Dehydration measurement using sweat sensor patch and pulse sensor
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ABSTRACT: Technology has increased visibly large. People find ways to easily detect their conditions. Heartbeat and dehydration level is one of the most common among people especially athletes. Athletes are drifted towards wearable technologies to track their training and recovery. Usually a dehydrated person sweats more. The sweat contains various physiological substance and health data. Based on studies sweat consists of salts and ions like $[\text{Na}^+]$, $[\text{K}^+]$, $[\text{Cl}]$, lactate, glucose and ammonia. We are developing a wearable sweat analyser that can detect the raise in concentration of sodium and potassium. The sweat patch consist of a counter electrode created by screen printing Silver Chloride (AgCl) nanoparticles on Polydimethylsiloxane (PDMS) material and reference electrode (RE) created on the patch material by adding a platinum nanoparticle. This sweat sensor patch is connected to a microcontroller along with a temperature sensor and a Bluetooth module. The data which is collected by the sweat patch and the temperature sensor is sent via Bluetooth to mobile application were the data is displayed.

Keywords: Dehydration detection, sweat analysis, sensor patch.

1. INTRODUCTION:

Wearable electronics play a vital role in the lives of people who have medical conditions that requires consistent monitoring of their daily activities and different parameters such as blood pressure, heartbeat, blood glucose and so on. A successful design will have higher impact on the field of medical science if it proves to be robust, compact, accurate and feasible. Flexible electronics can prepare an ideal platform to prototype future custom wearable devices due to its high versatility and manageability. Arising science of nanotechnology and materials has lately contributed to ground-breaking advancements in customized healthcare in flexible electronics. In the following article we will discuss about the recent developments of materials, the manufacture of products, design of sensors and the implementation of systems engage toward non-invasive wearable sensor.

Human body sweat is a complicated physiological combination of different forms of ions like Na+, K+, Cl and chemicals like glucose, ammonia and lactate. The structure of sweat may differ depending upon the physical conditions that connect with pathological illness, salt intake, drug abuse, heat dehydration and fitness conditions. Reports have it that levels of Na+ and K+ have been escalating as an indication of dehydration while fitness workout. Dehydration may result in loss of performance, headaches, vomiting and nausea, and sometimes in extreme cases can even lead to death that if 12%-16% of fluids is lost. Tracking the sweat structure is really a successful way of accessing human beings physical conditions like hydration and salt loss non-invasively. In the field of wearable sensing technologies, this research intends to establish a standardized electrochemical sensing system on the flexible material for constant tracking of ionic substances of body fluids enabling non-invasive
accessibility towards human beings physiological data. A patch material is made up of a sweat storage area, a counter electrode, and an embedded reference electrode. These electrodes could be altered to analyse other ions like Cl, NH3, and lactate, glucose with ion specific components, in the future.

2. WHAT IS DEHYDRATION?

Dehydration is the loss of fluid from the body, often followed by an imbalance of Na+, K+, Cl-, and other electrolyte. It is caused by lack of fluid intake or by losing more fluids than we take in. There are many symptoms through which dehydration can be detected. Many including vomiting, dry mouth, non-teary eyes, nausea and muscle cramps can be symptoms of dehydration. Blood tests and Urinalysis can be some ways through which dehydration can be tested invasively.

- **CAUSES**: Massive quantity of water can be drained out of an individual’s body with prolonged vomiting/diarrhea. Both of these can be resulted by a variety of conditions. Some are mentioned below:
  - Gastroenteritis, also known as “Stomach flu”, is inflammation of digestive tract.
  - Toxicity or drug abuse
  - Condition where the ability to digest or absorb nutrients from food is decreased.
  - Irritation or inflammation of the bowel.
  - Fever, burns.
  - Intense physical exertion and sweating.
  - Excessive urination due to many reasons such as uncontrolled diabetes and intake of medications, for example diuretics.
  - Addison disease, also known as Adrenal Insufficiency, occurs when body doesn’t prepare certain hormone.

