Wearable biosensors

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Time-resolved cortisol monitoring with skin-interfaced wearable sensors

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A wearable sweat sensor converts cortisol measurements into time-stamped readouts, revealing daily rhythms and acute stress responses with flexible, low-power systems.

Capturing the daily biochemical fluctuations that reflect an individual's health remains a central challenge for precision medicine and personal stress monitoring. Conventional lateral flow assays are quick, affordable, and widely used for diagnostics, yet they provide only isolated snapshots, missing the time-resolved changes that carry meaningful information[1]. Translating these assays into wearable cortisol sensors has proved difficult, as achieving sufficient sensitivity for the low cortisol levels in sweat while keeping the device compact, flexible, and passive has remained an unmet challenge. Now, writing in *Nature Sensors*, Rogers and colleagues[2] report a wearable platform that converts single-use lateral flow assays into time-stamped, on-skin measurements of cortisol, enabling continuous tracking of hormone fluctuations over hours.

The central sensing component in this work is the lateral flow assay (LFA), a paper-based strip that turns tiny amounts of sweat into camera-readable lines whose intensity reflects cortisol levels (Fig. 1). LFAs are widely used in diagnostics, from pregnancy tests to rapid SARS-CoV-2 assays, because they are low-cost, fast, and reliable[3]. Adapting these assays for on-skin use requires miniaturization, enhanced sensitivity, chemical stabilization for sweat conditions, and a viewing window resistant to fogging. By integrating multiple strips in series, the authors overcame the usual limitation of LFAs as single snapshots, allowing repeated sampling to build a time-stamped series. To control the timing of these measurements, they developed two design strategies. In the electronic approach, a small timer triggers iontophoresis

