Developing a Compact Belt for Lower Back Pain Prevention by Studying the Effect of Sitting Posture on Lower Back Muscle Stress

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Picture 1

INTRODUCTION

- **Lower back pain affects**:
  - Productivity at work :
    - 149 million workdays lost / year in USA
  - Economic stability :
    - 65 billion dollars spent / year on medical treatment
  - Mental health
  - Sleep disorders
- **Chronic back pain**
  - Lumbar Herniated disc
  - Disc Degenerative Disease

Picture 2

Picture 3

Picture 4

Picture 5

Anatomy of Lower Back

Good Sitting Posture:

- Maintains the natural curve of the spine

Poor Sitting Posture:

- Curves of the spine will increase.
- Spinal muscles and ligaments will go under stress to support spine.

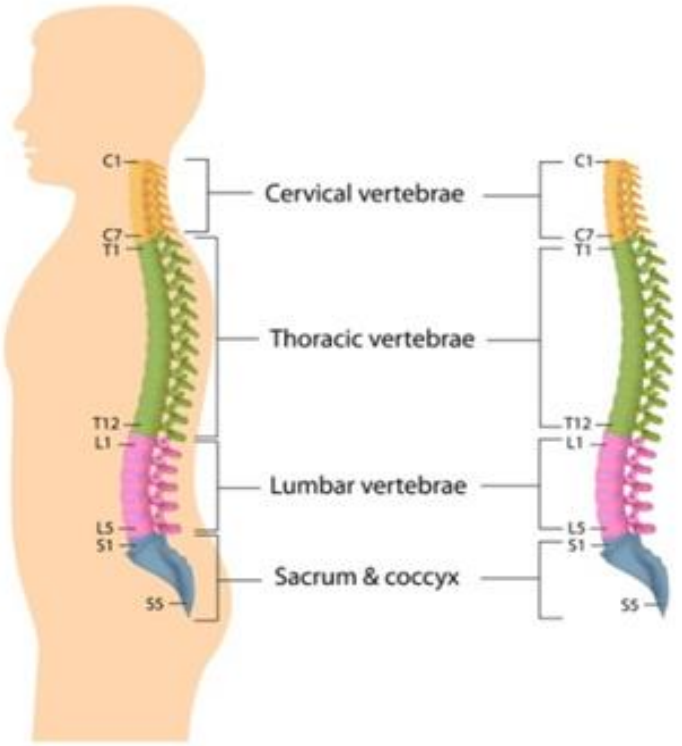


Figure 2: Oheme, D. (2016). Vertebral Column Anatomy [JPEG]. Dr. David Oheme Neurosurgeon and Spine Surgeon. https://www.doneurosurgery.com/spine--disc-anatomy.html

Erector Spinae Muscles

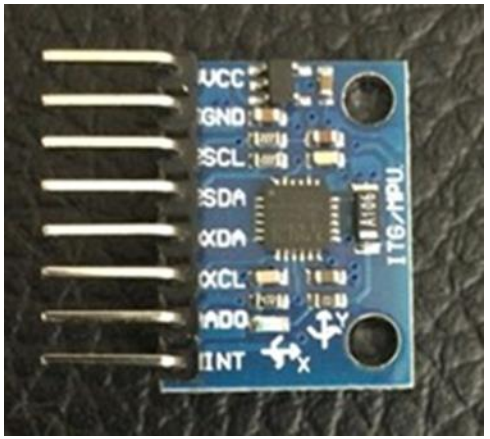
- Formed of three muscles
- Lies in the groove to the side of the vertebral column
- Increased activity of the muscle puts the load on the column which leads to strain on spinal discs

[Erector Spinae Muscle shown on a skeleton]. (2018). Erector Spinae Muscle [JPEG]. Yoganatomy. https://www.yoganatomy.com/erector-spinae-muscles/

