SWEAT ANALYSIS: A PAINLESS ALTERNATIVE TO REAL-TIME VITAL SIGNS ANALYSIS

PART 1: STATE OF THE ART (LITERATURE REVIEW)

Student's Name

Professor's Name

Institution

Date

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Importance of Vital Signs

Currently, more than 764 million people are living with chronic diseases all over the world (Vos *et al*., 2015). These disorders include diabetes, renal disease and cardiovascular disease, among others, contributing to significant health care expenditure in developing and developed nations. Affected individuals are required to visit health care settings to have their vital signs checked to ascertain whether they fall within the normal range or reflect abnormalities. This process often involves vast resources in terms of transportation costs to and from hospitals in addition to time that could have been spent on other meaningful tasks. It is estimated that a quarter of these patients could realise better health outcomes if they were able to keep track of their health from home (Huang 2015). On the other hand, incorporating available medical resources into mobile phones and other portable gadgets promises to prove beneficial for half of these patients. In addition, such devices would help in tracking and documenting specific measurements over time (De la Iglesia *et al*., 2015).

In most cases, taking vital signs involves simple procedures that patients can easily accomplish in the comfort of their homes with minimal assistance from health care providers. The convenience afforded by providing medical resources in the form of portable tools can be useful in the continuous monitoring of vital signs in pursuit of optimal health outcomes. Data collected by patients at home can then be conveyed to their health care providers through sensor networks and multiagent systems.

Monitoring vital signs during physical exercise is important from medical, health care and sports physiology perspectives. In professional team sports, training athletes while having the capacity to draw on scientific factors such as vital signs and physical indications generates better outcomes than merely relying upon a trainer's intuition and experience (Hara *et al.*, 2016). A classic example is the training of the Japanese national rugby team using personalised locations as exhibited by Global Positioning System (GPS) systems to measure speed and bursts of speed. This technology-enhanced training has led to substantial improvements in the athletes' performance. Similar tactics are being used by professional football teams in Japan through the introduction of information and communications technology (ICT) applications into sports (Hara, Kawabata and Nakamura, 2015).

The monitoring of vital signs is not limited to professional sports and medical practice. Physical education teachers in elementary and junior high schools are also urged to be cautious when involving schoolchildren in outdoor physical activities. A recent report in Japan shows that many schoolchildren have ended up in hospitals after suffering heatstroke while exercising (Hara, Kawabata and Nakamura, 2015). The researchers attributed these observations to drastic daily temperature changes and the fact that children require more time to acclimatise to heat than adults. Such mishaps can be avoided by incorporating an ICT gadget that can detect and measure vital and physical signs for each child during and immediately following exercise. However, a wide gap exists between specialised sports and school sports. Furthermore, the weight, dimensions and price of vital sign sensors as well as unsolved technical issues are currently limiting the use of these devices in school settings.

Sweat Analysis in Monitoring Vital Signs

Initially, sweat analysis was done by collecting sweat and subjecting it to conventional laboratory analyses similar to those involving other biofluids such as blood and urine. However, innovations in technology have steered the development of wearable sensor systems that facilitate determining the body's physiological status and delivering immediate feedback that allows prompt intervention. Therefore, these gadgets play a crucial role in assessing and improving individual health and functioning. At the moment, wearable technologies can be obtained commercially and used to observe physical activities and monitor vital signs. However, the currently available commercial technology cannot discreetly avail molecular-level data linked with the body's dynamic chemistry. Thus, the development of sweat-based wearable devices that monitor vital signs and offer biomonitoring capabilities promises to enhance health care.

Currently, several existing gadgets have the capability to use wireless innovations such as Bluetooth or Wi-Fi to establish connections that link to sensors when monitoring vital signs. Examples of such instruments are pulse sensors (Liu *et al*., 2018), glucometers or blood oxygen sensors. Nonetheless, these devices suffer from a shortcoming in that they can only display information transmitted through the mobile tool because they lack inherent information-processing capabilities (De la Iglesia *et al*., 2015). Furthermore, although available wearables track indicators such as heart rate and physical activity, they are not designed to provide information at a deeper molecular level. This technological gap has encouraged a rapid advancement in chemical sensors that can non-invasively detect analytes in accessible biofluids, providing a window into the body's overall dynamic biomolecular state (Bariya, Nyein and Javey, 2018).

