WIRELESS SWEAT SIGNAL ANALYSER

Mr. Goutham Raj[1] and Mrs. Rajine Swetha R[2]

[1]PG Student (BMSPI), RV College of Engineering, Bengaluru
[2]Assistant Professor, EIE Dept., RV College of Engineering, Bengaluru

gouthamraj.nagaraj@gmail.com

ABSTRACT

The available health monitors assist athletes for the physical monitoring training. While athletes train, the increase in muscular metabolic rate produces Lactic acid as a metabolic byproduct causing muscle cramps. To release muscle cramps sodium and potassium salt supplements are prescribed in higher dosage to athletes. The purpose of this study is to develop a system **WIRELESS SWEAT SIGNAL ANALYSER** for athletes, to provide athletes with adequate dehydration warning by sweat analysis. The sweat analyzer developed can aid in monitoring diseases related to salt deficiencies such as Goitre, Cretinism, Hyponatremia, Cystic Fibrosis etc. Though there are saliva and urine salt sensor, their accuracies are not appropriate for estimation of continuous dehydration levels, so sweat analysis comes as a viable solution for analyzing. The system proposed will use sweat as the biofluid along with low power components and the data can be wirelessly transmitted to the registered Smartphone, for further interpretations on dehydration analysis and provide adequate warning to the nearby mobile units and the athlete for salt supplementation.

Keywords: *Sweat Analysis; Wireless Dehydration Estimation; Salt Supplement Estimation; Athletic health*

INTRODUCTION

Dehydration is a condition that occurs when the loss of body fluids, mostly water, exceeds the amount that is taken in. Along with the water, small amounts of salts are also lost. Severe dehydration of the body can lead to death. Conditions causing dehydration are: Fever, heat exposure, diarrhea, and increased urination. So in order to avoid the dehydration, a person needs to consume at least 2 liters of water per day.

According to the survey by theguardian, a British newspaper, there has been around 2,162 deaths in 2003. And there has been an improvement in 10 years and it has reduced to 200 per year during 2012.

During exercise sweat is secreted in order to prevent hyperthermia and dissipating the heat produced during physical exercise and muscle activity. Sweat is considered as a non-invasive bio-marker which carries information about the conditions of the person.

In most athletes, the whole-body sweat losses can be around 2L/h during competitive sport, with rates of 3-4L/h during a short-duration, high-intensity exercise in the heat. Also, athletes during exercising and sweating for approximately 4-5 hours, the sodium concentration in the sweat is less than 50 mmol/L. Total sodium lost during this activity is about less than 10% of total body storage. Athletes while exercising at high intensity have a higher rates of heat production which is around 39^{o}c at the core, which has to be dissipated to prevent hyperthermia. Hyperthermia can be prevented by losing the body water by 4% [1].

In humans, the sweat is relatively in plasma state and occurs in the pH range of 4.5 and 7.0 [2]. Fig. 1 shows the proposed design after fabrication and integration. The temperature change in the human body varies approximately from 1^{0}C to 2^{0}C for particular amount of time. It also depends on the core temperature of the person.

This paper proposes a patch based circuit which is flexible in nature and also contains an electrode which involves in detecting the sodium-ion concentration.

LITERATURE SURVEY

This section deals with few literatures with similar methods of salt estimations and athlete’s health. According to *Daniel et.* al, the sweat is hypotonic in nature, and sodium concentration is ranging from 10 to 70 mmol/L, and athletes’ high intensity exercise in heat have sweat rates of 1-2.5L/hour [3]. According to *Bandodkar et.* al, the tattoo based ion-selective sensor to monitor the epidermal pH was almost accurate as pH meter. The pH was approximately 5.3 and ISE was used to calculate the concentration of sodium in the sweat [4]. According to *Denise et.* al Tattoo based sodium sensing was very effective and it may be implemented in military and medical applications, but integration of temperature sensor and miniaturization of transceiver had to be achieved before implementation [5]. According to *Morgan et.* al, the concentration of Na+ increased during the dehydration trials of physical exercise. And increase in Na+ concentration is due to less hydrated and this triggers sympathetic nervous system [6]. According to *Benjamin et.* al, the sweat occurring at forehead contains 56.7$\pm$28.9 mmol/L, whereas the value is half when measured at lower back. Hence measuring site also depends and dietary intake of salt will not correlate to sweat electrolyte concentration [7].