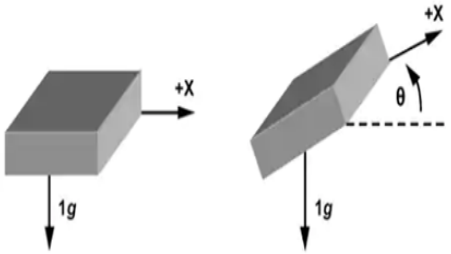
OVERVIEW OF RESEARCH

- *Question* : What is the best angle for sitting posture that minimizes stress on lower back muscles?
- *Hypothesis* : The stress of the lower back muscles is a function of the sitting posture. If the angle of the posture is above or below a certain interval, then the stress of the lower back muscles is higher.
- *Engineering Goal*: Designing a compact belt to alert the user when their sitting posture is detrimental.

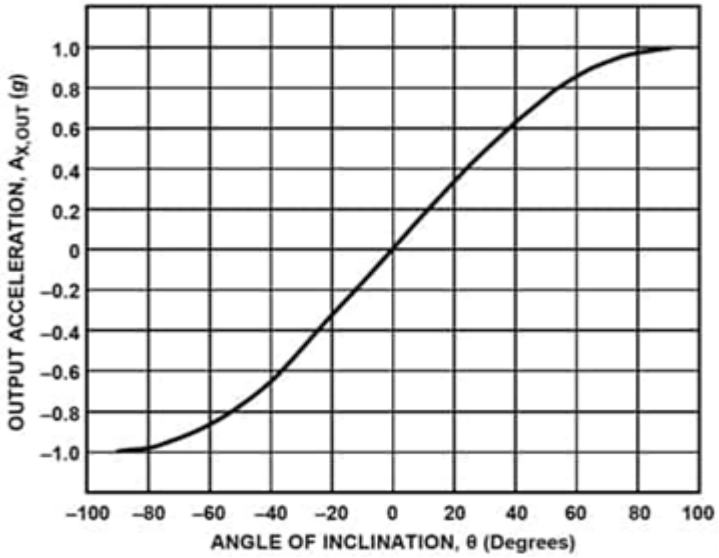
MPU – 6050 / Accelerometer



- Used to measure the angle of sitting posture.
- Triple- axis
- Output Voltage : -1 to 1
- Angle is calculated using sin inverse function



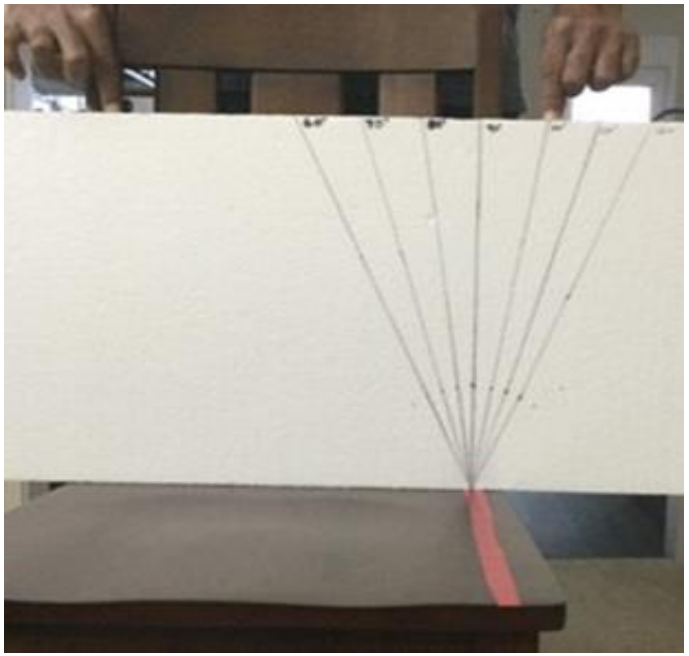
Fisher, C. (2006). Single Axis Used for Tilt Calculation [WEBP]. Digi-Key. https://www.digikey.com/en/articles/using-an-accelerometer-for-inclination-sensing

