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Arduino Pressure Sensor Cushion for Tracking and Improving Sitting Posture

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Abstract**—**The average American worker sits for thirteen hours a day, often with poor posture and infrequent breaks, which can lead to health issues and back problems. The Smart Cushion was created to alert individuals of their poor postures, and may potentially alleviate back problems and correct poor posture. The Smart Cushion is a portable, rectangular, foam cushion, with five strategically placed pressure sensors, that utilizes an Arduino Uno circuit board and specifically designed software, allowing it to collect data from the five pressure sensors and store the data on an SD card. The data is then compiled into graphs and compared to controlled postures. Before volunteers sat on the cushion, their levels of back pain were recorded on a scale from 1-10. Data was recorded for an hour during sitting, and then a new, corrected posture was suggested. After using the suggested posture for an hour, the volunteers described their level of discomfort on a scale from 1-10. Different patterns of sitting postures were generated that were able to serve as early warnings of potential back problems. By using the Smart Cushion, the areas where different volunteers were applying the most pressure while sitting could be identified, and the sitting postures could be corrected. Further studies regarding the relationships between posture and specific regions of the body are necessary to better understand the origins of back pain; however, the Smart Cushion is sufficient for correcting sitting posture and preventing the development of additional back pain.

Keywords**—**Arduino Sketch Algorithm, biomedical technology, pressure sensors, Smart Cushion.

I. Introduction

POOR posture can result in muscular imbalances in the body and can reduce the amount of oxygen supplied to the brain, resulting in elevated levels of cortisol in the bloodstream and increased stress. Sitting for extended periods of time can affect mental capacity, sleep schedules, and vision [2]-[4]. Sitting with poor posture and infrequent breaks can also lead to poor back health and ultimately back pain.

The Smart Cushion was constructed using a rectangular foam block that was divided into four quadrants; one pressure sensor was inserted into the center of each quadrant, with a fifth sensor placed in the center of the back half of the cushion, where the tailbone should rest. These sensors were connected to an Arduino Uno circuit board, and software was designed to record continuous pressure measurements over time.

A major factor that contributes to the development of back pain is poor sitting posture, which can be defined as the imbalanced distribution of pressure while sitting [3], [5]. An optimal sitting posture is one that distributes pressure evenly, preventing excessive stress from harming the back. Poor sitting postures can damage the back by contorting the spinal cord and applying excessive pressure to isolated areas of the back [1].

The combination of the Arduino Uno circuit board, pressure sensors, and sitting cushion allowed pressure values during sitting to be collected over a period of time. The ability to obtain numeric pressure values associated with an individual's sitting posture allows mathematical comparisons to be made between an individual's actual posture and a more desirable posture. Comparing an individual's posture with different controlled postures can determine where the individual applies the most pressure and how best to correct poor sitting postures.

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II. Experimental Methods

A. Materials and Electronic Parts

The Walfront DF9-40 resistance type pressure sensors are waterproof, thin-film, force sensors purchased from Ebay.com. The pressure sensors are flexible, created with nanometer pressure-sensitive materials supplemented by ultra-thin film substrates. The highly sensitive, flexible nanometer materials are able to detect very slight changes in pressure. The pressure values are recorded as analog values.

The sensors are 0.25 mm thick and are able to measure from 0.0 to 20.0 kg, with a precision of ±2.5%. When no pressure is applied to the sensor, the resistance is larger than 10 MΩ. The pressure sensors have a response time of 1 ms, a restoration time of less than 14 ms, and a test voltage of 3.3 V. The sensors are able to detect pressure values within a 9.0 mm diameter area.

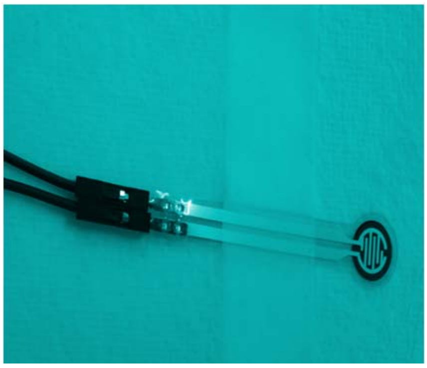

Fig. 1 A DF9-40 resistance type file force sensor

The Smart Cushion was built using a Novashion memory foam seat cushion purchased from Walmart. The memory foam material was able to retain its shape and conform to the volunteer during sitting. The cushion can be placed on any chair, making it portable. The dimensions of the seat cushion are 17.2x14.2x2.8 in.

