‘My Sweat my Health’: Real Time Sweat Analysis Using Wearable Micro-fluidic Devices

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Abstract— **In this work a robust, non-invasive and wearable micro-fluidic system was developed and employed to analyse pH of sweat in real time during exercise. The device is incorporated in an optical detection platform designed to provide real-time information on sweat composition. The device has been tested by monitoring the pH of sweat during 55 minutes of cycling activity. During these trials, the data obtained by the micro-fluidic system was compared to pH measurements obtained in parallel studies with a conventional electrochemical sensor.**

Sweat analysis, pH, micro-fluidic, LED

I. Introduction

Sweat is naturally generated during exercise and therefore it is an easy accessible body fluid. It is essentially a filtrate of blood plasma, containing many substances such as sodium, chloride, potassium, urea, lactate, bicarbonate, calcium, ammonia, amongst others [1]. Through analysis of its content, it is possible to obtain useful information about the physiological condition of the body, especially during sport activities.

There are several factors that correlate sweat pH and health. Changes in the pH of the skin are reported to play a role in the pathogenesis of skin diseases like irritant contact dermatitis and acne[2]. Patterson *et al.* showed that inducing metabolic alkalosis through the ingestion of sodium bicarbonate led to increased blood and sweat pH [3]. A relationship was also observed between pH and sodium (Na^+) levels in isolated sweat glands in that elevated concentrations of Na^+ were associated with higher pH values [4]. Exercising in a dehydrated condition appears to lead to increased levels of Na^+, through both direct measurements using a Na^+ selective sensor, and indirect measurements of sweat pH [5].

Different sweat collection techniques have been employed over the years [6]. A common method for testing the components of sweat after exercise is to use the whole body wash down technique. The procedure involves weighing the subject before and after exercise to determine whole body sweat loss. All fluids lost during the workout are collected and stored for analysis [4]. However, this method has been found to generate results with a high coefficient of variation, and attention has moved to sweat collection patches or capsules [7]. For example, a disposable sweat collector developed by Brisson *et al.* consisted of a capsule, created inside a flexible adhesive membrane pasted onto the skin [8]. The collected samples were then stored at low temperatures for subsequent analysis in the laboratory. However, this technique is not able to give real-time information about the physical condition of the body and, moreover, there is also a high risk of contamination of the sample.

With the miniaturisation of electronic components and the possibility to realise wearable, flexible and cheap Lab-on-a-Chip (LOC) systems new routes have been provided to perform on-line and real time sweat analysis. Several systems were developed such as the Biotex (EU-funded project-www.biotex-eu.com/) [6] and a pump-less wearable micro-fluidic device [9].

The device presented in this work improves the capabilities of existing technology by the fabrication of an micro-fluidic chip that, through the integration of a simple cotton thread in the channel, significantly improves the platform robustness and response dynamics.

II. Micro-fluidic Device Fabrication

The micro-fluidic device is made using poly(methyl-methacrylate) and PSA (pressure-sensitive adhesive) polymer sheets and lamination. Figure 1 shows a photograph of the chip as well as a scheme of the fabrication protocol. The sensing area is a piece of textile (1x1 mm) embedded in the middle of the device with a pH sensitive dye, which varies colour according to the pH of the sweat. Bromocresol Purple (BCP) dye is employed because its colour change is in the physiological pH range of sweat (pH 5-7).

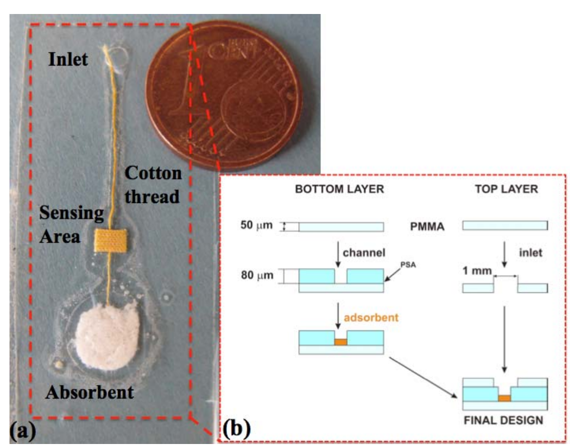

Figure 1. (a) Picture of the chip. The yellow colour of the sensing area and the thread is due to the acidic form of BCP. (b) Schematic representation of the chip fabrication.

