There's even an entire industry of products created to help keep people from sweating.

However, in extremely hot places — like Arizona's Maricopa County, which recorded 608 heat-related deaths in 2024 — sweating is the body's main line of defense. Yet the mechanics behind how sweat keeps us cool are not well understood.

Over the last couple of years, Konrad Rykaczewski has pioneered the use of a first-of-its-kind outdoor thermal manikin, ANDI, to understand how the body cools itself and how to optimize that process in extreme heat. In a recent study published in the Journal of the Royal Society Interface, he took that research to the next level.

An associate professor of mechanical and aerospace engineering in the School for Engineering of Matter, Transport and Energy, part of the Ira A. Fulton Schools of Engineering at Arizona State University, Rykaczewski conducted a series of experiments to understand how sweat keeps us cool, focusing on the least studied part of the sweating process: evaporation.

"We know a lot about how the body generates sweat, but when it comes to its evaporation, which is the most important part, we know surprisingly little," Rykaczewski says.

What he discovered will open doors to developing new tools and strategies that help people survive in extreme heat.

Why this research matters

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How sweat turns into vapor

Because sweat is 99% water, Rykaczewski's understanding of how water evaporates informed his approach to understanding the cooling process in humans.

“In engineering, evaporation and other phase change processes are known to be, by far, the most efficient ways of exchanging heat,” Rykaczewski says.

He explains that when water boils, it takes about 10% to 15% of the energy to heat it up to the boiling point. The rest of the energy goes into changing it from liquid to vapor.

The same principle applies to sweat: Even a small amount of liquid evaporating from the skin removes a tremendous amount of heat from the body, enabling survival in extreme conditions.

But what happens when sweat reaches the skin? Most importantly, how much of the sweat turns into vapor, cooling the body, versus accumulating and eventually dripping away?

The answer is surprisingly simple, but getting to it was complicated.

Solving a biological mystery with engineering

Rykaczewski’s team repurposed tools normally used to study heat exchange in mechanical engineering and materials science, including a miniaturized wind tunnel, to study how sweat turns into vapor in a way never done before.

The team used a combination of measurements to quantify the electrical properties of the skin and sweat rate, along with microscopic imaging.

Sweat forms in glands deep in the skin’s dermis layer and travels through microscopic ducts before reaching the surface.

Using a combination of mid-wave infrared cameras and optical coherence tomography microscopes, for the first time, Rykaczewski was able to observe sweat coming out of the pores to the skin’s surface.

“The mid-wave infrared camera is very sensitive to seeing water, and it gives us a high-resolution image of what’s happening on the surface, while the optical coherence tomography microscope shows us a cross-sectional image of what’s happening on the skin,” he says.

Examining both imaging perspectives, along with changes in sweat rate and electrical skin properties, could lead to an improved understanding that unlocks new technologies, including clothing designed to optimize cooling.

Rykaczewski says the real challenge was testing the process on people.

“Anyone can easily put a droplet on a surface in a lab and use a microscope to see how it turns into vapor,” Rykaczewski says. “When you conduct the experiment on a human being, who breathes, shakes and so on, it gets a lot more complex. That’s why it had never been done before.”

Sweating for science

As part of the experiments, Rykaczewski says that he had to lie in a heated suit for hours, which was uncomfortable at best. After dozens of experiments and tens of thousands of pictures analyzed, the team saw a pattern emerging.

The team noticed that sweat comes out in an irregular distribution. Sweat droplets bubble up in an on-off pattern, and then sweating proceeds in different modes, eventually drenching the person in sweat.

Rykaczewski says that how much a person sweats and the mechanism by which the sweat evaporates can depend on various factors. But one factor stands out as especially important for the body's cooling.

"We found that the biggest factor that helps the body cool faster is salty skin," he says.

When sweat turns into vapor, the byproduct is salt. Using running as an example, after you sweat, take a break, and then start running again, your body tends to cool itself more effectively the second time around.

Rykaczewski explains that initially, sweat struggles to spread because the skin's outer layer takes several minutes to absorb water. This causes it to gather in small puddles with limited surface area, reducing evaporation and cooling.

After the first round of sweating, salt crystals left behind allow new sweat to wick immediately into the salty layer, spreading into a thin film that covers more skin and evaporates far more efficiently.

"A million years ago, humans weren't showering every day," Rykaczewski says. "Having salty skin was more natural. It's not hygienic, but it does optimize the cooling of the body. Now, the interesting question becomes, 'How could we use that understanding to keep people cool in extreme heat?'"

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> **Konrad Rykaczewski**
> ASU engineering professor

Designing for comfort and cooling

Most clothes, especially those designed for athletics, are engineered to pull sweat off the skin so people don't feel it. But comfort comes at a cost. Evaporation happens on the shirt, not the skin, which reduces cooling.