In addition to the pressure sensors and seat cushion, an Arduino Uno board, breadboard, resistors, potentiometers, wires, and cables were used to construct the model.

Fig. 2 An illustration of the memory foam cushion

B. Placement of Pressure Sensors

Initially, the Smart Cushion was built using 12 sensors. However, after further testing, it was determined that 12 sensors were inefficient and yielded the same quality of data as five sensors. The front two pressure sensors were placed 50 cm from the back of the cushion, while the back three sensors were placed approximately 20 cm from the back of the cushion. All five pressure sensors record individual values.

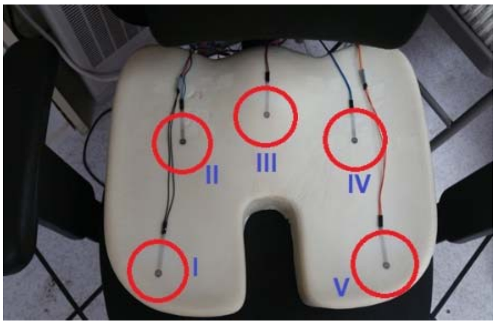

Fig. 3 The sensor placement on the memory foam cushion. The optimal placement of pressure sensors was determined through multiple seating tests

The Arduino system was constructed as shown in Fig. 4. The breadboard and Arduino Uno were hot glued to a plastic sheet, which was strapped to the back of a chair. A memory card shield was placed on the Arduino Uno, allowing data to be stored on an SD card. Each pressure sensor was connected to an individual potentiometer. The potentiometers acted as resistors and regulated the pressure values obtained from the sensors. The Arduino system recorded analog outputs, with a sampling rate of 9,600 bits per second.

C. Arduino Sketch Algorithm and Coding

Refer to Appendix.

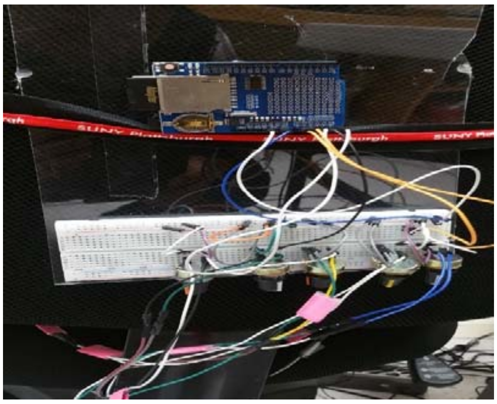

Fig. 4 The Arduino system was glued to a plastic sheet that could be strapped to the back of the chair on which the memory foam cushion containing pressure sensors was placed

D. Posture Trial

Data was collected during a two-part trial. In the first part, a volunteer sat on the Smart Cushion for one hour and rated his or her back pain on a scale from 1-10. To simulate working conditions, the volunteer was allowed to use a computer but was advised to remain fairly still and to not leave the seat. During the second part of the trial, the posture of the volunteer was adjusted to conform to an optimal sitting posture.

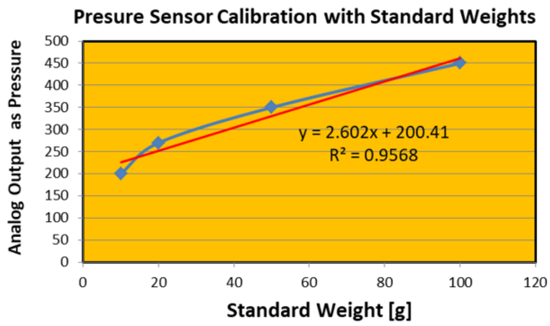

Fig. 5 The relationship between weight and changes in pressure as measured using standard weights from a balance kit

III. Results

A. Analog Outputs with Respect to Weight as Measured by the Pressure Sensors

Fig. 5 illustrates the relationship between weight and changes in pressure that can be measured by the pressure sensors. Although the sensor reported an abrupt increase from 10 g to 20 g, the graph shows an overall increasing trend.

B. Total Sensor Characteristics

Four different weights were placed on top of a single pressure sensor for 1 minute. As shown in Fig. 6, a decreasing trend can be observed in the pressure reported over time. Larger masses appeared to result in more consistent measurements being reported by the sensors.

