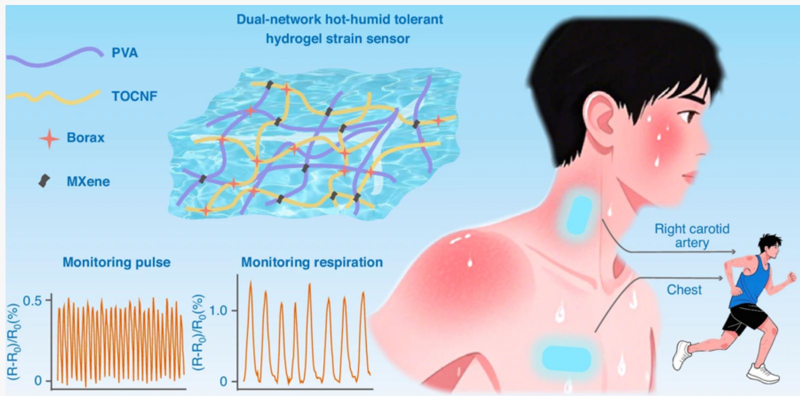
Heat, Sweat, and Motion: A wearable hydrogel for real-time cardiorespiratory monitoring

FAYETTEVILLE, GA, UNITED STATES, February 7, 2026 /EINPresswire.com/ -- Continuous monitoring of heart rate and breathing during intense physical activity is critical for early detection of cardiorespiratory risks, yet existing wearable devices often fail under heat, humidity, and motion.



Schematic illustration of the dual-network MXene hydrogel sensor with multifunctional properties for wearable cardiorespiratory monitoring under hot and humid conditions.

Endurance sports such as marathon running place extreme stress on the cardiovascular and respiratory systems, making continuous physiological monitoring essential for preventing sudden adverse events. However, most commercial wearable devices rely on rigid electronics or loose skin contact, leading to motion artifacts, discomfort, and unreliable signals during intense exercise. Conductive hydrogels offer a promising alternative because their soft, hydrated networks resemble human skin and conform closely to body movements. Despite this advantage, many hydrogel-based sensors suffer from dehydration, signal drift, or bacterial growth when exposed to sweat, elevated temperature, and high humidity. These limitations highlight the need for advanced wearable sensors capable of stable operation under hot, humid, and mechanically dynamic conditions.

Researchers from Xi'an Jiaotong-Liverpool University and collaborating institutions report a new MXene-based hydrogel sensor capable of stable physiological monitoring under extreme exercise conditions. Published (DOI: 10.1038/s41378-025-01102-2) in Microsystems & Nanoengineering in 2025, the study describes a dual-network hydrogel that combines mechanical resilience, electrical sensitivity, and antibacterial protection. In simulated marathon environments of high temperature and humidity, the sensor maintained reliable performance for hours, enabling accurate real-time tracking of heart rate and respiratory activity. The work offers a materials-based solution to long-standing limitations of wearable sensors used in endurance sports

The sensor is built from a dual-network hydrogel composed of polyvinyl alcohol and oxidized cellulose nanofibers, reinforced with conductive MXene nanosheets and dynamic borate crosslinks. This architecture provides high stretchability—up to 800% strain—while preserving stable electrical signal transmission. The optimized hydrogel exhibits a gauge factor of 7.79, allowing it to detect subtle skin deformations associated with pulse waves and chest movements during breathing.

Crucially, the hydrogel maintains more than 94% of its water content after six hours at 38 °C and 52% relative humidity, conditions that mimic the skin surface during endurance exercise. Electrical resistance and sensing sensitivity remain stable throughout prolonged exposure, overcoming a common failure mode of hydrogel sensors. In addition, the incorporation of MXene nanosheets confers strong antibacterial activity, achieving near-complete inhibition of both Gram-positive and Gram-negative bacteria, reducing infection risks during long-term skin contact.

As a proof of concept, the sensor was applied to monitor carotid pulse and respiratory motion during exercise at varying intensities. The recorded heart rate and breathing patterns closely matched reference measurements, capturing both linear cardiovascular responses and nonlinear respiratory changes as exercise intensity increased.

The researchers note that reliable monitoring during endurance sports requires sensors that function under simultaneous mechanical deformation, sweating, and elevated temperature. According to the study team, the dual-network hydrogel design addresses these challenges by combining moisture retention, self-healing capability, and antibacterial protection in a single material platform. They emphasize that capturing both heart rate and respiration in real time could enable early identification of abnormal cardiorespiratory responses, offering valuable feedback for athletes, coaches, and clinicians during prolonged or high-risk physical activity.

This hydrogel-based sensor opens new possibilities for wearable health monitoring in environments where conventional electronics fail. Beyond endurance sports, the technology could be adapted for rehabilitation, occupational safety, and continuous health tracking in hot or humid workplaces. Its skin-like mechanics and antibacterial properties also make it suitable for long-term epidermal applications, including electronic skin and human–machine interfaces. With further development, such sensors could support early warning systems for heat stress, respiratory dysfunction, or cardiovascular abnormalities, contributing to safer training, improved athletic performance, and more resilient wearable healthcare technologies.

References

DOI
10.1038/s41378-025-01102-2

Original Source URL
https://doi.org/10.1038/s41378-025-01102-2

Funding Information
The authors acknowledge the support from the programs of the Natural Science Foundation of Jiangsu Higher Education (24KJB460030), the National Natural Science Foundation of China (62204210, 62573363), the Science Foundation of Jiangsu Province (BK20220284), the XJTLU University RDF project (RDF-21-02-076, RDF-21-01-027), the XJTLU AI University Research Centre, Jiangsu Province Engineering Research Centre of Data Science and Cognitive Computation at XJTLU, the SIP AI innovation platform (YZCXPT2022103), the State Key Laboratory for Manufacturing Systems Engineering via the open project (SKLMS2023019), the Key Laboratory of Bionic Engineering, Ministry of Education at Jilin University (KF2023007), the Jiangsu Provincial Outstanding Youth Program (BK20230072), Suzhou Industrial Foresight and Key Core Technology Project (SYC2022044), and the Jiangsu QingLan Project and Jiangsu 333 high-level talents.

Lucy Wang
BioDesign Research
email us here