While major clothing brands invest billions into optimizing for comfort and aesthetics, Rykaczewski wants to introduce cooling into the mix.

“Humans aren’t just heat exchangers,” he says. “How we feel about things matters. The challenge is finding solutions that keep people safe and feel good enough that they’ll actually use them.”

Rykaczewski’s research shows that what sits on the skin plays a critical role in how effectively the body cools during heat. In the next phase of the research, he wants to understand how the body senses what’s on the skin’s surface.

“When do you know you’re starting to sweat?” he says. “How does the body notice it? Can you change that in some way, besides just wiping it dry? That adds another layer of complexity because it concerns the nervous system, but combining it with our current understanding of the sweating mechanism would unlock many impactful solutions 10 years from now.”

To handle this work, Rykaczewski plans to outsource the labor-intensive analysis to artificial intelligence, or AI, which will free up his time.

“I spent a month analyzing 25,000 images from just one experiment and trying to make sure that what I see is accurate,” he says. “Having a system that examines each one of these images and finds the patterns will play a strong role in the future of how we do this research.”

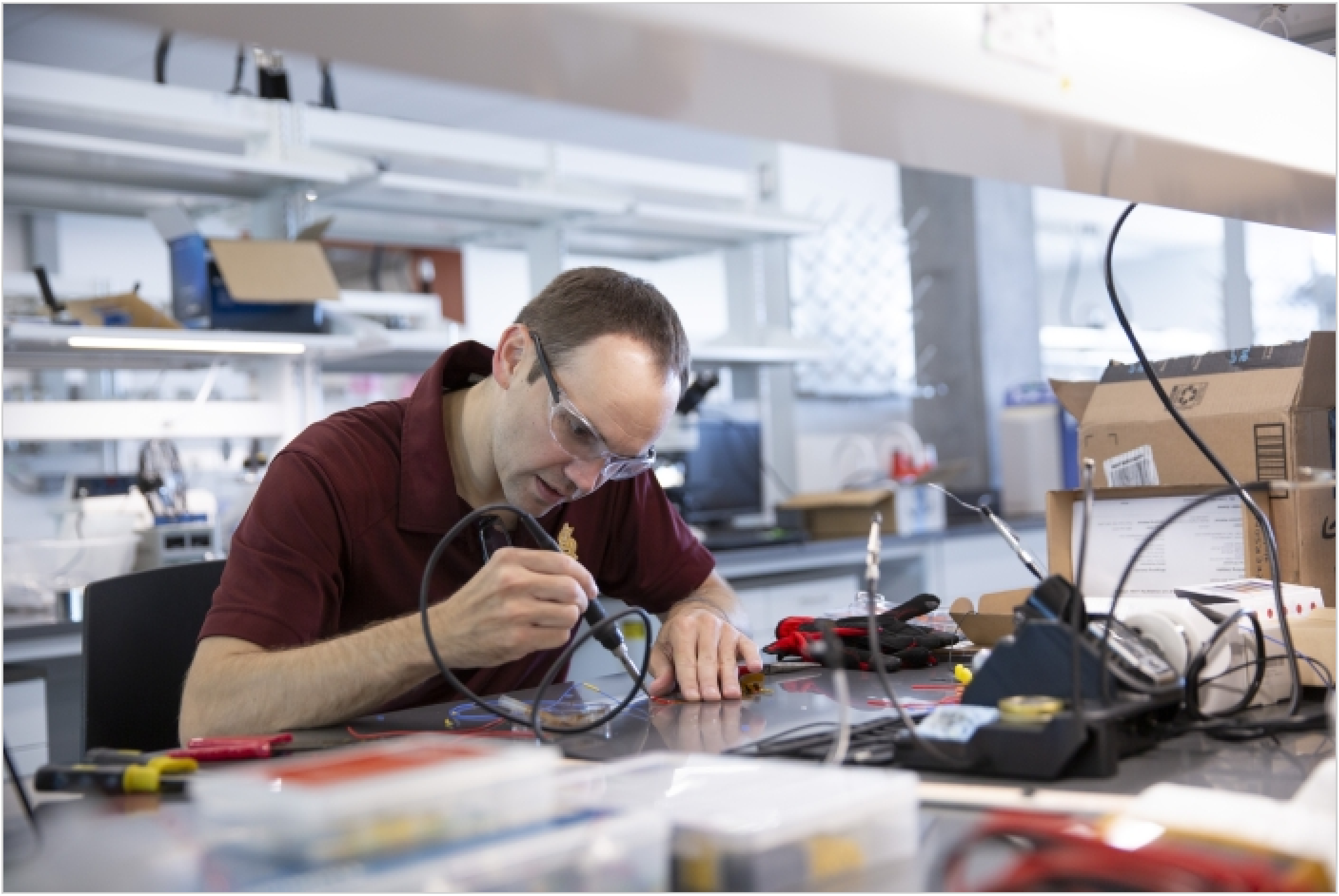
With AI, time and persistence, Rykaczewski hopes his findings could one day make it possible to comfortably hike in 110-degree heat without feeling icky.