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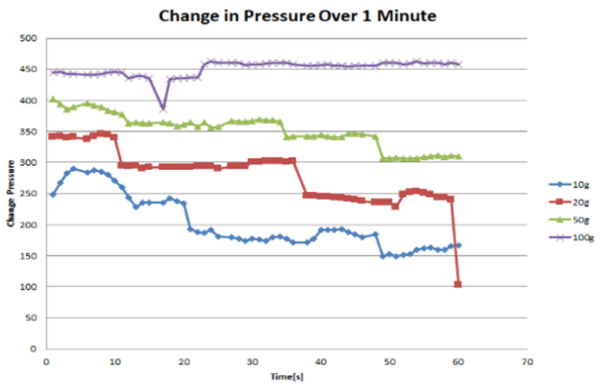

Fig. 6 The characteristic behaviors of pressure sensors

C. Average Changes in Pressure Measured for Posture 1

Posture 1 represents a balanced, upright posture and is generally considered to be the most favorable posture recommended by health professionals, as it evenly distributes pressure across all parts of the seat. Most of the pressure was applied to the front right and back left positions. Fig. 7 also shows that pressure was applied to the middle of the seat, while the right and left side sensors reported the lowest levels of pressure.

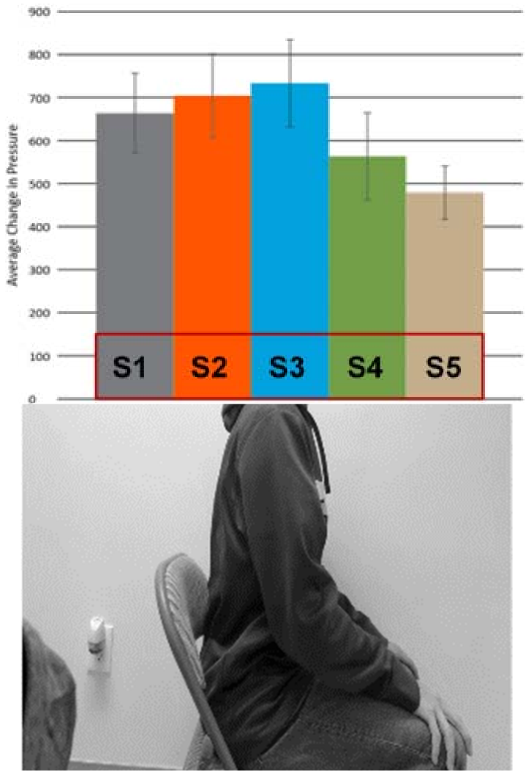

Fig. 7 The average changes in pressure for Posture 1

D. Average Changes in Pressure Measured for Posture 2

Posture 2 represents a seated position where the sitter leans against the back of the chair. In this position, the majority of the pressure was applied to sensors 1 and 2, while less pressure was detected by sensors 4 and 5. This posture is very imbalanced compared with Posture 1.