METHODOLOGY

This paper proposes two methods of estimation of water and electrolytes lost due to physical exercise.

Method a:

The Total Body Water (TBW) is similar to the body weight without any intake of food/fluid and no loss of feces/urine. So to calculate the TBW loss, we can take the weight of the person after the exercise and negate it with weight before exercise using any high precision scale with statistically averaging about 15-20 readings [8]. The TBW can be measured by considering the nude body weight as W_0 and W_i denotes body weight after an interval i. Then

$$V_i^{TBW} = W_0 - W_i \qquad (1)$$

Eqn. (1) denotes TBW loss after the i-th interval. Here i-th interval indicates the interval after the exercise with respect to initial workout.

Method b:

Fig. 2 shows block diagram represents how the analysis system works. The sweat which is secreted by the body is acquired and then it is analyzed according to the requirements. Feature extraction involves in extracting the data from sweat like Na^+ and Cl^- salt present, the difference in the salt amounts indicate the status, other types of salts being secreted out of sweat and so on. After the extraction of the required feature, we can process it by accommodating a suitable processor which can provide a precise output suitable to view and understand. Transmission block is used in the system to display the acquired signal in the digital read-out or by using a custom application which can display the amount of salt or amount of water lost has to be recovered. Again this depends on the requirements of the user.

The reader device initiates the communication and requests for the identification from the patch. The patch responds by load modulating the inductive coupling between itself and the RFID reader [9]. Custom commands for programming include reading, writing to memory registers, sensor configuration, power management and other functionalities not required for our present work. When stimulus from central nervous system will trigger the cellular membranes to push negatively charged chloride ions out, they drag positively charged sodium ions with them maintaining neutral charge in the sweat ducts [10]. The interiors of cells would become less salty than exteriors. The imbalance would imbibe water through cell membranes into sweat ducts until sodium and chloride concentrations again match which will result in shrinking of cells until they regain their shape by imbibing more water and salt from adjacent cells. The process repeats to create plenty of sweat [11].

Another kind of displaying the data using a transmission and reception components using filters and modulators. Amplifiers involve in amplifying the signal obtained from analysis which are weak in nature. The transmission and reception module works on radio frequency operating on 434 MHz. The filter in this system is used to remove any motion artefacts recorded during the exercise. An adaptive filter can be used to minimize the signal-to-motion artefact ratio (SMR). The difference equation is

$$e(n) = p(n) - \widehat{m}(n) \qquad (2)$$

Where $e(n)$ is the error signal, $p(n)$ is the measured signal and $\widehat{m}(n)$ is the motion artefact caused by physical activity. And the adaptive structure can be viewed in Fig. 3 [12].

This type of patch should help athletes who generate plenty of sweat every day. Also proposed method can measure sedentary people-for example cystic fibrosis, who do not sweat much. The solution is to use electrical process called Iontophoresis which stimulates skin to produce sweat [13]. Iontophoresis works by placing an electrically charged medication on the skin and using an electrode and low current which is less than 1 milliampere per square centimeter. Joint movements can be measured using fabric strain sensors [14]. In this way dynamic information maybe gleamed from textile e.g. wrist flexion during racquet sports, knee bend during running or gait analysis during walking.

Fig. 4 shows the final device integration involves from the bottom up: skin adhesives, electronics, paper microfluidics, and a vapour porous top adhesive textile. All of these layers are laser cut. An array of circular pores is cut in the bottom adhesive layer to facilitate sweat transmission to sensor. The microfluidic paper layer is interior to the coil and surrounds the sensor electrodes and electronics. If the sensors are placed face-up, then they are covered by the paper layer to bring the sweat to the sensors. Extensive wearability studies may not be performed with this patch in this initial demonstration, and in the event that further breathability is needed by skin areas covered by flexible circuit substrate, then paper-microfluidics layer can simply be integrated beneath the electronics layer to provide horizontal transport of vapour or fluid.