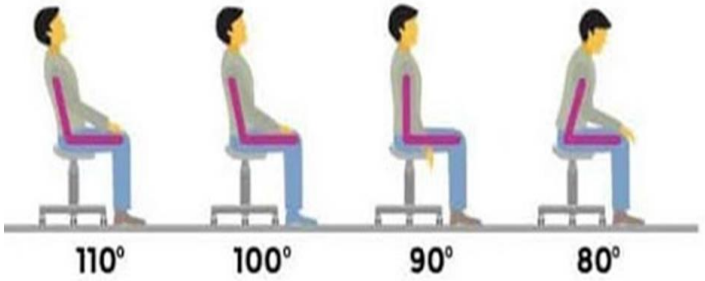


Fisher, C. (2006). *Output acceleration versus angle of inclination for single-axis inclination sensing* [WEBP]. Digi-Key. https://www.digikey.com/en/articles/using-an-accelerometer-for-inclination-sensing

METHODOLOGY FOR ANGLE MEASURING

1. 3 subjects were briefed with the general itinerary of the experiment and the risks associated with it.
2. A board was marked with the angles 60 to 120 degrees with 10 degree increments.
3. MPU-6050 is attached to the belt.





METHODOLOGY FOR ANGLE MEASURING

4. The subjects were instructed to change their sitting posture.

5. The angle output of the sensor is checked with the angles marked in the board.

Conclusion :

The accuracy of the sensor was found to be 87%

Surface EMG / MyoWare Sensor

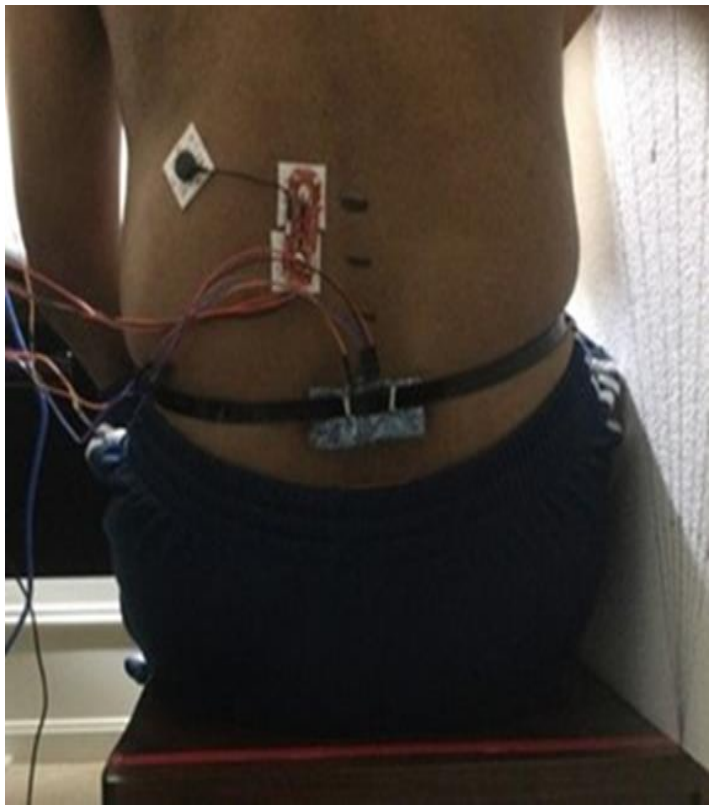
- Used to measure stress
- The muscle sensor outputs voltage from 0 to 5 V, which varies in magnitude and proportional to the activity of the muscle.
- Higher the voltage output of the sensor, the more the activity the muscle underwent.
- When the muscle has more activity, it undergoes more stress to support the spine

Mouser. (2018). SparkFun MyoWare Muscle Sensor Development Kit. [WEBP]. Mouser. https://www.mouser.com/new/sparkfun/sparkfun-myoware-development-kit/

Pololu . (2001). Example of Electrode Placement. [JPEG]. Pololu. https://www.pololu.com/picture/view/0J6840

Methodology for Measuring Stress

1. The subjects' L1-L5 vertebrae were marked.
2. The sEMG sensor was placed on the left erector spinae muscle. (left of the L1-L2 vertebrae)
3. The belt w/ the accelerometer is worn to measure the sitting posture angle, which changes in increments of 10 degrees
4. The output voltages were measured for each angle for each second in a five second window.
5. The process was repeated for the left erector spinae muscle on the left side of L3- L4.