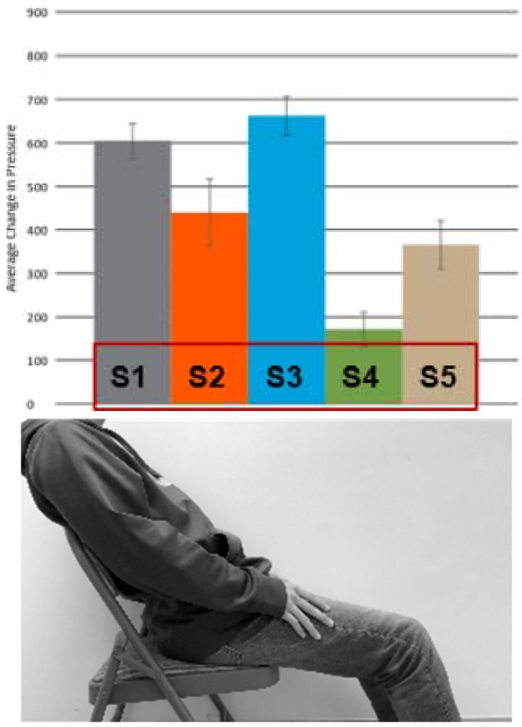

Fig. 8 The average changes in pressure for Posture 2

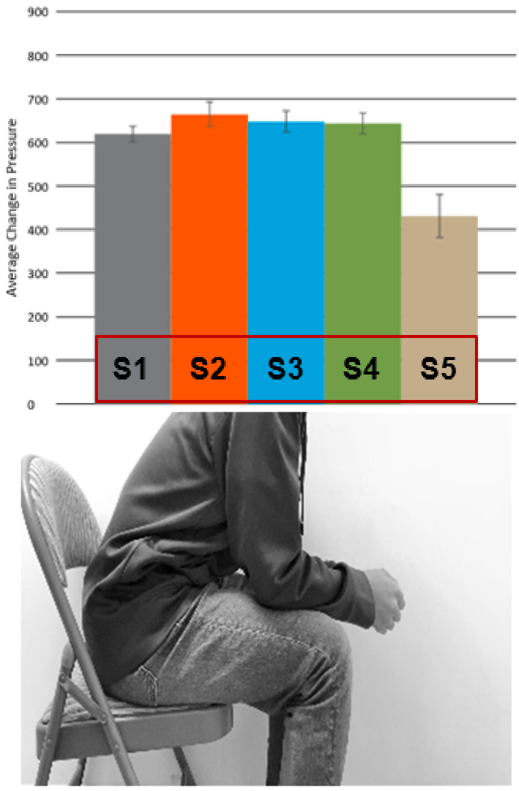

Fig. 9 The average changes in pressure for Posture 3

E. Average Change in Pressure Measured for Posture 3

Posture 3 represents a front-leaning posture, which displayed consistently high values for sensors 1-4. Without knowing the physical position of the individual, it would be easy to assume that this posture is balanced and preferable; however, due to the disproportionate pressure value reported by sensor 5, it can be determined that the individual was slouching; therefore, this posture is unbalanced.

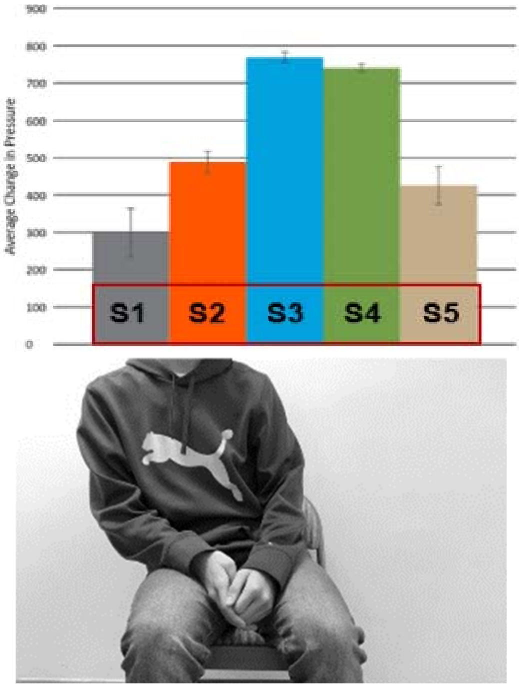

Fig. 10 The average changes in pressure for Posture 4

F. Average Changes in Pressure Measured for Posture 5

Posture 5 represents a left-leaning posture. As shown in Fig. 11, sensors 1 and 2 reported the largest pressure values. This was expected, as sensors 1 and 2 were responsible for collecting data on the left side of the cushion.

G. Average Changes in Pressure Measured for Posture 6

Posture 6 resembles Posture 1. However, during this posture, the arms are raised as if they are resting on a table. The pressure values reported by sensors 1, 2, and 5 were predicted to be the highest, while 3 and 4 were predicted to report lower values. This prediction was nearly accurate, as sensors 1 and 2 yielded the largest pressure values.

TABLE I
THE AVERAGE CHANGES IN PRESSURE REPORTED BY EACH SENSOR

Sensor 1 AVG	679.7159	STDEV	62.74028
Sensor 2 AVG	736.2185		51.09841
Sensor 3 AVG	645.9653		100.7326
Sensor 4 AVG	641.3858		55.98115
Sensor 5 AVG	455.7851		64.72707

