Sweat Collection Method with the Principle and Application of Wearable Sweat Biosensors

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Abstract. The accessibility of sweat as a bodily fluid and its rich composition of physiological information have garnered significant interest among researchers. In recent times, the utilization of flexible wearable biosensor devices for the detection of sweat has emerged as a prominent area of investigation, driven by the growing emphasis on personal health monitoring. The recent years have seen a remarkable increase in the development of wearable sweat sensors. In addition, there have been several improvements in the technology used to collect sweat, such as the whole-body washdown system, the Microarc conductivity system, and tiny microfluidic. The purpose of this study is to discuss the recent advancements in sweat collection technology and examine both the positive and negative aspects of these advancements. In this work, the classification of wearable sweat biosensors as well as the principles underlying their application are presented. The report also discusses the potential applications of the technology in a variety of different industries.

Keywords: Sweat, collection, biosensor, principle, application.

1. Introduction

The capacity to swiftly, constantly, and non-invasively record changes is a feature of wearable sweat biosensors. The detection of biological systems by biosensors is effective, and they have significantly advanced clinical diagnostics.

Wearable sweat sensor is an emerging technology. It can detect substances in sweat, such as the metabolites and micronutrients. In many different industries, including medical, business, the environment, process control, and biological samples, there is growing interest in biosensors. As a result, numerous studies have focused on creating adaptable, sensitive, and selective nanomachines that can target analytes using optical, electrochemical, and mass spectrometric techniques. Electrochemical studies, particularly those using ampere metric, impedimetric, potentiometric, and voltametric techniques, have a wide range of applications in these methodologies [1]. One of the most significant attributes of self-powered electrochemical biosensors is their capacity to operate at ambient temperatures without external heating, hence minimizing or eliminating the requirement for electricity [2].

2. Sweat collection device

2.1. Sweat Composition

The components in sweat are metabolites additional micronutrients (e.g., K+, Ca2+, Mg2+, Fe2+, and vitamins), cytokines, and cortisol [3]. Metabolites contain glucose, lactate, bicarbonate, amino acids, ethanol and urea. It is precisely because the components in sweat can reflect human information that monitoring the composition of sweat is very meaningful.

2.2. Sweat collection traditional method

There are several old methods for collecting and extracting sweat, such as the body flushing technology, the water absorbing patch technology and Macroduct.

When implementing the complete body wash-down procedure, it is imperative to exercise utmost caution and ensure the verification and reliability of its efficacy. Future research should prioritize the development of a novel methodology for collecting sweat from the entire body that is both reliable

and valid [4]. The accuracy of the whole body washdown method is attributed to its ability to collect and account for sweat runoff from the entire body surface area without impeding the natural process of evaporative sweating [3].

The simple, disposable foil-type sensor patch used in the water-absorbing patch technology may automatically gather a series of 5 samples. The design, sweat influx calculations, and laboratory tests are described first. Following a demonstration of the collector's operation, the new system is put to the test in a physiological test. During activity, the new patch collects sweat, which is then examined in the lab using ion chromatography [5].

The Macroduct conductivity system (MCS) is employed to collect undiluted sweat samples in a coil for the purpose of assessing total solute content by osmolarity or conductivity [6].

There exist two advantages associated with the utilization of the Monte Carlo simulation (MCS) technique in comparison to the gold standard Gibson and Cooke method (GCT). When comparing the GCT and MCS approaches, it can be observed that the MCS approach offers several advantages. Firstly, it is a faster and more convenient method. Secondly, if a sufficient amount of sweat is collected using the MCS technique, the subsequent chemical analysis of the sweat samples may be conducted with the same level of accuracy as the GCT paper collection, as stated in reference [6].

Moreover, it is worth noting that MCS exhibits four distinct drawbacks. Firstly, it requires personnel with specialized skills. Secondly, accurate instrument calibration and thorough cleaning of the conductivity cell after each test are necessary on a regular basis. Thirdly, the disposable MCS is associated with a considerable cost. Lastly, a relatively large number of tests may need to be repeated. These disadvantages have been discussed in a previous study [6].

2.3. New technology for sweat collection

In addition, there are two new technologies, oil film technology and mini microfluidic. Small microfluidics can accurately control and manipulate microscale fluids.

A good integration into a microfluidic system is necessary to fully use a biosensor and maintain its integrity, accessibility for the sample solution, and appropriate sample handling. The needs of a microfluidic system are highly influenced by the application at hand. Sample preparation processes, such as separation, enrichment, mixing, or dilution, may need to be added to sample transit, particularly when genuine samples are examined. Low sample quantities and affordable devices are still preferred, especially for point-of-care applications. Particularly promising in terms of miniaturization and integration with microfluidics are electrochemical biosensors. In-depth descriptions and comparisons of electrochemical detection techniques have recently been published. With a predilection for integrated microfluidic setups or multifunctional microfluidic systems, this study focuses on current advancements in microfluidic electrochemical biosensors [7].

Cell metabolites and clinical indicators are examples of small molecules; glucose is the most well-known member of this class. Food inspection and environmental testing are two more uses for tiny molecule detection. The results from the real biosensors have taken precedence over the fact that some of the devices described in the following identified several parameters. The following list of biosensors for glucose, lactate, ethanol, and cell metabolites made use of the relevant oxidases for analyte identification [7].

The equipment that is presently being utilized will provide more systematic and comprehensive investigations of the intra-individual variability and daily changes of sweat electrolytes inside an individual. This methodology involves the utilization of a unique device to enhance our understanding of sweat mechanisms, their correlation with blood parameters, and significant biomarkers present in sweat that can serve as indicators of an athlete's advancement [5].