Average of EMG values of different angles of three subjects

Angle(deg)	Avg. EMG Values of Subject 1 [Volts]		Avg. EMG Values of Subject 2 [Volts]		Avg. EMG Values of Subject3 [Volts]	
	L1 – L2	L3 –L4	L1 – L2	L3 –L4	L1 – L2	L3 –L4
60	1.22526	1.281901	1.171549	1.11849	1.058594	1.153971
70	0.842448	0.820964	1.094727	0.972005	0.753906	0.866862
80	0.633464	0.576172	0.594076	0.583008	0.525391	0.324544
90	0.609701	0.556315	0.574544	0.59082	0.359375	0.30957
100	0.628581	0.573568	0.584961	0.595052	0.578125	0.311523
110	0.843424	0.823893	0.611003	0.619629	0.702148	0.613932
120	1.058594	0.950521	1.076497	0.951172	0.945313	0.610352

Data Analysis : ANOVA

- Null hypothesis : no correlation between sitting posture angle and stress on the lower back muscles.
- The alternative hypothesis: a correlation between sitting posture angle and stress on the lower back muscles.

	L1-L2			L3-L4		
	Subject 1	Subject2	Subject 3	Subject 1	Subject 2	Subject 3
P values	7.74E-26	2.14E-29	1.84E-12	7.15E-22	1.92E-29	1.45E-12

TABLE OF P-VALUES FROM ONE-WAY ANOVA TESTING

ANGLE RANGE

- The stress level on the lower back muscle is minimum at 90 degrees most of the times.
- Not feasible to be in one angle all the time.
- Possible angle combinations in set of 3

{60,70,80} {60,70,90} {60,70,100} {60,70,110} {60,70,120} {60,80,90} {60,80,100} {60,80,110} {60,80,120} {60,90,100} {60,90,110} {60,90,120} {60,100,110} {60,100,120} {60,110,120} {70,80,90} {70,80,100} {70,80,110} {70,80,120} {70,90,100} {70,90,110} {70,90,120} {70,100,110} {70,100,120} {70,110,120} {80,90,100} {80,90,110} {80,90,120} {80,100,110} {80,100,120} {80,110,120} {90,100,110} {90,100,120} {90,110,120} {100,110,120}