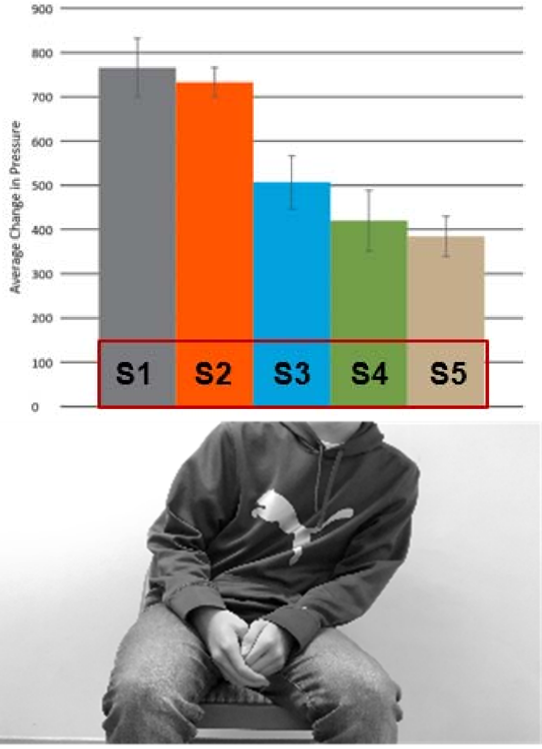

Fig. 11 The average changes in pressure for Posture 5

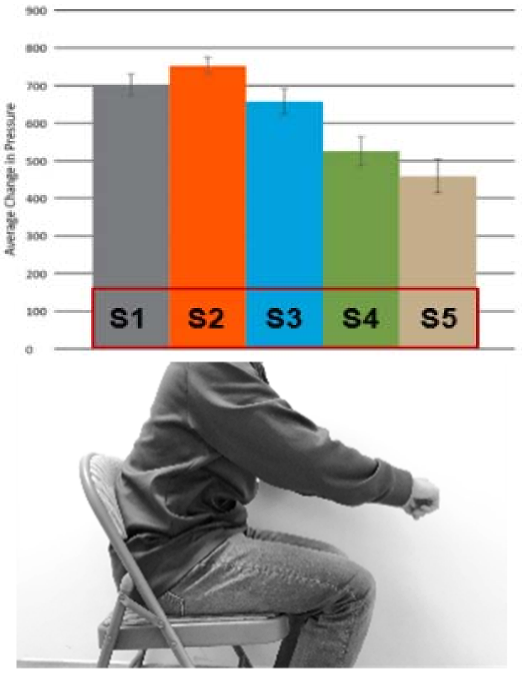

Fig. 12 The average changes in pressure for Posture 6

H. Trial 1: Position 1

As shown in Fig. 13, during part one of the seating trial, sensors 1, 3, and 4 showed increasing trends, with positive slopes. The trend for sensor 2 had the slope val ue that was the closest to 0, while sensor 5 displayed decreasing trends.

As shown in Fig. 14 and Table I, the average changes in pressure measured by sensors 1 and 2 were larger than those for sensor 4 and 5. This observation indicates that, during Position 1, more pressure is being applied the right side of the cushion. After sitting in Position 1 for an hour, the individual gave a back pain rating of 6. After implementing a balanced posture, the individual reported a back pain rating of 2.

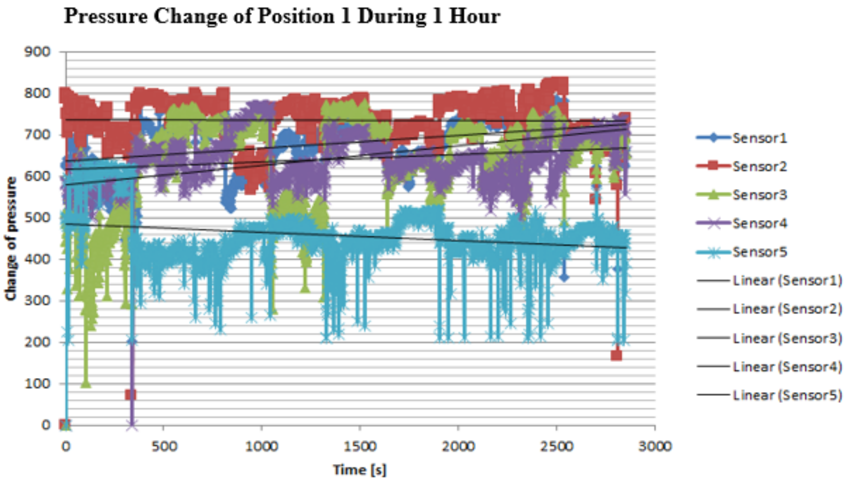

Fig. 13 The pressure changes recorded during part one of volunteer trial 1 over 1 hour; Slope values are as follows: Sensor 1, y = 0.031x + 635.23, R^2 = 0.1593; Sensor 2, y = -0.0008x + 737.17, R^2 = 0.0002; Sensor 3, y = 0.0467x + 579.07, R^2 = 0.1439; Sensor 4, y = 0.0184x + 614.87, R^2 = 0.0703; and Sensor 5, y = -0.0205x + 484.99, R^2 = 0.067