A few candidates exist for wearable sensing of physiological information. However, most of these have shortcomings that limit their application. For example, blood and interstitial fluid can be sampled continually by implantable devices but are not readily accessible through non-invasive means in a wearable format. As another example, obtaining tears can be painful or risky. Furthermore, reflex tears can be generated by irritation of the eyes, thereby interfering with sensor readings. Sensors that use urine cannot be executed on a wearable platform, and the constituents in saliva are largely influenced by the most recent meal and thus can provide a highly limited amount of physiological insight.

Conversely, sweat promises immense potential for wearable sensing because it can be produced whenever the need arises without the use of invasive procedures, for instance, through chemical stimulation at localised, convenient anatomical sites. Therefore, sweat is useful for the constant surveillance of physiological conditions. Furthermore, sweat sensors can be placed near the site of sweat production, enabling prompt detection before the analytes decompose. Even though sweat analysis offers challenges regarding the reliable quantification and interpretation of levels of biomarkers, its strengths over the analysis of other types of biofluids have made it the most ideal biofluid for inventions in wearable technology.

Various analytical procedures can be done using sweat to reveal physiological information. For example, electrochemical sensing can be accomplished during sweat analysis. In particular, skin conductance, also referred to as galvanic skin response (GSR), is an analytical method that estimates skin electrical conductance. This parameter often changes depending on the wetness levels on the outward skin and is valuable given that sweat glands are controlled by the sympathetic nervous system (Vinik *et al*., 2017). Consequently, the electrical resistance of the skin changes whenever an individual experiences a strong emotional change (Khan *et al*., 2016), making GSR a reliable sign of psychological or physiological arousal.

Rather than a diagnostic tool constrained to clinical application, skin sweat is a bodily indication used to evaluate human responses in various settings. Various life scenarios can lead to neurological responses from the autonomic nervous system and trigger a rise in skin perspiration. The ensuing moisture alters the skin's electrical conductance, permitting estimation of the amount of sweat produced by the sweat glands in what is referred to as the galvanic skin response (GSR). Because the autonomic nervous system also regulates other bodily features such as respiration, blood pressure and heart rate, GSR has been used to evaluate these life signs. For example, changes in the pace of an individual's pulse together with skin sweat can guide the classification of a person's mental state, assist in distinguishing different mental states and help in the diagnosis of mental stress (Dias and Cunha, 2018).

In physical activities, continuous surveillance of skin sweat is a valuable physiologic indication, offering numerous uses in sports and investigations of human behaviour. Sweat analysis also opens a novel area of inquiry into clinical situations such as dehydration. However, a knowledge of the milieu of physical activity should be a prerequisite to using sweat analysis findings to identify dehydration. These achievements are possible because skin perspiration lends itself to the acquisition of data about a participant's physiological status as a result of the different ions and biomolecules found therein. Therefore, sweat is an ideal biological liquid for non-invasive chemical assessment to detect medical disorders via examination of ion concentrations in clinical settings. Components of sweat can provide indications of electrolyte imbalance in addition to pathological states such as osteoporosis, cystic fibrosis, physical stress and bone mineral loss (Kim *et al.*, 2018). Evaluation of physical stress is particularly valuable in the psycho-physiological assessment of military officers undergoing intensive training (Familoni *et al.*, 2016).

Sensors in Sweat Monitoring

Sweat monitoring uses two major types of sensors: epidermal-based and fabric or flexible plastic sensors. The epidermal sensors provide a conformal connection between the surface of the electrodes and the biofluid that permits direct contact between the electrodes and the epidermis for uninterrupted monitoring. In contrast, plastic-based sensors are frequently used because of their ability to sustain continuous exchanges over a large skin surface area. Such sensors can be fixed into fabric or attached by screen-printing into cloth. Consequently, it is possible to collect precise measurements such as pH and levels of ions such as potassium, ammonium and chloride.

Even though analysing blood as a biofluid facilitates the direct detection of specific diseases, understanding regarding the levels of sweat analytes and health standing remains limited. In the endeavour to comprehend the correlation between sweat analytes and blood or interstitial fluid levels for the purposes of sweat examination for clinical or health checking, it is crucial to first appreciate the mechanism by which analytes are apportioned into sweat (Bariya, Nyein and Javey, 2018). Therefore, the following section describes the biology behind the formation and excretion of sweat.

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