

A Review on wearable devices on detecting body fluids for personal healthcare

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Abstract--Body fluids are essential for human survival and play a role in virtually every physiological process, from the cellular level to the overall function of organ systems. The major body fluids are blood and urine. These fluid levels should be maintained in our body for proper functioning our body. A significant loss of body fluid can have severe consequences, as seen in conditions like dehydration or severe blood loss. Symptoms can range from mild, such as thirst and dizziness, to life-threatening, such as organ failure and shock. The Fluid Guard device described in the prompt addresses this problem by monitoring for sudden fluid loss, helping to enable a timely response that could prevent these complications. This paper gives a review on various body fluids and the detection techniques using current technologies

Keywords – Body fluids, Wearable devices, blood, urine and sweat

I. INTRODUCTION

Over a person's life, the role of body fluids changes significantly due to age-related physiological shifts. While essential throughout all life stages, fluid balance becomes more fragile and difficult to regulate in older age, which increases the risk of medical issues. In infants, body water occupies 75% of body weight. In healthy adults, total body water stabilizes, typically comprising 50% to 60% of body mass. The most advanced technology in wearable technology, like smart watches, can be used for the easy tracking of movements and health indicators. Devices for the analysis of body fluids in children require special attention, as devices for children have to be made keeping in mind their smaller size, softer skin, and high level of activity [1].

Existing methods for detecting fluid loss in clinical practice have several limitations, as assessing decreased volume status through physical exams and standard

conventional metrics including pulse, BP, breathing rate, and oxygen levels tend to lack reliability [2-4]. Hemodialysis procedures require needle insertion into blood vessels, which can result in bleeding and increase patient risk, while earlier vessel detection methods relying on single- point optical detection are inadequate for monitoring larger areas. Although blood collection is the gold standard for chemical analysis, it is invasive, needs skilled personnel, and is unsuitable for ongoing monitoring—thus, sweat sensing emerges as a practical alternative or many medical applications [2-5]

Although it requires a longer preparation process, urine provides another reliable biological sample. Furthermore, the goal of normalizing the sample volume remains unfulfilled despite its widespread use [6-9]. If urine leakage (urinary incontinence) is not immediately obvious, it could be due to small leak volumes, temporary conditions, or an underlying neurological or anatomical problem. Due to less sensation, the person is unaware of the leakage. Urine, rich in cellular metabolites, is a highly accessible biological fluid and among the most effective biofluids for standard testing [10,11]. Up to 33% of individuals in health centers may experience urine leakage. Mostly these body fluids loss should be detected at early Stage.

Wearable health devices are increasingly enabling individuals to monitor their health more effectively [12], while supplying clinicians with richer datasets for earlier diagnosis and treatment planning [12]. Routine tracking of daily health metrics is highly valuable, as it raises the potential to foresee or avert diseases that are typically identified incidentally during standard medical evaluations. Although wearables that sense vital signs and physical activities offer a practical means for continuous health surveillance, commercial versions remain rigid and inflexible [13].

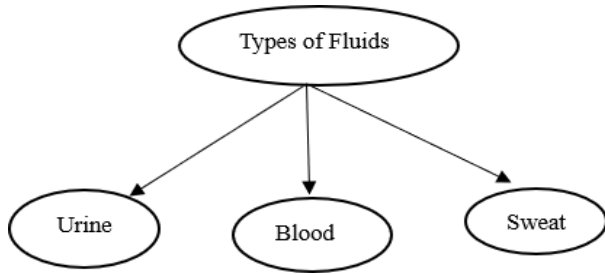


Fig. 1. Types Of Body Fluids

Fig. 1 describes Blood, sweat, and urine are key body fluids for health monitoring. The blood transports oxygen and nutrients, sweat controls temperature and carries biomarkers, and urine eliminates waste products. Wearable sensors monitor the non-invasive and real-time measurement of these bodily fluids, which plays a significant role in the early diagnosis and management of diseases.