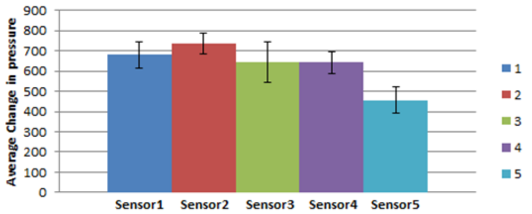

Fig. 14 The average changes in pressure reported by each sensor

I. Trial 2: Position 2

As shown in Fig. 15, during trial 2, the volunteer has a relatively balanced sitting position and leans to the left. The high positive slope for sensor 5 indicates that the volunteer applied pressure to the back of the seat while sitting. At the 500 second mark, there is a steep drop in the values recorded by sensors 2 and 4 can be observed, which could be due to the volunteer adjusting his or her sitting position during the data collection period. If the initial drops in the values reported by sensors 2 and 4 are ignored, then the slopes are more accurate. Because the slopes of all five sensors were similar, the posture of patient 2 is likely to be balanced. More pressure was applied to sensors 1 and 2, which can signify that the volunteer is left handed. During the first part of the trial, the volunteer provided a back pain rating of 5 after sitting for one hour with an imbalanced posture. After correcting the volunteer's posture, the back pain rating was reduced to 3.

IV. Conclusion and Discussions

Sitting for long periods of time with poor posture can harm back health and lead to back pain. The Smart Cushion was designed provide an early warning regarding unhealthy sitting posture. The Smart Cushion is a portable, rectangular, foam cushion, with five pressure sensors distributed strategically throughout the cushion.

As shown in Fig. 6, a higher mass results in a more consistent value being reported by the sensor. Because the data becomes more consistent at 100 grams, it can be concluded that this is the minimum mass required for the sensor to function properly. Masses greater than 100 g result in more precise values being reported by the pressure sensors.

The two-part trial portion of the experiment yielded favorable results. The initial back pain levels reported by the first and second volunteer ratings of 6 and 5, respectively, decreased to posture-corrected values of 2 and 3, respectively, demonstrating that the Smart Cushion was able to identify and correct poor sitting posture.

Analyzing the data reported by the sensors within the cushion allows the determination of sitting postures, which can be used as an early indicator of back pain and as a means for correcting bad posture. The Smart Chair's unique ability to quantify sitting postures allows the use of careful and precise methods to adjust unhealthy postures. Further research regarding the relationship between sitting and the specific parts of the body could enhance the Smart Chair's ability to prevent and reduce back pain.