However, precision is not provided for commercial ISEs, and the required values depend on the application. Even simple measurement of trending of Na^+ itself is valuable, Na^+ concentration predicts sweat rate as it increases by 10s of mM in concentration with increasing sweat rate [15]. This patch therefore maybe utilized even in its current form as an athletic exertion sensor, for example. The flex circuit is placed on top of bottom adhesive layer using the vacuum placement tool. Next, the microfluidic paper is placed between the coil and rest of the circuitry. Finally, the top protective layer is aligned and placed, sealing the circuit and sensor within. A final communication test with the RFID reader is performed to verify the operation, and the sweat sensor is ready for programming. As the circuits used in this patch needs to be water-proof, the sealing is very much required or there are chances of sensor damage or salts interfering between connections and damaging them.

SUMMARY AND CONCLUSION

Future work will involve further stabilizing of the Ag/AgCl reference electrode to increase stability of the measured values. Collectively, this paper suggests that the developed sensor is suitable for sweat electrolyte monitoring. Measuring the lactic acid is also useful for athletes, to see if they are getting exhausted or not. By measurement of water loss in the body, we can notify the athlete to balance it by intake of water and salt and reduce the chances of muscle cramps. This analysis involves estimation of sodium salt concentration in the sweat. This information which is obtained is transmitted wirelessly to nearby mobile units so that the user will be able to read and balance his/her salts by intake of salts in order to avoid the muscle cramps. The concentrations of the sodium and chlorine salts in the sweat will increase when the person is forbidden from drinking any type of fluids. Another possible explanation is that the concentrations of Na^+ and Cl^- were increased in blood serum when drinking fluids were forbidden. It is unlikely to observe the increase in concentration of Na^+ and Cl^- as it had to be lost in sweating process. But Na^+ and Cl^- concentration increase maybe due to decrease in water content in the blood through sweating. This reduces the blood volume and Na^+ and Cl- ions could distribute and increase their concentration.

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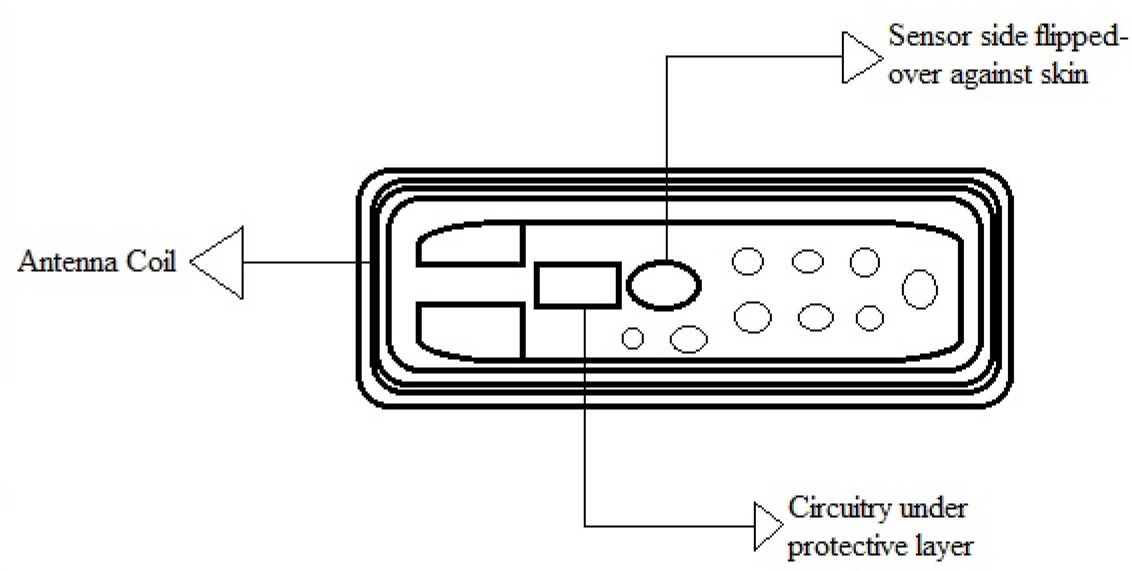

Fig. 1 Shown to illustrate the electronic and sensor features designs.