II. LITERATURE SURVEY

The increase in the incidence rate of chronic diseases, the increase in the number of elderly people, and the increase in the number of bedridden patients require more sensitive and urgent health monitoring systems, especially for monitoring the loss of body fluids that can lead to critical life-threatening situations if not recognized early enough. Conventional systems for monitoring patients' conditions rely on the monitoring of critical Physiological parameters such as heart rate, BP, respiratory rate, and the amount of oxygen in the blood. However, major studies carried out to investigate the situation indicated that these parameters only provide delayed and indirect symptoms of acute fluid loss in patients. This led to the development and innovation of wearable devices that employ biosensors to directly detect different bodily fluids such as blood, sweat, and urine in the field of health monitoring. Early developments in the field involved the design of a wristband sensor for detecting blood leakage, especially in patients undergoing hemodialysis, and a textile sensor for detecting the loss of menstrual blood. For sweat sensing, progress has been made using flexible, calorimetric, and electrochemical wearable sensors that monitor the rate and composition of sweat. Although these technologies have helped overcome some of the shortcomings associated with blood sampling, there are issues associated with the rate of sweat and contamination. On the other hand, urine sensing using smart textiles and smart toilets has helped in the detection of leaks and biomarkers, mainly for the elderly or those suffering from neurological deficits. The use of wireless communication and IoT has helped caregivers receive real-time notifications from the wearable biosensors.

Yet, despite these advances, most commercial and clinical offerings are only capable of detecting a single fluid or do not have the capacity to quickly discriminate among fluids. They do not offer emergency alerts, which is particularly important in immobilized or cognitively impaired patients. New research trends in fluid detection attempt to address these deficiencies by using multimodal sensor technologies that take advantage of the convergence of flexible biomedical engineering, real-time embedded analytics, and pervasive connectivity. For example, FluidGuard uses an integrative approach that includes humidity, pH, optical sensors, along with a microcontroller such as ESP32. It has real-time alerts that include local alerts such as vibration and buzzers, as well as remote alerts such as applications and SMS with GPS. It uses advanced pattern classification

algorithms to ensure that false alarms do not occur. This device is intended to aggregate high-risk patients. Thus, the literature indicates that there is an increasing focus on sophisticated, AI-enabled, multi-sensor wearable technologies that promise to address the deficiencies in traditional fluid detection, revolutionizing healthcare outcomes.

III. BODY FLUIDS

Body fluids are used to transport and circulation, maintaining homeostasis and immune defense. The major disadvantages of fluid loss are

- Dehydration: loss of fluid is more than the intake, fluid loss takes place, leading to symptoms such as tiredness and dizziness.
- Overloading of the blood vessels (hypervolemia): may strain the heart and kidneys and may lead to swelling (edema).
- Electrolyte imbalance: Abnormal concentration of electrolytes such as sodium may cause headaches and tiredness and in serious cases may be fatal.

A. Blood Loss

Low-volume blood loss can be compensated by humans with little alteration in olden days vital signs. We postulated that, in comparison to conventional vital signs, a unique algorithm that continually estimates compensatory reserve by analyzing photoplethysmogram (PPG) wave patterns will have higher sensitivity and specificity for low-volume blood loss. The compensatory reserve index (CRI), which ranges from 1 to 0, measures the percentage of compensatory reserve remaining to compensate for decreased central blood volume. A CRI of 1 indicates normal blood volume when in the supine position, whereas a CRI of 0 indicates the threshold for hemodynamic instability to begin. These results suggest that the CRI algorithm deserves further evaluation in a true trauma setting [4].

Designing, creating, and evaluating a wristband monitoring device for blood leak detection is still under research. This consists of a photo interrupter, a Bluetooth 4.0 wireless module, as well as power and alert units. The validation outcomes show that it only takes a small quantity of blood, about 0.01 ml, and identifies blood leakage in 1.6 seconds. Additionally, this device's battery lasts longer than those of the commercial goods that are already on the market.

