Effect of Changes in Skin Conductance, Heart Activity at Constant Temperature for Detecting Binary Pain by Analyzing Nociceptive Stimulation

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Abstract. Pain is a highly inter-variated and subjective feeling. One person's experience of severe pain might not be the same as another's. This study aims to examine physiological signals like skin conductance and heart rate variability (HRV) in order to develop a correlation with nociceptive pain and, eventually, a low-cost module that can recognize the presence of pain in the body. Here we are mainly focusing on the sensation and detection of pain. We believe that skin conductance can yield superior outcomes to any current research.

Keywords: Heart rate variability · Nociceptive pain · Skin conductance · Sympathetic nervous system

1 Introduction

When a stimulus is applied, nociceptors, which are specialized sensory receptors in the peripheral nervous system, are excited, and this causes a signal to travel to the central nervous system. The body's "Fight or flight response" and its defense against damage from our surroundings depend on nociception. Pain that is caused by the activation of nociceptors is referred to as nociceptive pain. Pain differs from the traditional senses (hearing, smell, taste, touch, and vision) in that it is both a discriminative sensation and a graded emotional experience linked to current or potential tissue damage [1]. According to a commonly accepted paradigm, pain is made up of the four components: nociception, sensation, suffering, and behavior. When our body detects the existence of pain, our nociceptors are quickly engaged. Our sweat glands start producing electrolyte-containing sweats as a physiological reaction to the nociceptive signals that reach our peripheral nerves [2]. Sweating and electrical impedance are related because skin conductivity is influenced by the electrolyte content of perspiration.As a result, both respiration and pulse rates increase. In our method, we provided a way to identify the presence of pain

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by observing changes in these physiological indicators. With the use of this technique, pain may be measured, which is important in orthopedic and autism treatment, as well as in surgery, rehabilitation, and pediatric drug dosing and evaluation. The detection of pain is crucial in the area of medicine as it can help with diagnosis, treatment, monitoring, and research. Pain level identification improves diagnosis, treatment, and quality of life.

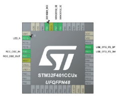
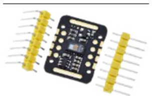
2 Related Works

The many methods that are now being used to distinguish between binary pain using temperature analysis, heart rate, and skin impedance have some limitations. Some of these systems have complex structures and cost a lot of money, whereas others do not. Yet, new and successful pain detection models have been developed as a result of the various studies that have been conducted on the subject. A study was conducted where acute pain was induced in participants through cold exposure. The study focused on observing the effect of acute pain on skin impedance, skin temperature, and heart rate. However, the results showed low accuracy and a high level of error in the measurements taken [3]. In one study, the effectiveness of pain reduction strategies was evaluated by measuring pain responses in infants [4]. Another study investigated the use of skin conductance as a predictor of postoperative pain severity. The feasibility of determining electrode impedance and impedance reduction due to electrolyte spread and increased electrode area were also examined. However, this approach was associated with high power consumption and frequency dependency [5]. Another study looked into the relationship between the skin conductance response and emotional stressors in postoperative patients which corresponds to the idea of dolorimetry that essentially detects the severity of pain. The findings revealed that in these patients, skin conductance response was linked with pain, anxiety, and nausea [6]. Pain and variations in skin impedance are also correlated with heart rate activity. According to research, inducing pain causes an increase in heart rate activity. Heart rate and respiratory rate both rise as a result [7]. Additionally, a study done on healthy people revealed a connection between pain and heart rate [8]. The mechanism of pain is also influenced by temperature. A study that looked at the effect of cold discomfort on hand temperature found a small rise in temperature during acute pain [9]. Another study explored the effect of ambient temperature on human pain and temperature perception. The findings indicated that the mean skin temperature was influenced by the ambient temperature [10]. Previous research did not establish a clear correlation between pain and impedance measurements. The recommended idea stands out for its uncomplicated yet brilliant design and, more importantly, the fact that it is affordable for everyone.

3 Tools

A microcontroller, two different kinds of sensors, and various other tools were utilized (Table 1).