This story originally appeared on ASU News.

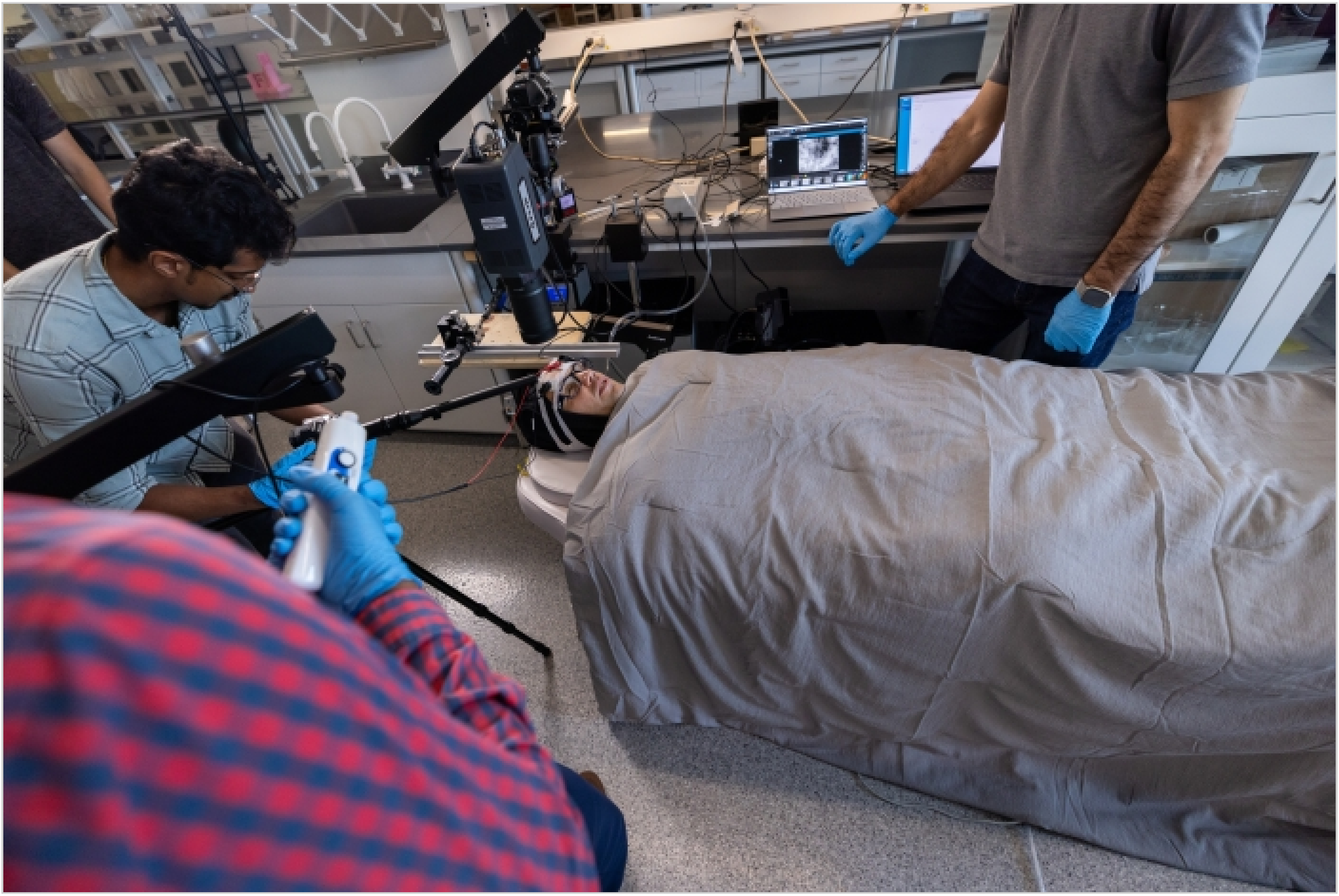
Main image

Konrad Rykaczewski, associate professor of mechanical and aerospace engineering, conducts an experiment to understand how sweat turns into vapor and cools the body. Photo by Samantha Chow/ASU

Text image(s)



Konrad Rykaczewski works with a soldering iron in his lab. In a study published in the Journal of the Royal Society Interface, he recently revealed new insights into sweating mechanisms. Photo by Erika Gronek/ASU



Wearing a thermal suit, Rykaczewski and Cibin Thomas Jose (left), a mechanical engineering doctoral student, demonstrate how sweat is studied at his lab. Photo by Samantha Chow/ASU