Detecting exhaustion during physical exertion with smart sportswear

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DOMYOS

Laufhose: The textile sensor above the knee is connected to an antenna embedded in the waistband. Together, they form a circuit that can be used to measure movement. Credit: Valeria Galli / ETH Zurich

Researchers at ETH Zurich have developed an electronic yarn capable of precisely measuring how a person's body moves. Integrated directly into sportswear or work clothing, the textile sensor predicts the wearer's exhaustion level during physical exertion.

Exhaustion makes us more prone to injury when we're exercising or performing physical tasks. A group of ETH Zurich researchers led by Carlo Menon, Professor of Mobile Health Technology, have now developed a textile sensor that produces real-time measurements of how exhausted a person gets during physical exertion. To test their new sensor, they integrated it into a pair of athletic leggings. Simply by glancing at their smartphone, testers were able to see when they were reaching their limit and if they ought to take a break. The new technology is published in the journal *Advanced Materials*.

This invention, for which ETH Zurich has filed a patent, could pave the way for a new generation of smart clothing: many of the products currently on the market have electronic components such as sensors, batteries or chips retrofitted to them. In addition to pushing up prices, this makes these articles difficult to manufacture and maintain.

By way of contrast, the ETH researchers' stretchable sensor can be integrated directly into the material fibers of stretchy, close-fitting sportswear or work clothing. This makes large-scale production both easier and cheaper. Menon highlights another benefit: "Since the sensor is located so close to the body, we can capture body movements very precisely without the wearer even noticing."

Garn: A rigid wire (orange) is wrapped in spirals around a length of elastic rubber (black)—both are conductive. Left slack, right stretched. Credit: Tyler Cuthbert / ETH Zurich

An extraordinary yarn

When people get tired, they move differently—and running is no exception: strides shorten and become less regular. Using their new sensor, which is made of a special type of yarn, the ETH researchers can measure this effect.

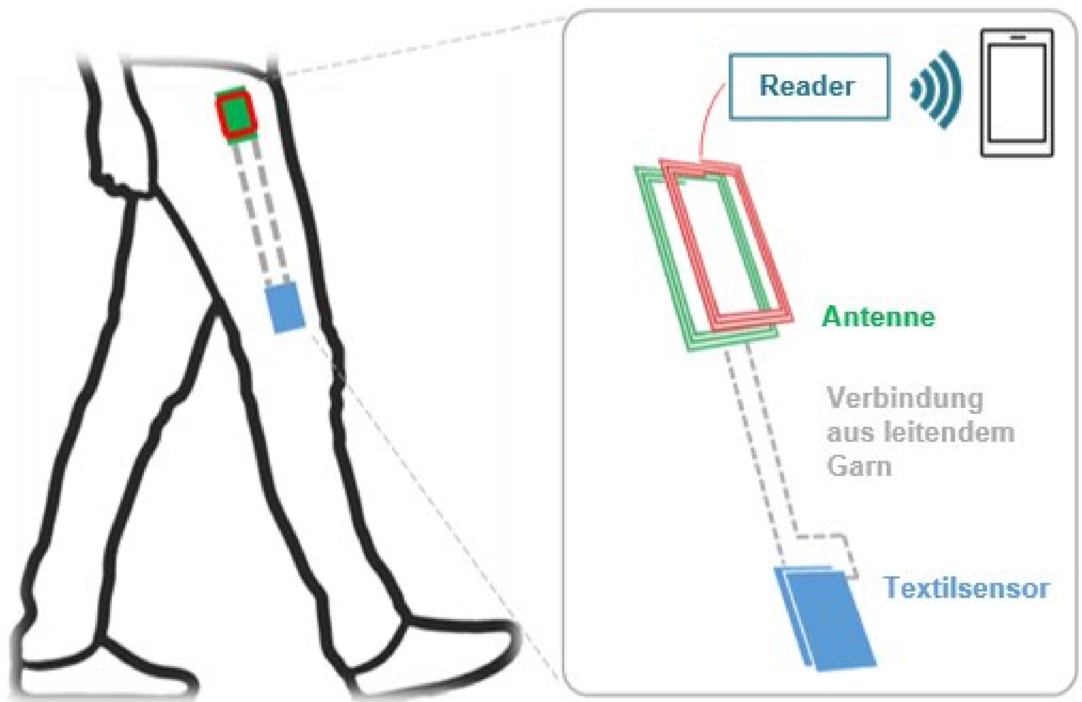
It's all thanks to the yarn's structure—the inner fiber is made of a conductive, elastic rubber. The researchers wrapped a rigid wire, which is clad in a thin layer of plastic, into a spiral around this inner fiber. "These two fibers act as electrodes and create an electric field. Together, they form a capacitor that can hold an electric charge," says Tyler Cuthbert, a postdoc in Menon's group, who was instrumental in the research and development that led to the invention.

Smart running leggings

Stitching this yarn into the thigh section of a pair of stretchy running leggings means that it will stretch and slacken at a certain rhythm as the wearer runs. Each movement alters the gap between the two fibers, and thus also the electric field and the capacitor's charge.

Under normal circumstances, these charge fluctuations would be much too small to help measure the body's movements. However, the properties of this yarn are anything but normal: "Unlike most other materials, ours actually becomes thicker when stretched," Cuthbert says. As a result, the yarn is considerably more sensitive to minimal movements. Stretching it even a little produces distinctly measurable fluctuations in the sensor's charge. This makes it possible to measure and analyze even subtle changes in running form.