Table 1. Functions of the Basic Components

Name of the Parts	Function	Figure
Microcontroller	It is a high-performance microcontroller based on ARM Cortex-M4 architecture	 **Fig. 1.** STM32 F4 01CCUx
Heart Rate Sensor	It is very small and is based on PhotoPlethysmoGraphy (PPG) It can be worn on a finger or wrist to gather data	 **Fig. 2.** Max30102
Temperature Sensor	One sort of temperature sensor is the DS18B20, which provides readings of temperature in the range of 9 to 12-bits	 **Fig. 3.** DS18B20

4 Methodology

The fundamental objective, in this case, is to establish a connection between discomfort and skin conductance. For this, we split the process into two steps. Since we are unable to carry out the procedure on any patients, we will first manually cause discomfort before observing impedance with pain. We must keep in mind that the patient must initially be in a stable position before attaching the torturing device to the volunteer (Fig. 1).

Our volunteers must be between the ages of 18 and 65, be of any gender, and have no ongoing medical problems. Our volunteers are not eligible if they have ever had heart disease, used certain drugs, such as antibiotics or antidepressants, are pregnant, or have participated in another study within a specific time period. Additionally, the volunteer must be kept in a closed and monitored environment. All participants consented to the

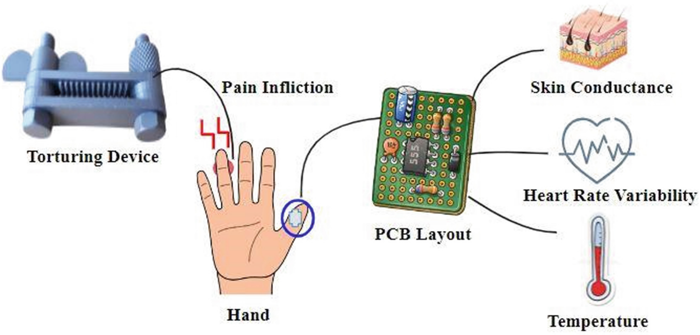


Fig. 1. Methodology Diagram

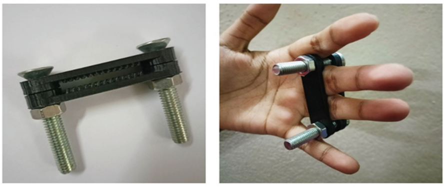


Fig. 2. Torturing Device Designed on SOLIDWORKS and Fabricated by a 3D Printer

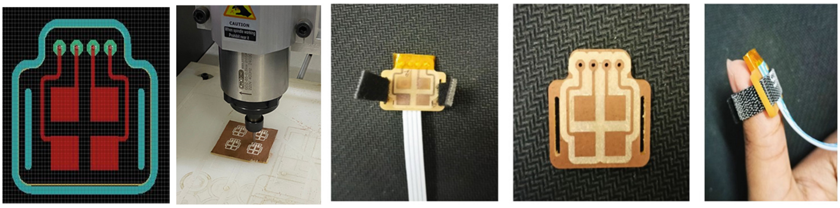


Fig. 3. Designing and Manufacturing of the Electrode to Measure Skin Conductance

study and signed an informed consent form prior to the start of the test. There were twelve healthy, young volunteers, ranging in age from 20 to 25 years. Data collection will begin as soon as the participants are at ease, and this data will serve as a baseline. Once more, the second data will be collected after inflicting discomfort.

4.1 Designing of the Torturing Device

We've constructed a simple torture tool that will deliver steady pressure that will cause discomfort for a brief period of time. In order to accurately assess the discomfort, constant pressure is very necessary. A pressure sensor can make it simple to keep track of the level of discomfort at the thumb (Fig. 2).

4.2 Development of the Electrode

Getting the physiological signals from the participant's skin is a crucial step in measuring the skin impedance. We want a good electrode for this purpose that will fit into our preferred place (the thumb) and continuously collect signals. We have designed the PCB electrode utilizing Eagle AutoCAD software where four electrodes with a surface area of 4mm by 4mm make up this design where we will utilize one as input and another at the output port. Using a CNC X4–800 machine, this copper-plated electrode was fabricated. Following manufacturing, we carried out shouldering to accurately link the electrode with the circuitry using wire. Additionally, we used velcro tape to ensure that the electrode is applied to the skin properly (Fig. 3).