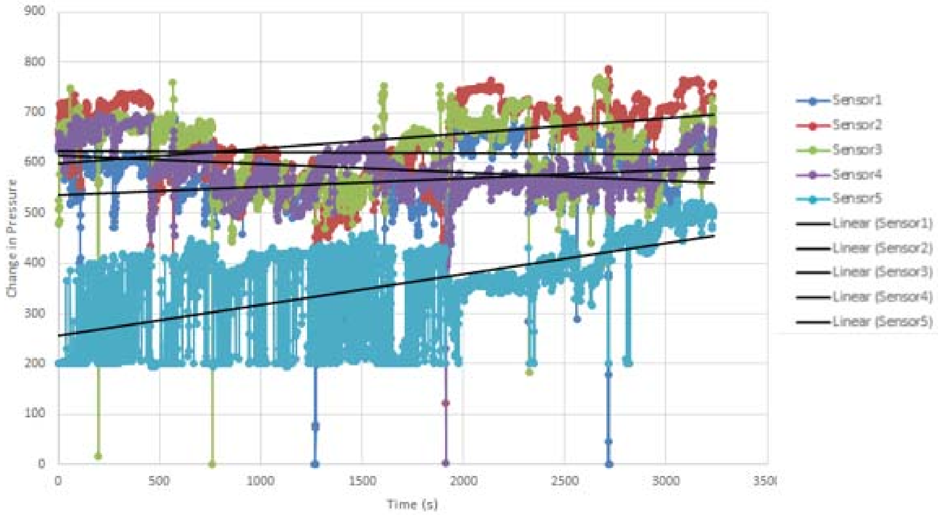

Fig. 15 The pressure changes recorded during part 2 of volunteer trial 1 for 1 hour; Slope values are as follows: Sensor 1, $y = 0.0162x + 536.27$, $R^2 = 0.0293$; Sensor 2, $y = 0.03x + 597.67$, $R^2 = 0.1237$; Sensor 3, $y = -0.0023x + 624.14$, $R^2 = 0.0011$; Sensor 4, $y = -0.0167x + 614.21$, $R^2 = 0.1054$; and Sensor 5, $y = 0.0613x + 256.79$, $R^2 = 0.3598$

APPENDIX I

Arduino Sketech Algorithm and Coding

```
#include "SD.h"
#include <Wire.h>
#include "RTClib.h"

SoftwareSerial btSerial(7,8);
const int chipSelect = 10;//set up CS
RTC_DS1307 RTC;//real time clock.
DateTime now;// function of recording time
int sensor1 = A0;
int sensor2 = A1;
int sensor3 = A2;
int sensor4 = A3;
int sensor5 = A5;
int sensorValue1;
int sensorValue2;
int sensorValue3;
int sensorValue4;
int sensorValue5;

void setup()
{
 Serial.begin(9600);
 btSerial.begin(9600);

 Wire.begin();
 RTC.begin();//check or the real time clock is on
 if(!RTC.isrunning()){
            Serial.println("RTC is Not running!");
            RTC.adjust(DateTime(__DATE__,__TIME__));
           }
 while(!Serial){;//wait for serial prot to connect. Needed for native USB port only
   }
    Serial.print("initializing SD card....");
      if(!SD.begin(chipSelect)){
                Serial.println("initialization failed!");
                return;
                }
  Serial.println("initialization done.");
now = RTC.now();
File myFile = SD.open("smart.txt",FILE_WRITE);
myFile.print("start logging on: ");
myFile.print(now.year(),DEC);
myFile.print('/');
myFile.print(now.month(),DEC);
myFile.print('/');
myFile.print(now.day(),DEC);
myFile.println(" ");
myFile.println("s1  s2  s3  s4  s5  Time");
myFile.close();

}
void loop()
{
  DateTime now;// funtion of recording time

  sensorValue1 = analogRead(sensor1); // read the sensorValue A0
  btSerial.println(sensorValue1); // print the A0 signal
  Serial.print("    sensorValue1 : ");
  Serial.print(sensorValue1);

  sensorValue2 = analogRead(sensor2);
  btSerial.println(sensorValue2);
  Serial.print("    sensorValue2 : ");
  Serial.print(sensorValue2);

  sensorValue3 = analogRead(sensor3);
  btSerial.println(sensorValue3);
  Serial.print("    sensorValue3 : ");
  Serial.print(sensorValue3);
  sensorValue4 = analogRead(sensor4);
  btSerial.println(sensorValue4);
  Serial.print("    sensorValue4 : ");
  Serial.print(sensorValue4);

  sensorValue5 =(analogRead(sensor5)-800)*5.00394631;
  btSerial.print(sensorValue5);
  Serial.print("    sensorValue5 : ");
  Serial.println(sensorValue5);
```

```
 File myFile = SD.open("smart.txt",FILE_WRITE);
 now = RTC.now();
if(myFile){
 Serial.print("Writing to Smartchiar.txt....");
 myFile.print(sensorValue1);
 myFile.print("  ");
 myFile.print(sensorValue2);
 myFile.print("  ");
 myFile.print(sensorValue3);
 myFile.print("  ");
 myFile.print(sensorValue4);
 myFile.print("  ");
 myFile.print(sensorValue5);
 myFile.print("  ");
 myFile.print(now.hour(),DEC);
 myFile.print(":");
 myFile.print(now.minute(),DEC);
 myFile.print(":");
 myFile.println(now.second(),DEC);
 Serial.print("     ");
 Serial.print(now.hour(),DEC);
 Serial.print(";");
 Serial.print(now.minute(),DEC);
 Serial.print(";");
 Serial.println(now.second(),DEC);
 myFile.close();
 Serial.println("done.");
 delay(1000);
 }
 else{
 Serial.println("error opening Smartchiar.txt");
 }
}
```

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