In order to improve the flow characteristics, a thread of cotton (also dyed with BCP) was inserted into the channel. With this novel configuration, fresh sweat easily reaches the sensing area. Moreover, the sweat is drawn continuously by capillary action to the absorbent generating a continuous flow of fresh sweat through the sensing area of the chip. The whole device is 44x20 mm, with a thickness of 180 µm, ensuring high flexibility and minimising loss of contact between the chip and the underlying skin surface.

III. Results And Discussions

The micro-fluidic device was calibrated with buffer solutions at different pH values using artificial sweat prepared according to the standard ISO 3160-2. The detection of pH takes place by means of a surface mount photodiode and a light emitted diode (LED) placed above and below the sensing area (Figure 2). Correlating the light intensity with the pH, a calibration curve of the dye was obtained with a pK_a of 6.8, which slightly greater than the value of 6.2 reported previously in the literature.

Sweat pH was monitored in real-time throughout a 55 minutes cycling trial. The device was fixed to the lumbar region of the back using a belt, with Velcro tape to close the sweating area and keep it dark during data collection, Figure 2. To verify the reliability of the measurements of the micro-fluidic device, a conventional glass pH electrode was used to make reference measurements.

In Figure 3, the pH of sweat reported by the device agrees with the parallel measurements obtained by the pH electrode. At 20 and 30 minutes, the pH deceases substantially due to an increase in the sweat rate, when the volunteer was cooling down after intensive cycling activity.

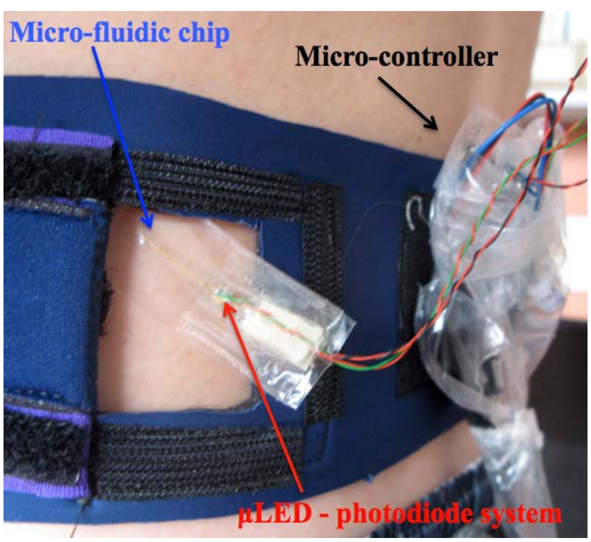

Figure 2. Sensor placed on the back during an exercise trial.

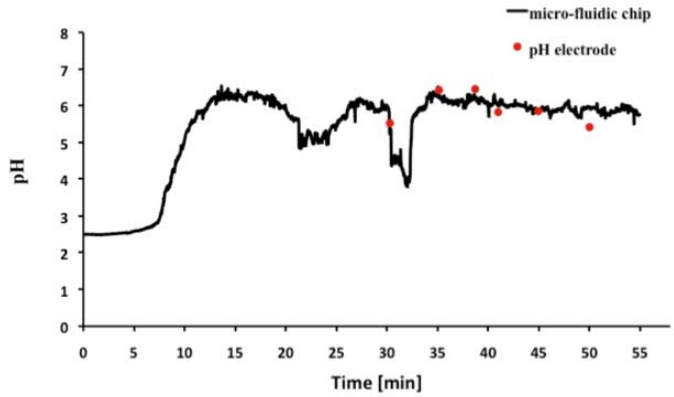

Figure 3. pH of sweat monitored during 55 minutes of cycling exercise.

IV. Conclusion

The micro-fluidic device reported in this paper provides a robust and reliable means to track changes in sweat pH in real-time, by means of an innovative wearable LED-photodiode detection system. Using this device, it is to perform real time analysis of sweat during training by means of a non-invasive sampling technique. Moreover, the device is flexible and comfortable to wear, avoiding any inconvenience for the wearer.

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