4.3 Development of the Circuitry

We utilized a MAX 30102 photoplethysmography sensor for HRV and a DS18B20 sensor for temperature and our designed sensor for measuring skin conductance. The

DS1B20 communication protocol and the I2C communication protocol are used by the photoplethysmography sensor, respectively. The microcontroller STM 32 transfers the analog data to digital representation after receiving all the data. All of the processed data is once more sent to the PC through CDC-type USB. However, due to switching issues, the STM is unable to directly receive any commands from the PC. Because of this, we created a hardware debugger called ST Link V2 to relay all commands to the STM32. We gave all of the commands using the native STM32 integrated environment (Fig. 4).

In our custom made circuit for measuring skin conductance only the junction voltage will be measured. If the voltage is high, the skin conductance will also be high, denoting a low skin impedance. Additionally, there is a buffer circuit that is used to stabilize the received signal (Fig. 5).

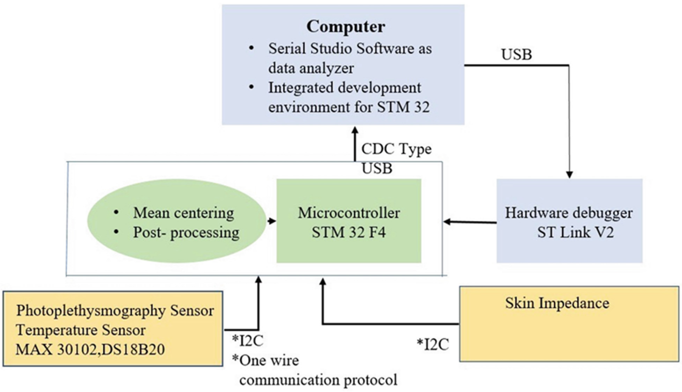


Fig. 4. Block Diagram of the Circuit

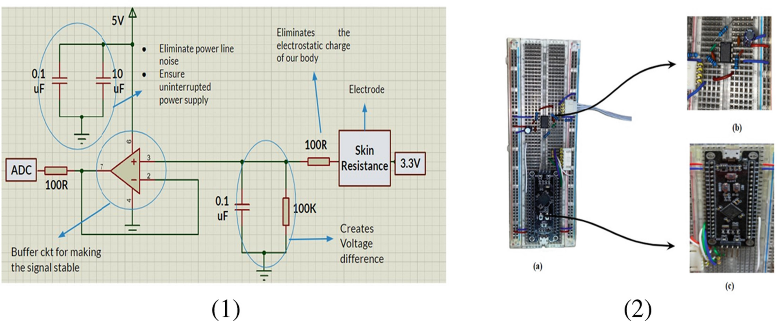


Fig. 5. Basic Circuitry; (1) Circuit diagram drawn in Proteus for measuring skin conductance; (2) (a) Main circuit, (b) Skin Impedance Circuit, (c) STM 32.

5 Results and Discussions

We assessed the skin conductance level of 12 volunteers from various age and gender groups over the course of five days by repeatedly measuring each person's skin conductance level.

Skin conductance level of 12 individual volunteers before and after being subjected to pain. A patient's normal conductance level is shown by a blue bar in Fig. 6 which is the baseline and is almost persistent at constant temperature and physiological conditions. The conductance level following the infliction of pain is shown by an orange bar. Even though the pressure we are applying to the volunteer is relatively minimal, we found a measurable change in skin conductance. In Fig. 7, we can see a graphical illustration of how the degree of skin conductance level has changed generally as a result of discomfort. This outcome is independent of where the pain is being inflicted in the volunteer's body.