It can monitor constantly for up to 41 hours and continuously sound an alert for 18 hours. Furthermore, the Bluetooth wireless signal's transmission range can be increased to 23 meters. The blood leakage monitoring system developed in this research is a standalone system that can be readily used along with the existing hemodialysis machine. In addition, the monitoring system is a non-invasive tool that enables the easy mounting of the detector on the human arm. In addition, the alert will be sent to a monitoring computer via Bluetooth 4.0 wireless transmission, which is installed with the designated user interface software for the purpose of alerting the appropriate medical staff for the purpose of providing treatment right away. The main objective of the developed blood leakage monitoring system is to react as soon as the blood leakage is sensed., a warning light along with a sound alert will be triggered. Self-monitoring of the volume of menstrual blood loss has the potential to facilitate the early identification of various gynecological disorders. The present

study describes the development of a textile-based blood volume sensor that can be integrated into sanitary napkins for the accurate measurement of blood loss during the menstrual cycle. The principle behind the blood volume sensor is the detection of resistance change, expressed as variations in output voltage. The research showcases the creation of this menstrual blood volume sensor and explores how various design factors influence its volume-sensing capabilities. A key advantage of the textile-integrated sensor is its adaptability, making it suitable for a range of wearable applications. This sensor can also be used to measure the volume of other physiological fluids, such as sweat and urine, because it has already been tested with other salinity liquids [15]

The blood vessel in which the AV Fistula needles are inserted is detected by using a multisensory based on the electrochemical principle using the impedance sensor. The main components of the blood leak detection system include multiplexer, instrumentation amplifier, impedance analyzer, microcontroller, Wi-Fi, and alarm mechanism. The signal is separated into real and imaginary parts by using the impedance analyzer. The real and imaginary parts of the signal are used to calculate the magnitude of the signal. For the detection of the nature of the sample, whether it is human blood or not, the classification of the digital signal is performed by using the artificial neural network algorithm. The classification results are displayed in the form of messages by using the impedance analyzer. The messages are sent to the alarm mechanism for the activation of the visual and audio alarms [5].

B. Sweat Loss

In this article, the authors proposed a novel wearable multi-electrode system that overcomes existing challenges by using one-step electrodeposited platinum nanostructures that ensure reproducibility and biocompatibility. This adaptable platform has four electrodes that enable simultaneous analyte detection, a temperature sensor, and a stable reference electrode with an ionic liquid junction. Additionally, the authors proposed a cost-effective cotton-based fluidic system that enables the continuous supply of fresh samples to the sensor area while removing used samples. The biocompatible and reproducible sensor component has been successfully tested in water, artificial sweat, and human subjects. This adaptable platform has four electrodes that enable simultaneous analyte detection, a temperature sensor, and a stable reference electrode with an ionic liquid junction. Additionally, the authors proposed a cost-effective cotton-based fluidic system that enables the continuous supply of fresh samples to the sensor area while removing used samples. The biocompatible and reproducible sensor component has been successfully tested in water, artificial sweat, and human subjects. The sensor that is biocompatible and reproducible has been successfully tested in water, artificial sweat, and human subjects. This wearable technology addresses several of the basic issues that exist in the current wearable technologies.

It is highly reproducible and performant, it is biocompatible, and it enables the effective management of the sweat samples via a low-cost cotton fluidics approach that is effective in providing fresh fluid to the sensing area [9].

It has only been about ten years since the exploration of sweat-based sensing devices began. With the latest

developments in wearable technology for monitoring activity and physiology, researchers have examined the components of sweat like those in blood, leading to intensive studies of corresponding wearable devices. The various sweat collectors, sensors and integration are discussed in this paper. However the challenges still facing by these wearable devices are calibration contamination, reusability and real time issues [16]

In this research, a wearable and flexible sensor sheet for the measurement of sweat pH, which includes an ion-sensitive field-effect transistor and a flexible temperature sensor, has been developed. The aim of this research is the development of a fully integrated healthcare patch based on the proposed device, which has been tested for sensor, flexibility, and stability aspects. In addition, real-time measurement of sweat pH and skin temperature has been achieved by directly touching the sensor with the skin. The adaptable integrated sensor has the possibility of further improvement for the development of a chemical sensor for sweat, which can be used in the fields of healthcare and sports. In this work, a flexible sweat pH sensor based on the InGaZnO material for the ISFET and a printed flexible temperature sensor have been developed for real-time monitoring of the accuracy of the analysis of the sweat pH and the skin temperature using the proposed sensor and the results from the control measurement using the commercial sensor.

As has been discussed earlier, the InGaZnO material system has immense potential in the future for the fabrication of low-cost, disposable, and flexible electronics, as well as highly integrated multifunctional electronics, because of the various synthetic methods that can be used for the preparation of the material, such as solution-based methods or semiconductor display fabrication techniques [13].