DATA ANALYSIS : ANOVA

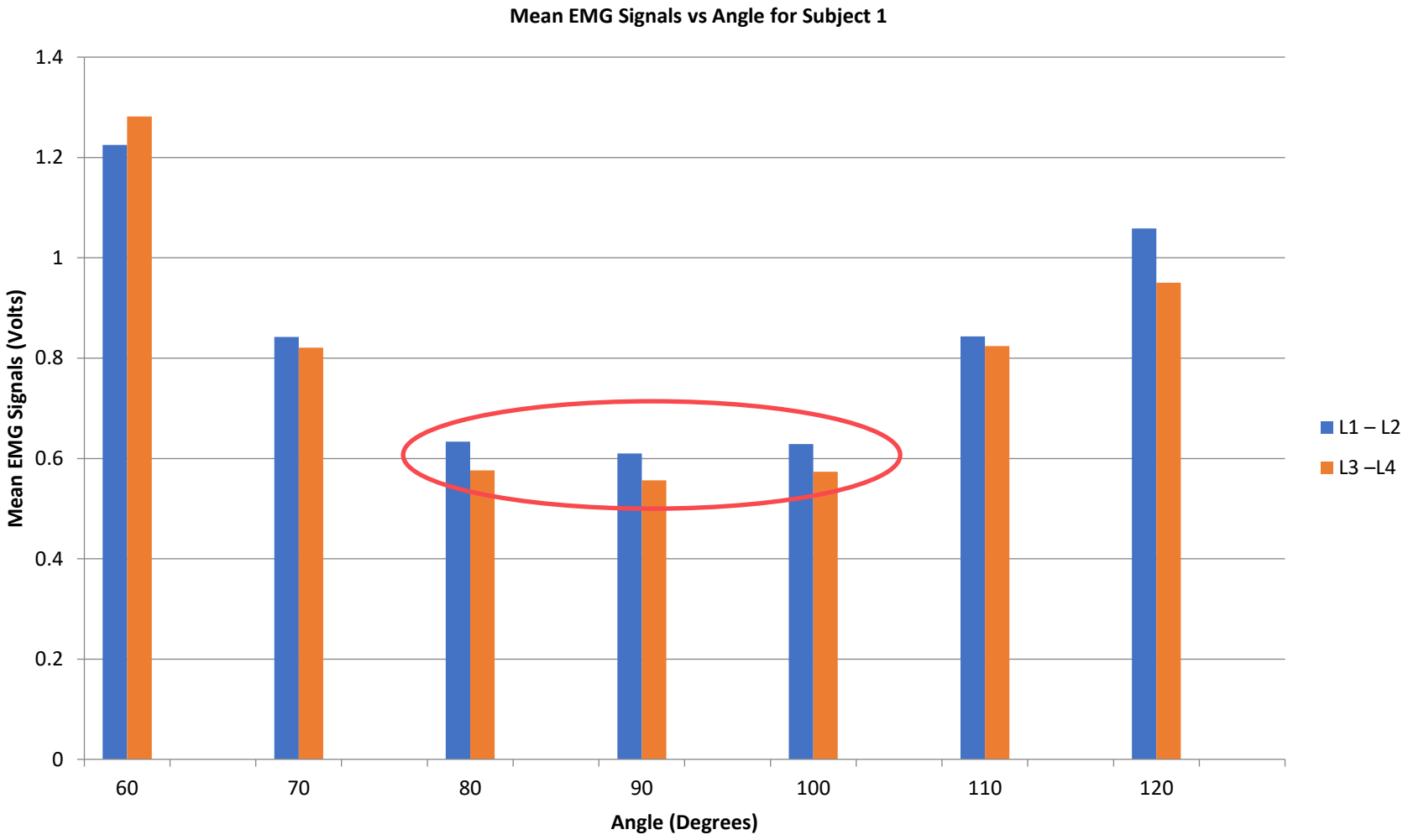
- Null hypothesis : there is no statistical differences between the angles of a group.
- Alternative hypothesis : there is a significant statistical difference between the angles of a group.

TABLE OF P-VALUES FROM ONE-WAY ANOVA TESTING

P values						
	L1-L2			L3-L4		
Angles Range	Subject 1	Subject 2	Subject 3	Subject 1	Subject 2	Subject 3
60 -90 -100	4.89E-14	1.05E-14	1.13E-08	2.21E-13	6.97E-16	4.29E-06
60-90-110	2.41E-13	5.36E-14	1.89E-08	1.86E-12	3.8E-16	1.57E-05
60-90-120	8.37E-13	4.69E-13	1.91E-06	7.79E-10	1.06E-13	1.52E-05
70-90-100	4.61E-09	1.95E-14	6.31E-08	1.55E-11	1.63E-13	4.56E-13
70-90-110	3.44E-09	1.3E-13	4.59E-08	9.84E-11	1.21E-13	2.14E-12
70-90-120	4.24E-11	6.91E-13	6.05E-06	1.4E-07	3.95E-12	6.99E-13
80-90-100	0.210501	0.077706	1.92E-12	0.118943	0.166251	0.148725
80-90-110	1.15E-09	0.014264	1.05E-11	5.36E-11	0.001209	2.77E-12
80-90 -120	3.08E-12	9.12E-14	1.92E-06	3.96E-08	1.74E-12	1.04E-13

