Contact Force Measurement Approach for Measuring Glove-Skin Interfacial Pressure

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Abstract. Pressure garments for medical had been widely used to enhance the recovery after an operation, for treatment of arthritis, deep vein thrombosis, leg ulcers, varicose veins or hypertrophic scars. This research aims to develop a contact force measuring approach to measure glove-skin interfacial pressure. With the aid of a force measuring sensors system, it is easier to study the efficiency of pressure garments. Besides, occupational therapists can also design a user-friendly pressure garment that is comfortable and easy to donning and doffing, especially for children. Two types of flexible force sensors were used to measure the glove-skin interfacial pressure using two types of pressure therapy gloves. Pressure therapy glove is selected to represent pressure garments. The measuring sensors were placed at three different locations on the dorsal side of the hand, and the glove-skin interfacial pressure was measured in two different postures, which is full fist and tabletop posture. It was found that different postures had led to different interfacial pressure. The glove-skin interfacial pressure was found to be greater during full fist posture compared to tabletop posture. This show that the applied glove-skin interfacial pressure is affected by postures and movement.

1 Introduction

Pressure garments are garments that are designed to be closely fit around the skin. It was widely used for treatment purposes such as deep vein thrombosis, leg ulcers, varicose veins or hypertrophic scars [1]. It can enhance the recovery and thus improve the subsequent performance of the wearer. A pressure garment is said to reduced collagen formation and increased collagen lysis because of the decreased blood flow and oxygen supply to the scar tissues and increased apoptosis [2]. Most of the pressure garments used in the medical industry normally need to be worn for a whole day or continuous for some time. Thus, the pressure garment must be comfortable to be worn [3].

According to Soto (2011), due to the difficulty in measuring the pressure exerted by garments, there is limited scientifically proven that pressure exerted by pressure garments is beneficial on the treatment [3]. Furthermore, the sensors being used to monitor the pressure exerted by the pressure gloves are required to have a very small resolution which is less than 0.5kPa. There are limited commercial sensors that can detect such low interfacial pressure [3]. Furthermore, each of them has its strength and weakness.

Besides that, there is not a common pressure standard for pressure garments internationally. For instance, the pressure of 15-20mmHg is considered moderate intensity in the US standard, but it is classified as low intensity in the British standard [1]. According to Varan (2017), the pressure required to treat hypertrophic scars may differ among patients [4]. The pressure depends on the time of wound healing and rehabilitation responses of the patients. For example, some patients need pressure garments with low pressure (0-15mmHg) and some might need a high pressure (24mmHg pressure or above) [4]. There may be different pressure for different levels of treatment respectively; hence, it is easier to customize the pressure garments using force measuring sensors [1].

This project aims to develop a force measuring sensor system for pressure gloves applications. With the aid of a force measuring sensors system, it is easier to study the efficient relationship between pressure garments and treatment outcomes. Besides, occupational therapists can also design a comfortable pressure garment that would be used for certain hours in a day.

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2 Materials

In this study, sensors were attached to the dorsal side of the hand to measure the glove-skin interfacial pressure; hence, the sensors chosen need to be flexible. This is because the surface of our skin is not flat, and it may bend when the hand is in a grip posture or others postures. In addition, the glove-skin interfacial pressure is very small and requires a resolution of around 0.5kPa, so the chosen sensors shall have a minimum sensitivity of 0.5kPa. Therefore, the Pololu Force Sensing Resistor and Flexi Force Sensor were selected because both sensors are flexible and can measure small resolution.

Commercially available pressure therapy gloves were selected and tested in this research. Both gloves are used to reduce swelling and pain by applying a certain degree of pressure, as claimed by the manufacturers. Based on the manufacturers’ measurement guide and the measurements of the manikin hand used in this study, glove size S was selected.

3 Method

A preliminary test was carried out to examine and observe the sensor’s performance to ensure the functionality of the sensors. Next, the force measuring sensors system was developed. The pressure exerted by the pressure glove onto the hand was recorded as an analogue input. Arduino MEGA act as a DAQ device to transfer the analogue input from the sensors to a computer through the USB cable. Arduino MEGA is a good choice for any IoT application design as it can receive and carve programs according to the requirements [5]. Lastly, the data from sensors were analyzed using Microsoft Excel.

3.1 General hardware setup

The force measuring sensors were attached to the manikin hand and connected to Arduino MEGA unit before the pressure glove was don. Arduino MEGA was then connected to a computer using USB. Finally, Arduino ADC (analogue to digital) pin was connected by the analogue input from the sensors and the data were then acquired using Simulink Arduino IO Package [6]. Figure 1 shows the hardware setup used in this study.

3.2 Development of glove-skin interfacial pressure system by using Arduino IDE

Arduino IDE software was used to create the force measuring sensor system. The programming language being used is C++ programming. The coding of the force measuring sensor system can be generally divided into two parts.