A system has been developed and tested that is capable of carrying out the measurement of the rate of sweat using the method of calorimetry. The system that is used to monitor the measurement of the rate of sweat has been validated in the lab with a syringe pump and through real human tests.

Internet of Things (IoT) setup is included in the design, with the sensor using a Simblee board and a Raspberry Pi. The whole system can transmit the sweat rate data immediately to a smartphone or the cloud. A calorimetric flow rate sensor and a Macroduct sweat collector were used to measure the rate at which the body is producing sweat.

The data is collected by using an IoT system in either of two ways: by showing the sweat rate on the smartphone or by showing the sweat rate in the cloud using ThingSpeak. To test the efficiency of the system in dealing with varying flow rates, a syringe pump is used. Human tests were conducted to check the working condition [17].

Wearable devices that measure sweat loss have been suggested as a way to improve upon the shortcomings of tracking biomarkers and lower the differences in results between people and within the same person over time. These devices also show great promise in keeping an eye on the body's internal balance, since sweat loss is a key part of regulating body temperature and maintaining skin moisture. These wearable devices also helps to check the body's internal balance using the key sweat. Major drawback of this device is sweat rate is not even throughout the body and often contamination occurs [18]

C. Urine Loss

In this paper, a system has been proposed that is wearable and has the ability to detect urine leakages with the help of a sensor stitched in the cloth. The system has three main parts: the sensor, the processor, and the server. The system has a moisture-sensitive textile capacitive sensor and the necessary parts for the processor and server. The system is capable of collecting the information from the sensor and sending the information wirelessly using Wi-Fi connectivity and saving the information in a database. Later, the information can be accessed using the help of the Grafana tool and can be made available for the medical staff or the caregiver. The results obtained from the system were compared with the results obtained from the normal system under various test conditions, and similar results were obtained. The system can be used in underwear and bed sheets for the detection of urine leakage. The results obtained can be used for the analysis of the information and developing new protocols for the use of the system in hospitals and homes [10].

Traditional point-of-care urinalysis devices need urine to be collected manually, which can be uncomfortable, difficult to use, or lead to mistakes. To solve this, the toilet itself can be used as an alternative way to collect urine samples and perform tests. By adding a biosensor along with microfluidic technology to a smart toilet, point-of-care urinalysis could be greatly improved. The smart toilet would have a biosensor that can detect and analyze many different biomarkers in urine, giving useful health information about the user. In addition, the smart toilet could keep checking the user's health continuously, providing health information regularly. The data collected by the toilet can be sent wirelessly to a remote system, allowing healthcare workers to view the information as it happens in real-time [11].

An new urine tester was designed that helps provide healthcare services for the elderly and people with limited resources. It allows them to check their health on a daily basis from a distance and decide if they need to go to a hospital or clinic for more detailed medical tests. To ensure that the cost remains low, we have used a charge-coupled device camera for the color-based urine test and test strips that are already available in the market. Other electronic parts have been produced in large quantities to minimize costs. We have tested our urine tester and compared it with the best available device in the market. Our device has been found to be very accurate in detecting different components of urine. This urine tester is part of a non-invasive method of diagnosis and monitoring of health conditions. It has a low-cost CCD camera that acts as the sensor for colors, electronic parts that have been produced in large quantities to minimize costs, and test strips that are already available in the market for the urine test [19].

We recommend merging data from bio health smartphone applications with continuous metabolic data collected from urine metabolites. Despite including only two participants, our analysis-available through an interactive online tool-presents a starting point for tracking lifestyle factors like diet, how the body processes drugs, physical activity, and sleep using urine metabolites. In addition to the technical and financial difficulties of creating such a device, there are many ethical concerns related to collecting, storing, sharing, and understanding personal metabolic data. While these challenges will slow down the development of such a

biosensor, we are sharing this dataset along with interactive web-based tool to show our hope for the future [20].

This paper discusses how a monitoring system is designed, which can be used to monitor urine glucose levels during daily activities. The system consists of a biochemical sensor, hardware with a PIC microcontroller, a control circuit, and a part that analyzes the signals. To test how effective the system is, it was compared with another device, a YSI glucose analyzer, using solutions of glucose mixed with urine. The biochemical sensor used in the system is reproducible, easy to use, and inexpensive enough for mass production [21].