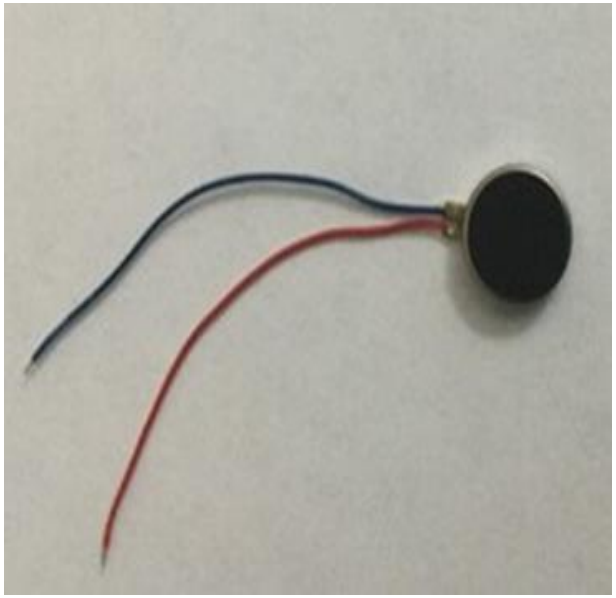
- Alternative hypothesis accepted for every group except 80 – 90 – 100.
- Conclusion : Best angle range is 80 – 90 – 100.

