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Sweat Analysis: An Emerging Technology for Assessing Health

Medical Materials & Technologies

Sweat. We usually try to avoid it – but sweat helps regulate our body temperature and provides insight into our health. The keys to using sweat in monitoring and diagnosis include choosing the right analyte (for some purposes, sweat analyte levels should correlate with blood analyte levels) and getting enough sample to detect. Sweat sensing technology is still in its infancy. We have a lot to learn and discover.

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How and when is sweat made?

The eccrine and apocrine sweat glands produce sweat. The apocrine sweat glands are found mainly in the axilla (underarm) region and in the groin, whereas the eccrine sweat glands are distributed throughout most other body surfaces. Most research activities and products employing sweat obtain the sample from the conveniently located eccrine sweat glands.

The thermoregulatory center (in the hypothalamus of the brain) triggers sweat production. Sweat evaporates to cool the body and offset the potential rise in core body temperature resulting from metabolism and muscle activity, as well as from heat absorbed from the external environment.[1]

Once the brain indicates the body needs to be cooled, the secretory cells lining each sweat gland pump negatively charged chloride ions into the lumen reservoir of the sweat gland. This is followed by movement of positively charged sodium ions into the lumen to maintain electrical neutrality. Then, osmotic pressure forces water into the lumen. As sweat rises toward the surface of the skin, chloride, followed by sodium, is reabsorbed by the body to conserve salt. The chloride pumps that normally reabsorb salt do not function properly in patients with cystic fibrosis, so their sweat contains abnormally high levels of sodium and chloride and thus it is used as a diagnostic marker for health.[1]

What information can sweat provide about health?

How we sweat impacts *what* we sweat. Sweat from extreme exercise, for example, shows high metabolic activity.[2] Skin warming, vigorous exercise, or work in an extreme environment all cause sweat. Key areas for where sweat detection may be used include: health monitoring, such as early disease detection; monitoring of high-performance athletes; and monitoring of stress, dehydration, and exhaustion in personnel who work under extreme conditions. Practitioners can obtain resting-state sweat (preferred for medical screening) by local induction of sweating by warming or by chemical means, such as by iontophoresis using a pharmaceutical.

Various sweat components and characteristics can be measured as follows:

Volume

For high-performance athletes, or in people who are working in extreme conditions, measuring the volume of sweat produced within a time period can supply information about fluid loss.

Ions

During dehydration (for example, from athletic competitions or work in extreme environments), the concentrations of ions (sodium, chloride, potassium) in sweat do not necessarily increase.[3] This is because salt ions (sodium and chloride) are reabsorbed by cells in the sweat gland before the sweat reaches the skin surface. The ionic content of sweat does increase during profuse sweating because the sweat is secreted so rapidly that reabsorption of sodium and chloride ions lags production during profuse sweating.

Sweat analysis could also provide a window on extreme fatigue. The concentration of ammonium ions in sweat and in blood rises during exhaustive exercise (such as during sprinting), but not during endurance exercise, to five or so times the value when sweating is induced by warming the skin.[4] Thus, a rise in ammonium ion concentration in sweat is a marker for exhaustion.[4]

Small molecules, including metabolites:

Body tissues that lack enough oxygen to metabolize glucose produce lactate to generate energy. Muscles generate lactate during exhaustive exercise, accompanied by an increase in lactate concentration in the blood and sweat. Thus, like ammonium ions, lactate in sweat can help indicate physical exhaustion.[4] (One potential complicating factor that must be considered in the use of lactate as a marker for exhaustion is that the sweat gland itself is composed of tissues, and under exhaustive exercise, the sweat gland tissues can make lactate and secrete it in sweat.[3]) Lactate sensors utilize an enzyme, lactate oxidase, that converts lactate to another organic molecule and hydrogen peroxide. This process is accompanied by electron movement and can therefore be detected using an electrochemical sensor.

Sweat-based glucose sensors mirror changes in blood glucose during exercise.[5] Glucose can be detected in a manner like that used for detecting lactate, except that the enzyme used in the electrochemical sensor for glucose is glucose oxidase. Glucose in sweat may have important uses in monitoring diabetes.

The cortex of the adrenal glands produces a small organic molecule called cortisol that is released into the blood during daily rhythmic timing and stress. Sweat level cortisol has been shown to correlate with blood level cortisol.[6] Cortisol helps suppress the immune system, so cortisol levels may provide a convenient way to detect stressed and immunocompromised states.

Some research has been directed toward determinations of blood levels of drugs and their metabolites. Ethanol (drinking alcohol) concentration in sweat is highly correlated with blood ethanol concentration.[7] Determining whether it is practical to measure absorption and metabolism of other drugs using sweat analysis requires studies to assess the level of correlation of the drug or marker in sweat and in blood.

What components are needed in sweat sensor development?

To sample blood and other fluids (e.g., interstitial fluid) health-monitoring sensors currently require skin puncture or insertion of a filament into the skin to sample blood and other fluids (e.g., interstitial fluid). An attractive alternative to those invasive measures is detection of biomarkers from sweat. Continuous sweat monitoring requires systems of electronic sensors that adhere to skin.[8] The electronic sensors must be thin, flexible, and wireless, and the skin adhesive should be comfortable and otherwise acceptable to the end user who typically must wear such a sensor for hours or days to collect information to monitor, diagnose, and/or treat a health condition. Moreover, the sensor must maintain good skin adhesion during showering and exercise. Electrical sensing technology and skin adhesion science are vital components for the success of sweat- sensing innovations.

References:

[1] Tierney LM, McPhee SJ, Papadakis MA (2001). Current Medical Diagnosis & Treatment (40th Edition, pp 289-290, 894, 1543-1544). Lange Medical Books: McGraw Hill.

[2] Nariya M, Nyein HYY, Javey A (2018). Wearable sweat sensors. Nature Electronics. 1: 160–171.

[3] Heikenfeld J. (2014). Let them see you sweat. IEEE Spectrum 51 (11): 46-63.

[4] Mitsubayashi K, Masayasu S, Eiichi T, Isao K (1994) Analysis of metabolites in sweat as a measure of physical condition. Analytica Chimica Acta (289): 27-34.

[5] Hong YJ, Lee H, Kim J, Lee M, Choi HJ, Hyeon T, Kim D-H (2018). Multifunctional Wearable System that Integrates Sweat Based Sensing and Vital Sign Monitoring to Estimate Pre /Post Exercise Glucose Levels. Advanced Functional Materials 28 (47).

[6] Kinnamon D, Ghanta R, Lin K-C (2017). Portable biosensor for monitoring cortisol in low-volume perspired human sweat. Scientific Reports 7 (13312).

[7] Mena-Bravo A, Lugue de Castro MD (2014). Sweat: A sample with limited present applications and promising future in metabolomics. Journal of Pharmaceutical and Biomedical Analysis 90 (5): 139-147.

[8] Xu S, Jayaraman A, Rogers JA (2019). Skin sensors are the future of healthcare. Nature 571: 319-321.

[9] Yang Y, Gao W (2018). Wearable and flexible electronics for continuous molecular monitoring Chemical Society Reviews.

[10] Bandodkar AJ, Wang J (2014). Non-invasive wearable electrochemical sensors: a review Trends in Biotechnology 32.

[11] Bandodkar AJ, Jeang WL, Ghaffari R, Rogers JA (2019). Wearable sensors for biochemical sweat analysis. Annual Review of Analytical Chemistry 12: 1-22.

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