IV. PROPOSED METHODOLOGY

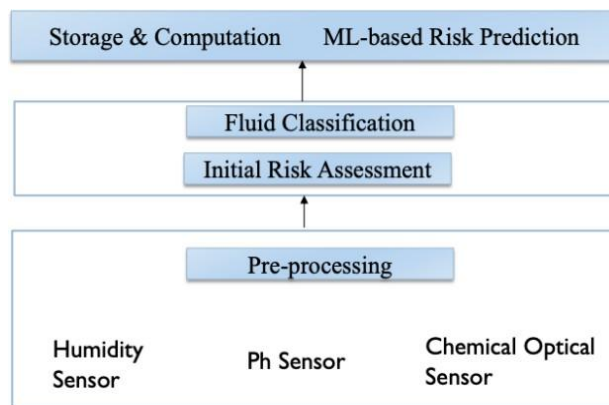


Fig. 2. Architecture for Proposed Work

A representation of the layered architecture of the fluid loss detection system in the healthcare industry is presented in Figure 2. At the core level, the system will be able to monitor the humidity, pH, and chemical optical sensors that will be used in the detection of the fluid loss. After the data is collected from the sensors, the data will be subjected to a pre-processing stage. After the data has been subjected to the pre-processing stage, the fluid classification and initial risk assessment will be conducted. Finally, the data will be forwarded to the higher-level module that will be used in the storage and computation of the data, which will be used in the prediction and assessment of the risk using the machine learning algorithm.

A. PROPOSED ALGORITHMS

Sensor Detection: Signals from the biosensors (humidity, pH, optical) are constantly monitored for the presence of body fluids in the wearable patches.

Fluid Classification: The signals received from the biosensors are used for the classification and differentiation of body fluids using logical thresholds or AI techniques.

Risk Assessment: The level of seriousness of the body fluid detected is determined by classifying the situation as Normal, Warning, or Emergency based on the type and amount of body fluid detected.

Alert Communication: Alert messages are communicated using vibrations, buzzers, and application-based alert messages; in the case of emergency, SMS or voice calls with GPS are sent to the caregiver.

V. EXPERIMENTAL RESULTS

The Fluid Guard project had better outcomes compared to older technologies used in detecting body fluid loss. The older technologies could only detect one type of body fluid, producing many false alarms. The Fluid Guard, however, can detect different types of body fluids, including blood, urine, sweat, and vomit, sending instant alerts to caregivers via vibration, sounds, messages, or GPS. The Fluid Guard detected body fluid loss in a short time of less than 5 seconds, with minimal false alarms, compared to older technologies, which take a longer time to detect only one or two types of body fluids.

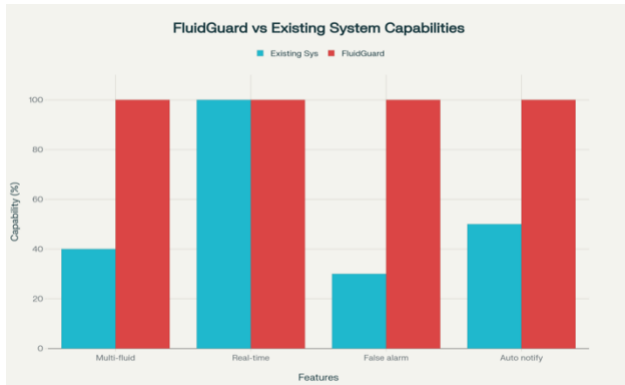


Fig. 3. Comparison of Detection and Alert Capabilities: Existing Systems vs. Fluid Guard

VI. CONCLUSION

The review article has examined various types of body fluid loss and how to address these issues with wearable health monitoring technologies. A diverse array of bodily fluids can be analyzed. In this paper, we focused on blood, sweat, and urine; similarly, we could also explore saliva, tears, vomit, and others. Thanks to technological advancements, it is possible to design a wearable device that can specifically detect losses of body fluids such as urine, blood, and sweat, alerting the affected individual. By developing these health monitoring devices, we can significantly enhance the early identification and diagnosis of potential health complications.

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