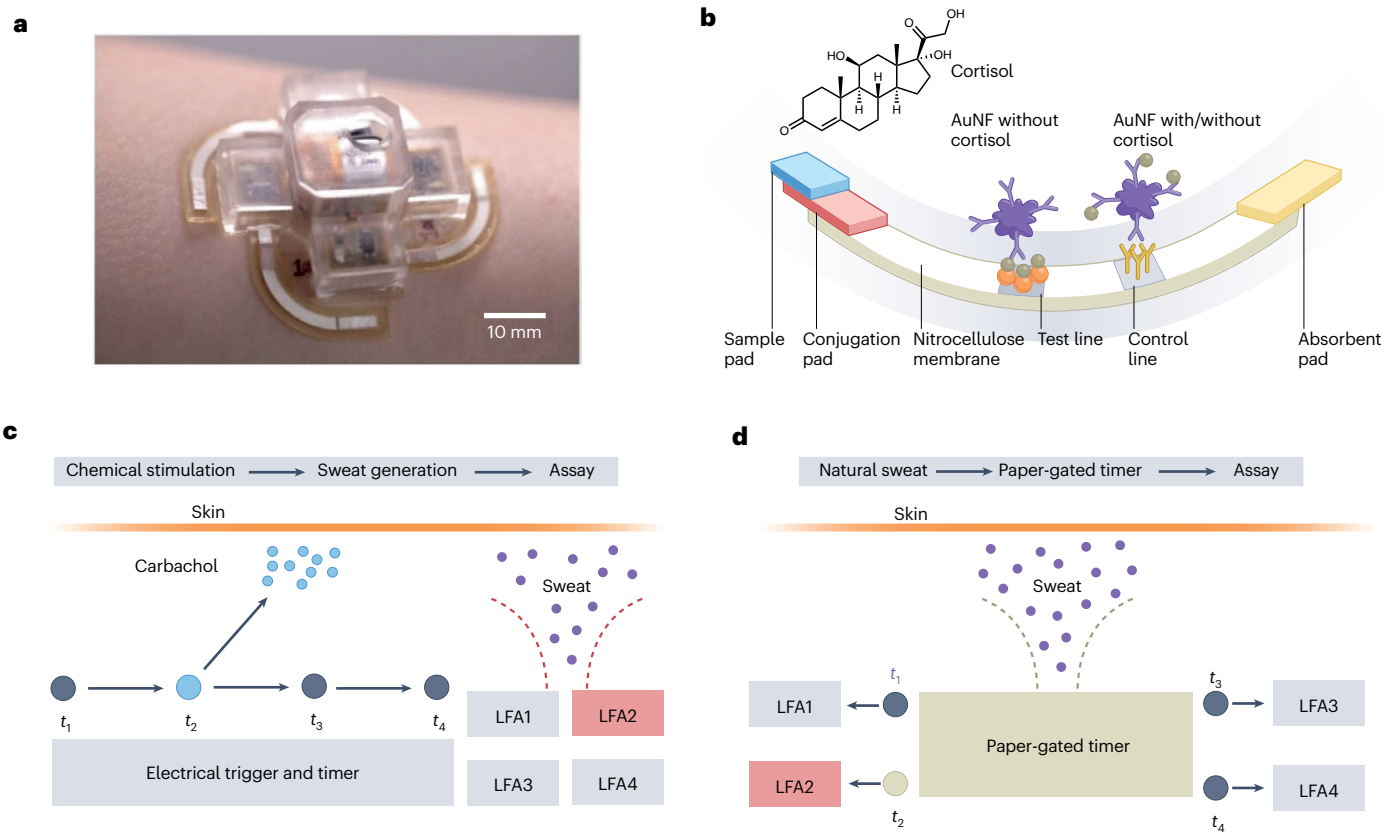

Fig. 1 | Skin-interfaced, time-resolved sweat sensing. a, Wearable LFA patch with integrated electrical trigger and timer. **b**, Structure and mechanism of the LFA. **c**, Concept of an active timing path with electrical trigger and timer. **d**, Concept of a passive timing path with paper-gated self-timing cell. Figure adapted from ref. 2, Springer Nature Ltd.

electrodes at set intervals, stimulating sweat at different skin channels and routing it to fresh LFAs (Fig. 1c). In the passive approach, dissolvable paper gates release sweat sequentially, with a built-in electrochromic cell serving as a visual timer (Fig. 1d). Both strategies share the same interchangeable sensing layer design, allowing flexible deployment. Electronics provide precise actuation on demand, whereas the passive route favours simplicity and disposability. Cortisol detection relies on a competitive assay format (Fig. 1b): sweat cortisol competes with a cortisol-tagged label for antibody binding on gold nanoparticles. Higher cortisol concentrations reduce binding at the test line, yielding a lighter signal, while the control line confirms proper flow. Sensitivity is enhanced using gold 'nanoflowers' with a larger surface area for stronger optical signals, and preconditioning of the strips for sweat pH and salt strengthens antibody binding. The device design also combines superhydrophilic and superhydrophobic layers above the strip to prevent fogging and unwanted wicking.

The wearable LFA devices with electronic timing were tested in everyday-relevant scenarios to show what time-resolved sweat cortisol can reveal. In a multi-day study, measurements followed the expected daily rhythm with higher levels in the morning and lower levels later in the day, matching patterns seen from saliva tests and correlating across participants. In a cold-pressor challenge, where participants immersed a hand in ice water, both sweat-based and blood-based cortisol rise and then recover on the same time scale, indicating the system can capture acute stress responses with meaningful timing. Finally, in jet-lag cases after long-haul trips, morning/afternoon cortisol patterns temporarily flip and then normalize over days, aligning with reported symptoms and showing how the platform can track circadian disruption and recovery.

This work successfully extends the use of LFAs from static tests into wearable, continuous biosensors, broadening their reach into personal health monitoring. Whereas commercial LFAs are rigid, box-shaped, and limited to point-of-care snapshots, the authors transform them into flexible, wearable systems that preserve the low-cost materials and modular architectures compatible with most existing strip designs. Yet several frontiers remain. Capturing rapid biomolecular dynamics requires overcoming the natural time resolution barrier[3]. The current system achieves 20-minute resolution from stimulation to assay completion, constrained by the 6–12-minute fluid transit time through the porous medium. Consequently, such delays risk missing more rapid biochemical fluctuations. Multiplexing is also limited as the compact design accommodates only four strips, enabling just 1.5 hours of passive monitoring if performed immediately in series. Achieving faster assay completion, denser multiplexing, and extended operation without compromising sensitivity will be key for continuous, whole-day monitoring[4]. Most commercial LFAs remain qualitative to minimize user variability and regulatory complexity, but the next generation will demand quantitative, automated readouts[5,6]. While camera-based analysis is an accessible option, it still requires user action, introducing latency between biochemical fluctuations and user awareness. Integrating real-time data transmission could close this loop, enabling immediate feedback. Overall, this study represents a significant step toward continuous biosensing that is high-resolution, ultrasensitive, long-time, and low-cost, using minute samples and minimally invasive methods. The authors already meet many of these criteria; future advances could focus on accelerating assay kinetics and achieving around-the-clock, passive sampling to faithfully capture the daily rhythms of health and disease.

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Competing interests

The authors declare no competing interests.