But how can this be used to determine a person's exhaustion level? In previous research, Cuthbert and Menon observed a series of testers, who ran while wearing athletic leggings equipped with a similar sensor. They recorded how the electric signals changed as the runners got more and more tired. Their next step was to turn this pattern into a model capable of predicting runners' exhaustion which can now be used for their novel textile sensor. But ensuring that the model can make accurate predictions outside the lab will require a lot of additional tests and masses of gait pattern data.



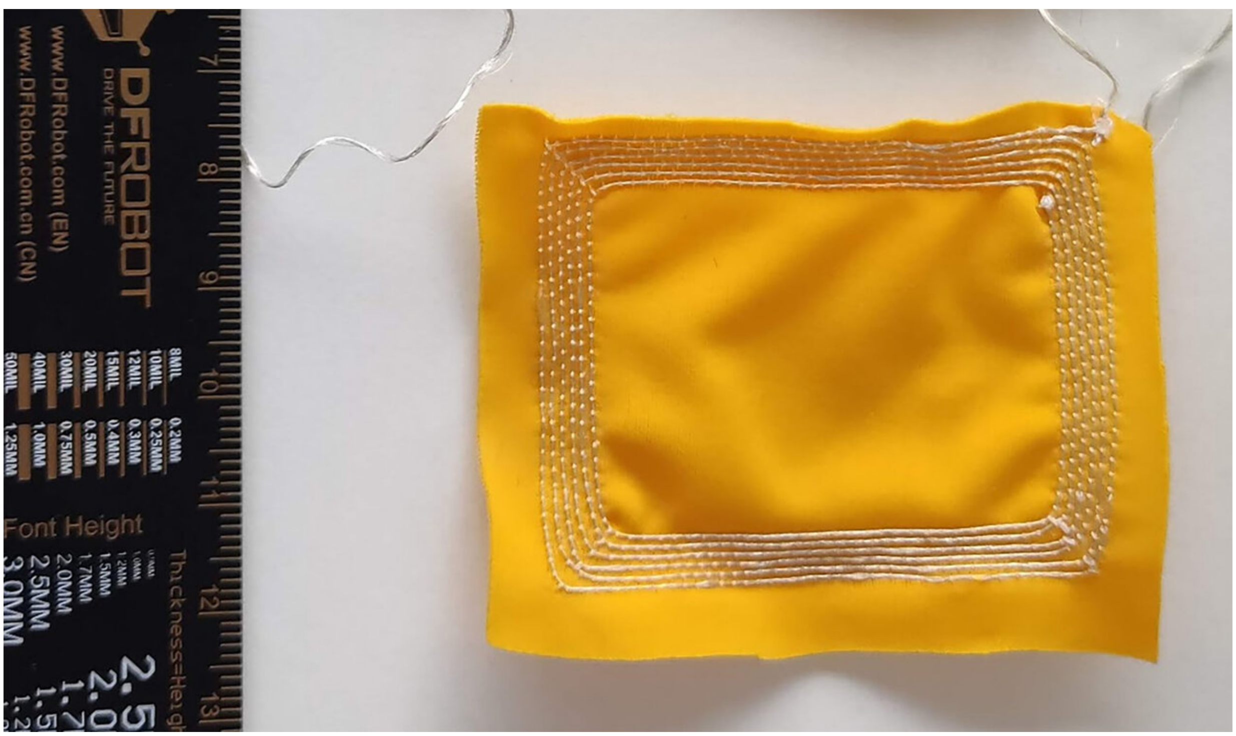
The textile sensor and antenna form an electrical circuit. When the sensor stretches, the antenna sends a signal that can be read by a smartphone. Credit: Valeria Galli / ETH Zurich

Textile antenna for wireless data transfer

To enable the textile sensor to send electrical signals wirelessly to a smartphone, the researchers equipped it with a loop antenna made of conducting yarn, which was also sewn directly onto the leggings.

"Together, the sensor and antenna form an electrical circuit that is fully integrated into the item of clothing," says Valeria Galli, a doctoral student in Menon's group.

The electrical signal travels from the stretchable sensor to the antenna, which transmits it at a certain frequency capable of being read by a smartphone. The wearer runs and the sensor moves, creating a signal pattern with a continuously fluctuating frequency, which a smartphone app then records and evaluates in real time. But the researchers still have quite a bit of development work to do to make this happen.



The antenna is sewn directly onto the material in loops. Credit: Valeria Galli / ETH Zurich

Applications include sports and workplace

At the moment, the researchers are working on turning their prototype into a market-ready product. To this end, they are applying for one of ETH Zurich's sought-after Pioneer Fellowships. "Our goal is to make the manufacture of smart clothing cost-effective and thus make it available to a broader public," Menon says. He sees the potential applications stretching beyond sports to the workplace—to prevent exhaustion-related injuries—as well as to rehabilitation medicine.

More information: Tyler J. Cuthbert et al, HACS: Helical Auxetic Yarn Capacitive Strain Sensors with Sensitivity Beyond the Theoretical Limit, *Advanced Materials* (2022). DOI: 10.1002/adma.202209321

Provided by ETH Zurich