- **SYMPTOMS**: symptoms of dehydration can change with duration and person to person. Dehydration in early stages doesn’t have any symptoms, but mild to moderate dehydration can have visible symptoms. In severe cases, dehydration can cause evidently serious symptoms. Those include:
  - Increased in thirst
  - Dryness or/and stickiness in mouth
  - Constipation
  - Less or no tears
  - Fatigue
  - Dry skin
  - Headache
  - Feeling dizzy.
  - Less or lack of regular urination, and urine may appear dark yellow in colour.
  - Fast breathing
  - High heart rate
3. EXISTING METHODOLOGIES:

Dehydration is basically detectable by clinical symptoms and conditions. For early or mild stages of dehydration, laboratory testing is not required, but a group of non-laboratory tests are required for assessing an higher or severe cases of dehydration.

Non-Laboratory Examinations are done when the dehydration level is mild or moderate. In these cases, the individual is observed throughout the day to detect any symptoms of fluid loss or dehydration. Laboratory Examinations are done in case of severe dehydration, to check imbalance of electrolyte and acid-bases and functions of kidney.

Below tabulation (1) shows the various tests available for the detection of dehydration.

| EXAMINATIONS                      | METHODS                                                                 |
|-----------------------------------|-------------------------------------------------------------------------|
| Non-Laboratory Examinations       |                                                                         |
| Urination and tear production     |                                                                         |
| Dryness of skin layers and fluids | Examination of skin dryness and fluid loss is observed                  |
| Breathing rate                    | Rapid or normal rate is observed                                        |
| Heart rate                        | Rapid or normal rate is observed                                        |
| Blood pressure                    | Low or high rate is observed                                             |
| Skin elasticity                   | A part of skin is pinched and is observed if the skin bounces back if it relaxes slowly |
| Capillary refill rate             | Pressure is applied to the sterile matrix (nail bed) until it turns white completely, indicating the loss of blood. The pressure is then released and the time taken for the nail bed to turn pink again, indicating the rush of blood, is observed. |
| Appearance of eyes                | The eyes looks to be sunken or not is observed                           |
| State of consciousness            | Dehydration usually cases dizziness.                                    |
| Laboratory Examinations           |                                                                         |
| Basic metabolic panel             | This panel provides information of body health as well as fluid balance: |
|                                  |   • Electrolytes                                                         |
|                                  |   • BUN also creatinine.                                                |
Urinalysis: Collection of urine and evaluating the colour and concentration as well as the water level.

Complete blood count: Haematocrit is evaluated, as it is elevated due to dehydration.

Glucose: Increase in glucose is the result of uncontrolled diabetes.

Urine-blood osmolality: To evaluate the fluid level in the body.

When the reason of dehydration is evident, then other tests are not required. But if the cause is unknown, several other tests are performed to evaluate the underlying causes. Tests performed for the conditions related with prolonged diarrhea and/or vomiting are:

- Stool culture – done for bacterial infection
- Clostridioides difficile toxin test
- O&P – detection of intestine parasites

Other varieties of tests done to discover the reason for the underlying cause of the symptoms are:

- Blood ketones – to examine diabetic ketoacidosis
- Drugs overdose tests – to detect an overdose
- Liver tests – detecting diseases in liver.
- Anti-diuretic hormone – to detect a deficiency
- Cortisol – to detect abnormalities like Addison disease.

### 4. EFFECTS OF DEHYDRATION:

*Haemoglobin and haematocrit*

Haemoglobin and haematocrit increase during dehydration. A test conducted for 10 subjects for the detection of dehydration shows the effects on haemoglobin and haematocrit before and after exercise for total 60 minutes.

| Table 2. Tests conducted on 10 subjects | In a duration of 0 – 60 minutes |
|----------------------------------------|---------------------------------|
|                                        | Before exercise | After exercise |
| Haematocrit (%)                        | 42.7 ± 0.5      | 44.7 ± 0.5     |
| Haemoglobin (g/dl)                     | 14.8 ± 0.2      | 15.8 ± 0.2     |
| Plasma solid (g/dl)                    | 8.4 ± 0.1       | 9.1 ± 0.1      |
Capillary blood glucose measurements

Dehydration can lead to hypotension which in turn leads to increased used of glucose in tissues leading to false low results of CBG.