The graph in Fig. 8, shows how a single volunteer's skin conductance changed over time as a result of being subjected to pain. The same volunteer was tested three times, and we discovered that the change in skin conductance caused by the same intensity of pain is not constant. We had been using a copper electrode to record the skin conductance signal. We are aware that copper employs an electrolysis response on our skin since it is very much reactive. Additionally, copper corrodes at an extremely high rate. As a result, we had a really positive outcome early on in our trial. However, when the signals grew

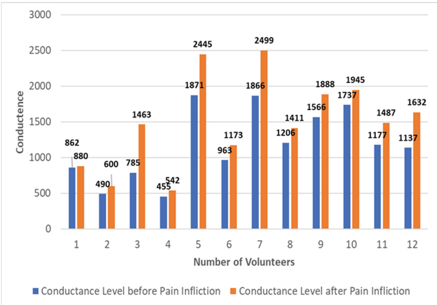


Fig. 6. Change in Skin Conductance Level

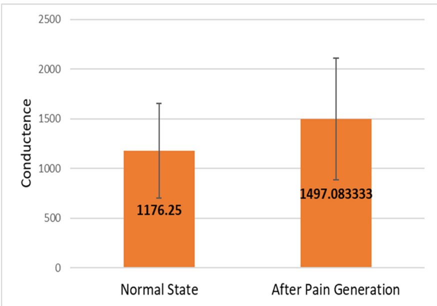


Fig. 7. Avg in Conductance Level with error bar

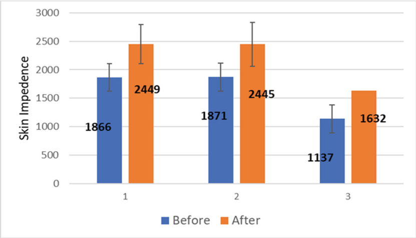


Fig. 8. Variation in Conductance Level

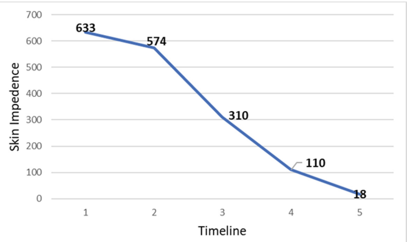


Fig. 9. Conductance Changes (Electrode Corrosion)

weaker after day 3, the conductance level variations were reduced. The data shows in Fig. 9, that skin conductance levels are not changing significantly over time as a result of copper electrode corrosion. However, this outcome suggested that the least chemically reactive metals should be used for electrodes. We conducted a t-test using two sets of data. T-test(paired) between pre and post pain-inducing stimulus data (mean: 1176.25 vs 1497.08; SD: 496.87 vs 638.57) showed a highly significant difference (t-value = 4.9756, p.0004).

When one's level of pain fluctuates, this may be seen in their heart rate variability. The heart rate increases and the heart rate variability diminishes after the pain has been administered using the torture equipment. We did not gather the HRV data precisely because this hypothetical study was focused on skin impedance, but we did monitor, and it confirmed that the theory was correct regarding the relationship between HRV and physiological pain.

This is a volunteer's heart rate variability data in real time extracted by serial studio software as shown in Fig. 10. The heart rate is higher and the pain was experienced here because the left side has a lower degree of HRV. However, the HRV is greater, indicating that the heart rate is normal in the right side region and that no discomfort was present here.

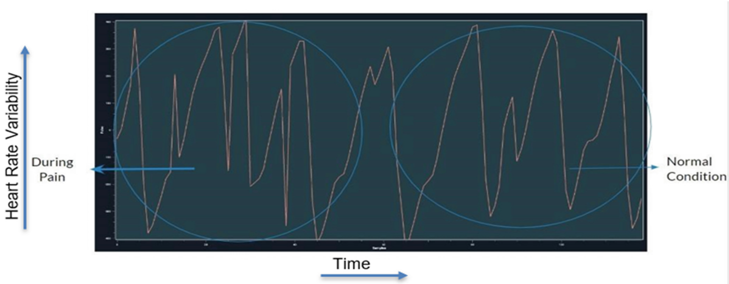


Fig. 10. Correlation between Skin Conductance Level and Heart Rate Variability

6 Conclusion

The project is developed with the intention to establish a hypothetical relationship between physical stressors and skin conductance and heart rate variability which has been proven successful. The journey is not over though. Only using heart rate variability and skin impedance to create a full gadget that can tell us how much pain a patient or individual is feeling during a life-or-death situation like surgery is never enough. Other factors and technologies, such as muscular activity, hormonal reaction, etc., must be included.

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Conflict of Interest. The Authors declare that they have no conflict of interest.

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