The first part is the setup part. In this part, the multiple force sensor resistors pins were defined as A0, A1, and A2, respectively. All these force sensor resistors were defined as input. The working mechanism overall can be categorized into 5 sections by using if / else logic code. The reading which is less than 10 is classified as nothing, less than 200 classified as light, less than 500 was classified as lightness, less than 800 was classified as medium. The second part was the loop. The main logic of the circuit was defined, and it ran in a loop repeatedly. The loop function can only run once the setup was completed. In this section, force sensors resistors act as input and the reading was taken consistently.

Fig 1. Hardware setup.
3.3 Development of circuits

After the software part was developed, the hardware had to be built for the experiment. 10k ohm resistors and force sensors resistors are being connected to the Arduino Mega 2560. Figure 2 shows the virtual and real circuits of the force measuring sensor system.

![Circuit of force measuring sensor system.](image)

**Fig 2.** Circuit of force measuring sensor system.

3.4 Testing, measurement and analysis

The commercial flexible sensors were placed at three different locations on the dorsal side of the manikin hand before donning the glove. Medical tape (Elastoplast Elastic Fabric) was used to ensure that the sensor adhered well to the skin. The glove-skin pressure was measured in two different postures, which is full fist and tabletop posture. Figure 3 shows the location of the sensors and the manikin hand used in this research.

During the testing, the experiment setup was similar as discussed in the general hardware setup. After the analog input of the sensors had been converted by the Arduino MEGA and sent to a computer through USB, the data was generated and analyzed by using excel. In excel, the data were tabulated and using graphical method for analysis purposes.

![Location of sensors on dorsal side of manikin hand.](image)

**Fig 3.** Location of sensors on dorsal side of manikin hand.

4 Results and discussion

In the preliminary testing phase, 1.5 litre hall full bottle was placed on the force sensor resistor. Next, the reading was monitored using the serial monitor and plotter of Arduino IDE software. From the reading above, data A0 was taken as a sample to calculate the standard deviation. The reading of force sensors resistors was a bit disperse during the preliminary testing (Figure 4). However, the system was considered as stable overall [7]. From this preliminary testing, it can be said that the force sensors resistors and the force measuring sensor system can function correctly.
Fig 4. Graph of preliminary testing.

The glove-skin interfacial pressure in two different postures of the hand was shown in table 1. The mechanism of the force sensor resistor was focusing on the changing of resistances. From table 1, it can be seen that when the hand changed to a particular posture, the reading changed. In the initial state of the sensor, when no pressure was exerted, the sensor was like an infinite resistor (open circuit), hence the resistance was maximum, and the voltage was hard to flow through. However, when the sensor was pressed, the resistance between the two terminals decreased, increasing the voltage flow. In the interfacial force sensor measurement, the voltage flow through the sensor was defined as output and convert into number for reading. In Table 1 below, A0, A1 and A2 represented one force sensor resistor that acted as an output.

Between the two different force sensor resistors and pressure garments, the readings recorded were quite similar. However, the force sensor resistor located at the middle of the knuckle of the hand recorded the highest reading. This difference was due to the blood pressure under our skin and our body structure, such as the shape of bones [8-9]. When the hand is in grip or tabletop postures, the shape of the middle knuckle is the largest and prominent.

From the experiment result, the glove-skin interfacial pressure is found to be greater during grip hand posture than the tabletop posture. According to Macrae et al., 2016, the applied glove-skin interfacial pressure is affected by posture and movement [10]. In addition, the glove-skin interfacial pressures were different at separate locations in the same posture. Therefore, our results are similar as reported by previous studies [11-12].

Table 1. Reading identification for ISOTONER glove and IMAK glove in two different postures.

| Hand postures | ISOTONER glove | IMAK glove |
|---------------|----------------|------------|
|               | FSR type 1     | FSR type 2 | FSR type 1 | FSR type 2 |
| A0=0.48       | A0=0.44        | A0=0.56    | A0=0.52    |
| A1=0.60       | A1=0.56        | A1=0.64    | A1=0.60    |
| A2=0.52       | A2=0.52        | A2=0.52    | A2=0.48    |
|               | A0=0.48        | A0=0.40    | A0=0.48    | A0=0.36    |
| A1=0.56       | A1=0.60        | A1=0.60    | A1=0.48    |
| A2=0.44       | A2=0.52        | A2=0.36    | A2=0.40    |

5 Conclusion

In conclusion, a force measuring sensor system for measuring glove-skin interfacial pressure was designed and developed. By monitoring the glove-skin interfacial pressure, it is easier to study the efficiency of applied pressure for treatment purposes and the comfort of the wearer when using pressure garment. It was found that glove-skin interfacial pressure was different in different postures and locations of the hand.
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