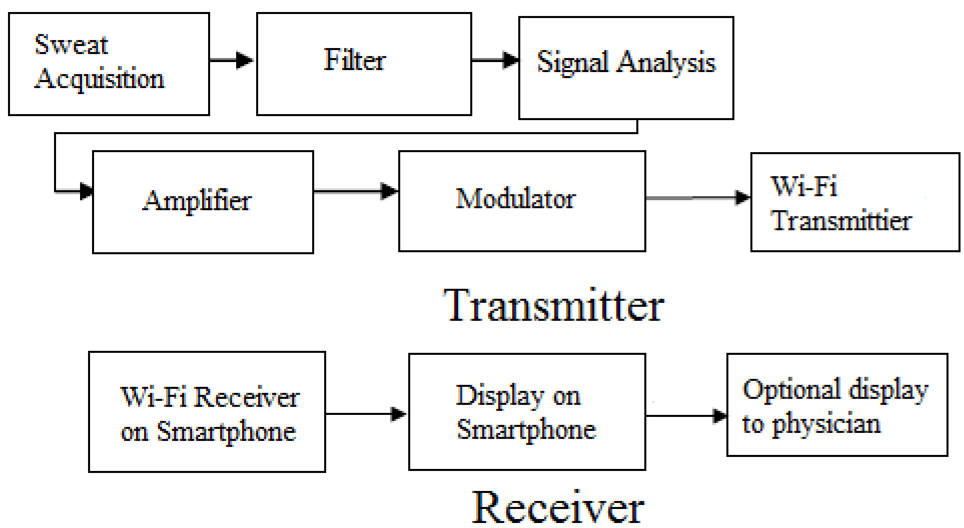

Fig. 2 Showing Block Diagram of Sweat Analysis.

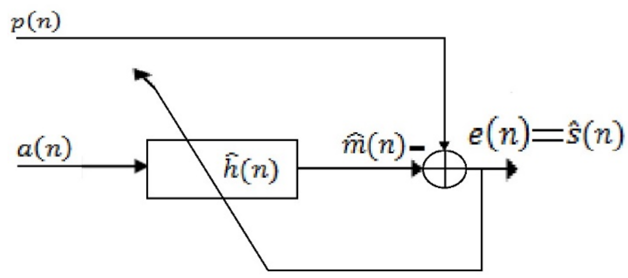

Fig. 3 Showing Adaptive filter for reduction of motion artefacts.

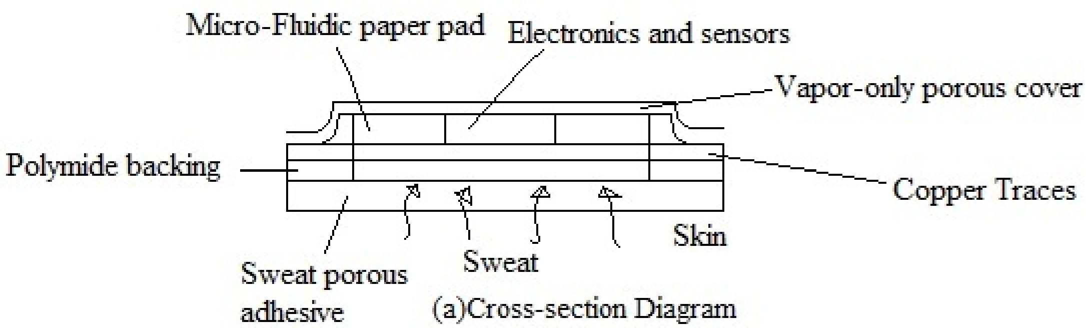

Fig. 4 Showing the final device integration.