These methods of collecting sweat have some limitations. Firstly, it is essential to consider the necessity of qualified employees. Second, the high cost of instruments. The evolution of new technologies in the future may bring new solutions to these limitations. Regardless of the chosen collecting methods, it is imperative to ensure the reproducibility of results by conducting a minimum of two tests.

3. Flexible Sensor Components

Electrochemical biosensors [2] typically consist of the following components: an analyte, receptors, signal, transducer, and data analysis system. An analyte can be any biological or chemical component, including bacteria, viruses, chemical components, and others. Sometimes, this component is referred to as the target. Analytes can come in a variety of forms. Potentiometric sensors and ampere metric sensors are the two categories that are typically utilized when dividing electrochemical sensors into subgroups. The following types of sensors can be differentiated from one another according to the method of measuring the analyte: The second form of potentiometer detects shifts in the electrical current, whereas the potentiometric kind evaluates the response to the analyte based on the differences that are induced in voltage [2].

3.1. Substrate

During the preparation process, in order to enhance the tensile properties of the device, the commonly used processing methods include: (1) making a thin film of a flexible substrate; (2) Forming a network structure of elastomers or polymers; (3) Affix and stretch the flexible circuit with the substrate polymer.

3.2. Electrochemical Biosensors

3.2.1. Principle

An analyte, receptor, transducer, and recording system are components of electrochemical biosensors. When specific molecules (such as proteins, sugars, drugs, etc.) react with biological elements, biological reactions occur.

Biological reactions can trigger electrochemical reactions, such as electron transfer, ion transfer, etc. These electrochemical reactions can be detected through electrodes. Generation of electrical signals: When an electrochemical reaction occurs, the electrode generates an electrical signal that can reflect the reaction of the biosensor element.

3.2.2. Classification

Electrochemical biosensor can be divided to metabolite biosensor, hormone biosensor, pH biosensor and temperature biosensor. For the detection of metabolites in particular, enzymatic electrochemistry biosensors have been created. These sensors stand out for their high bio-catalytic activity and selectivity [8].

3.2.3. Application

Electrochemical biosensors have essentially become the standard in today's medical practice. In the past few decades, electrochemical biosensors have undergone significant development. In clinical contexts, certain of these biosensors, such as glucose meters, uric acid meters, and blood lipid meters, are frequently used as commercial commodities. Examples include glucose meters, uric acid meters, and blood lipid meters. Electrochemical biosensors have also seen widespread application in other areas, such as the food business and the monitoring of the environment [8]. This is due to the exceptional properties that electrochemical biosensors possess.

In order to reach their intended target cells, hormones must first be released by a certain cell type, which is often found in a gland These electrochemical techniques, sometimes referred to as traditional analytical methods, have several benefits for hormone detection in terms of affordable, high sensitivity, quick responsibility, and simple procedure. Additionally, these methods do not need for costly equipment or specialized personnel [9].

Different methods are needed to monitor these various analytes. This study serves as a proof-of-concept for the viability of employing flexible fibers as either ampere- or potentiometric electrochemical sensors. Furthermore, it is shown in mice that the lactate sensors are capable of measuring physiologically significant changes in real time. New sensing equipment, such as those presented here, with real-time measuring capabilities of neurochemical dynamics in the brain offer

substantial promise in the quest to quantify brain function and for diagnostics [10]. These instruments are similar to those reported here.

Because of its affordability, stability, ease of use, minimal sample requirements, and low detection limits, electrochemical biosensors are often utilised in commercial settings. It is quite accurate and repeatable, and it costs less than most other approaches. Electrochemical biosensors continue to address the rising demand for quick, easy, and affordable detection methods for a variety of drug active chemicals in the broad usage of electrochemical sensors found in daily life [1].

However, it only has a little or restricted applicability in marketing. Their shelf life is between six months to a year, which is short or limited. Other compounds can interfere with some electrochemical sensors. Knowing the substances that could interact with the suggested sensor is crucial. Both of these fields will continue to require the capacity to function in a complex biological matrix, which compels researchers to find solutions to biocompatibility and stability issues. Therefore, characteristics that should be taken into account while creating and marketing biological sensors include the following: must be affordable, compact, precise, repeatable, selective/specific, appropriate for multiple analyte detection, and stable. Few sensors—if any—show optimal characteristics for all aspects. Depending on the intended use and the target substance, several aspects may be given priority when creating electrochemical biosensors [1].

3.3. Signal Processing Device

The signal processing device generally consists of a signal acquisition part, a signal processor, and a memory. The basic principle of signal processing is to convert the signal into digital form and then process the digital signal. A digital signal is made up of a number of digital samples, each of which represents the signal's value at a particular instant in time. The transformation of analog signals into digital signals is made possible by devices known as analog-to-digital converters. An analog-to-digital converter takes an analog signal's amplitude value and changes it into a form that can be stored and processed in a computer. This digital signal can then be used to do further processing.

4. Summary

The wearable sweat biosensor developed rapidly. The positive points of biosensor are sensitivity, stability and reliability. Biosensors use these advantages to detect human sweat and detect human health. Biosensors are promising analytical devices that can be used for medical diagnostics. They play a significant part in quantifying certain chemicals in biological matrices [9]. However, the current technology is not fully mature and the cost of biosensor is high, so sweat sensors are not yet widely available. There are also some challenging in sweat collection, such as skin contamination, sweat evaporation, long refreshing time cause errors and limited academic research about sweat biomarkers.

In the future, sweat biosensors have broad research prospects. Sweat biosensors have strong biological system detection capabilities and support important advancements in clinical diagnostics, drug development, food process control, and environmental monitoring.

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