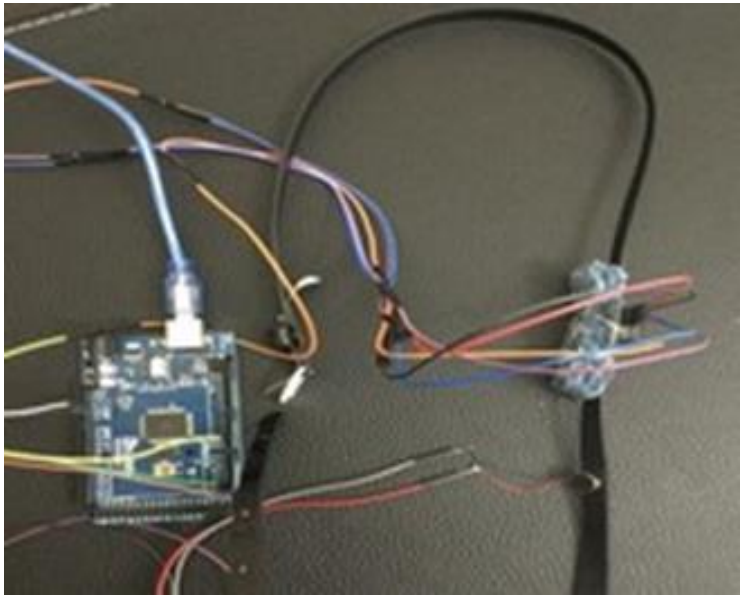
Mean EMG signals vs Angle for Subject 1

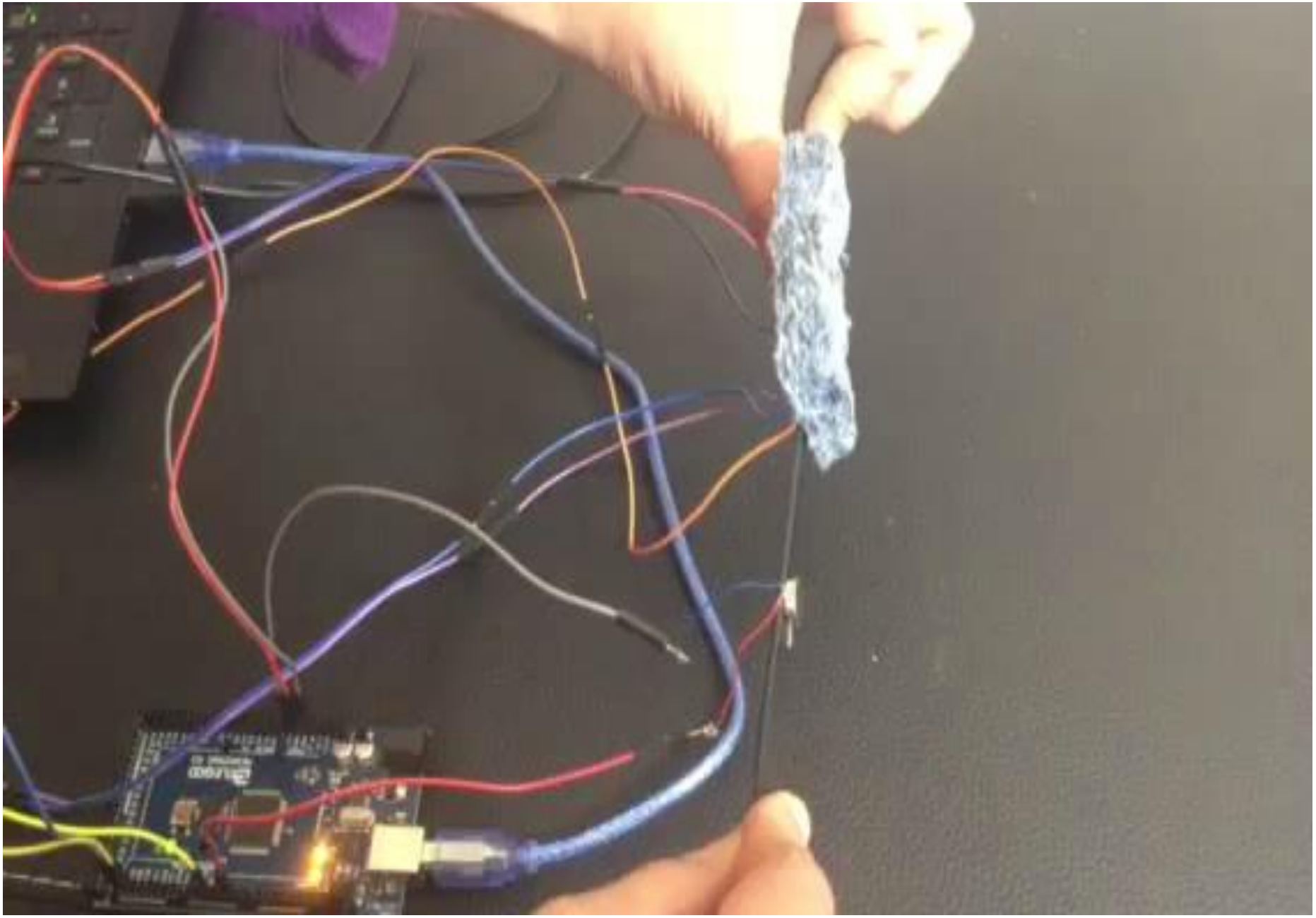


Final prototype

- Vibration motor is attached to the belt
- Programming code was modified that when the angle is outside the range of <80-90-100>
- Vibration motor vibrates for 2 seconds







Conclusion

- The accuracy of the sensor is found to be 87%.
- The output EMG values are found to be at minimum at an angle of 90 deg for 83%.
- There is a correlation and a significant statistical difference between the sitting posture angle and the stress exerted on the lower back muscle.
- There is no statistical difference in the angle range <80-90-100>.
- There is a minimum stress exerted in the angle range <80-90-100>.

Challenges Faced

- Choosing the sensor- Accelerometer, Muscle Sensor
- Soldering.
- Choosing the appropriate statistical analysis

Limitations and Future Work

- Prototype still no ready for market use.
- Mini microcontroller with rechargeable batteries can be used.
- Wireless connectivity – Bluetooth and an app can be designed.
- Target other muscle groups – manufacturing and warehouse jobs, exercise equipments
- Ergonomics design.

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Acknowledgement

I would like to thank all the volunteers who participated in this experiment. There were no risks involved to the participants because all the sensors used in the project were of low power. There may have been slight discomfort due to change of sitting posture angles during the time of experiment. The experiment and the research were conducted under the supervision of an adult and followed state and federal regulatory guidance applicable to the humane and ethical conduct of such research.