Blood Glucose

Dehydration drives up blood sugar. The loss of fluids from the body can lead to hyperglycaemia, high and concentrated sugar level, and high glucose can cause us to urinate more, resulting in dehydration.

Renal function tests

The above study shows, the changes of electrolyte concentration and osmolality in plasma after dehydration (1). Evident difference was evident for the variables between control and dehydrated conditions in the duration of 0-60 minutes.

5. WEARABLE TECHNOLOGIES AND MATERIALS
Accurate sweat complexity measurements and sweat bio-markers need developed groups of wearable molecular devices which are having the capability of interface with the skin directly to track and evaluate the sweat constantly and real time transmitting of the resultant data to the owner via Bluetooth and in case of transmitting to a doctor is done via internet. In this chapter, we study the various methods of the demonstrated biosensor, wireless transmission method, electronics module, and designing for such practical capabilities of systems.

6. WEARABLE SENSING MODELS

Main specifications of the sweat sensor are the skin interface which involves rapid response time and it should be highly sensitive and specificity, durability during different environmental circumstances and the electricity-efficiency should be optimal. Technological advancements in the nanomaterial help us to miniaturize the sweat sensor devices and are highly sensitive towards measurements of very low concentration level of sweat. As it is with traditional methods, wearable sensors provide a working electrode in which the analyte needs to undergo a process of electrochemical reaction and a reference electrode is kept to identify the potential of the working electrode, and the counter electrode which provides the device with current collector to the wearable sensor.

7. WEARABLE SUBSTRATES AND EMBODYING MATERIALS

The traditional electronics as well as electrochemical sensors materials like fiberglass materials, silicon, and glass which all exhibit a rigid and fragile physical characteristic. The human beings surface
epithelium of the skin is very soft and it is also very curvy and the shape is not constant like deformable. This inevitable technical fault of mismatching frequently causes annoyance, discomfort, weak signal reliability, irritation and wearable device system failure for efficient sweat collection and accurate sweat analysis. Therefore, by using highly developed designing technology concepts, soft embodying materials and compatible material perform important tasks in achieving suitable comfort and strong signal reliability, and waterproof skin interfaces devices are created. The materials which have comparatively very low Young modulus like the fabrics, flexible plastics, and special polymers that are very elastic like rubbers, represent as acceptable substrates, embodying top layer, and wearable sensor skin coatings.

![Figure (3)](image1.png) ![Figure (4)](image2.png)

Even though the elastic modules of slim plastics cannot aligned with the skin and is required to bend a fixed non-rigid structure into one unit of curvature, wide range of conductive materials, visual transparency, chemical stiffness lead to increasing need for wearable sensors in different types such as Polyethylene terephthalate (PET), polyester (PE), Polydimethylsiloxane (PDMS), polyimide (PI), inkjet temporary tattoo paper, screen printing.

Although by using these polymers the breathability becomes poor and the incapability to stretch the skin and to fit in the natural movements of skin is restricted, limiting the functional usage of these substrates to miniaturization of designs and tasks that involves skin for a shorter period.
8. CONCLUSIONS

Recent advancements and developments in the wearable field, sweat sensing is mostly triggered by the research in the field of flexible and stretchable compounds as well as fabrication of various solid state electrodes along with technology of microfluidics that could are skin-interface able. The features and capability of the biophysical signal sensors in the existing wearable devices could be enhanced for improved accuracy and reliability through the support of these recently emerging designs. The physiological human health can be accurately monitored to greater extend using the aid of result obtained through proper integration and analysis of the biochemical as well as the biophysical readings. Testing’s and evaluation different wearable model of chemical based sensors proved to be capable of measuring various metabolites, wide range of electrolytes, different heavy metal as well as various hormones and drugs. More research is required on the topic of wearable sensors and instruments so as to enhance the sensing capability and design models with improved accuracy and robustness. On-going studies in the fields of engineering, medicines and sciences can provide an immense contribution to the field of wearable devices if their technologies can be efficiently integrated. A successful design will have high beneficial impact on the field of medical science if it proves to be robust, compact, accurate andfeasible.

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