Wearable microfluidic sensor to measure lactate concentration in real time

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It's important to use non-irritating materials in the design of wearable sensors that are used for quantifying lactate levels during exercise. Credit: Tokyo University of Science

With the seemingly unstoppable advancement in the fields of miniaturization and materials science, all sorts of electronic devices have emerged to help us lead easier and healthier lives. Wearable sensors fall in this category, and they have received much attention lately as useful tools to monitor a person's health in real time. Many such sensors operate by quantifying biomarkers, that is, measurable indicators that reflect one's health condition. Widely used biomarkers are heartrate and body temperature, which can be monitored continuously with relative ease. On the contrary, chemical biomarkers in bodily fluids, such as blood, saliva, and sweat, are more challenging to quantify with wearable sensors.

For instance, lactate, which is produced during the breakdown of glucose in the absence of oxygen in tissues, is an important biomarker present in both blood and sweat that reflects the intensity of physical exercise done as well as the oxygenation of muscles. During exercise, muscles requiring energy can rapidly run out of oxygen and fall back to a different metabolic pathway that provides energy at the "cost" of accumulating lactate, which causes pain and fatigue. Lactate is then released into the bloodstream and part of it is eliminated through sweat. This means that a wearable chemical sensor could measure the concentration of lactate in sweat to give a real-time picture of the intensity of exercise or the condition of muscles.

Although lactate-measuring wearable sensors have already been proposed, most of them are composed of materials that can cause irritation of the skin. To address this problem, a team of scientists in Japan recently carried out a study to bring us a more comfortable and practical sensor. Their work, which was published in *Electrochimica Acta*, was led by Associate Professor Isao Shitanda, Mr. Masaya Mitsumoto, and Dr. Noya Loew from the Department of Pure and Applied Chemistry at the Tokyo University of Science, Japan.

The team first focused on the sensing mechanism that they would employ in the sensor. Most lactate biosensors are made by immobilizing lactate oxidase (an enzyme) and an appropriate mediator on an electrode. A chemical reaction involving lactate oxidase, the mediator, and free lactate results in the generation of a measurable current between electrodes—a current that is roughly proportional to the concentration of lactate.

A tricky aspect here is how to immobilize the enzyme and mediator on an electrode. To do this, the scientists employed a method called "electron beam-induced graft polymerization," by which functional molecules were bonded to a carbon-based material that can spontaneously bind to the enzyme. The researchers then turned the material into a liquid ink that can be used to print electrodes. This last part turns out to be an important aspect for the future commercialization of the sensor, as Dr. Shitanda explains, "The fabrication of our sensor is compatible with screen printing, an excellent method for fabricating lightweight, flexible electrodes that can be scaled up for mass production."

With the sensing mechanism complete, the team then designed an appropriate system for collecting sweat and delivering it to the sensor. They achieved this with a microfluidic sweat collection system made out of polydimethylsiloxane (PDMS); it comprised multiple small inlets, an outlet, and a chamber for the sensor in between. "We decided to use PDMS because it is a soft, nonirritating material suitable for our microfluidic sweat collection system, which is to be in direct contact with the skin," comments Mr. Mitsumoto.

The detection limits of the sensor and its operating range for lactate concentrations was confirmed to be suitable for investigating the "lactate threshold"—the point at which aerobic (with oxygen) metabolism turns into anaerobic (without oxygen) metabolism during exercise. Real-time monitoring of this bodily phenomenon is important for several applications, as Dr. Loew remarks, "Monitoring the lactate threshold will help optimize the training of athletes and the exercise routines of rehabilitation patients and the elderly, as well as control the exertion of high-performance workers such as firefighters."

The team is already testing the implementation of this sensor in practical scenarios. With any luck, the progress made in this study will help develop the field of wearable chemical sensors, helping us to keep better track of our bodily processes and maintain better health.

More information: Isao Shitanda et al, Continuous sweat lactate monitoring system with integrated screen-printed MgO-templated carbon-lactate oxidase biosensor and microfluidic sweat collector, *Electrochimica Acta* (2020). DOI: 10.1016/j.electacta.2020.137620

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