

## Background

- Half of all the Americans have back pain. [2]
- Back pain leads to > 264 million lost work days annually [2]
- Low-back pain costs >\$50 billion in health care costs each year [2]
- Lost wages + decreased productivity cost additional \$50 billion [2]
- Poor posture is a leading cause of back pain [2]

## Abstract

The goal of this research is to design an exoskeleton system to support correct posture and reduce back muscle strain, based on user's real time Electromyography (EMG) muscle signal and motion data. Unlike traditional posture correcting devices, our goal is to design the powering mechanism of this exoskeleton suit using soft actuators. This dynamics system provides personalized upper torso support without interfering the user's autonomous motion.

To accomplish the goal, our team has gone through phases of soft components design and motion sensors comparison. Multiple trials were performed to get to ideal mixed portion of silicone and we custom built our first prototype to fit onto the dimensions of the EMG shirt. Passive motion tracking using image processing analysis was used in phase one to monitor and study participants' posture, but we switched to inertial measurement unit system-based motion tracking (up to 500Hz) for higher resolution in phase two. EMG shirt was included in both phases of study to provide reference data on muscle fatigue and tension.

## Motion Tracking Analysis

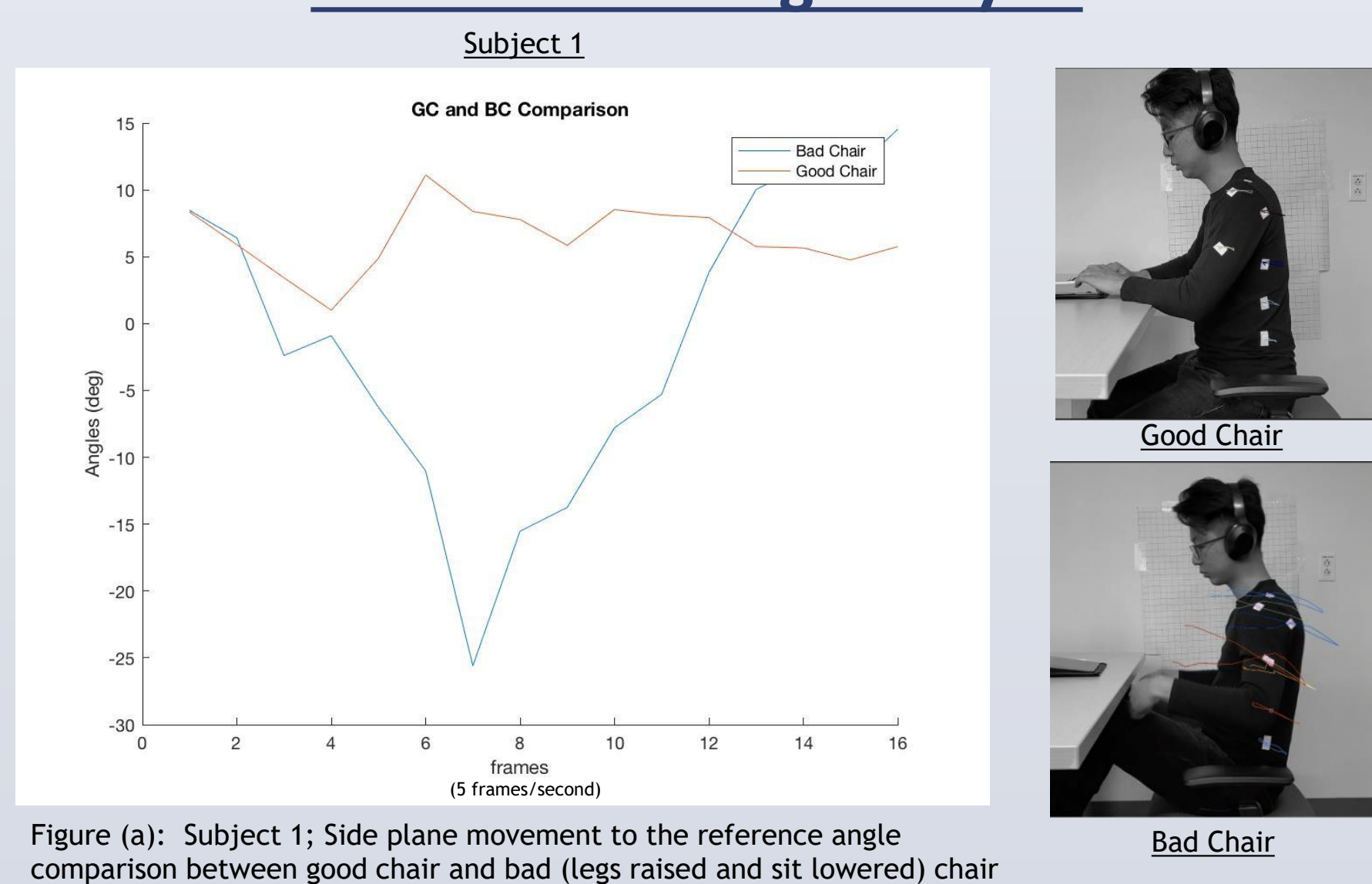


Figure (a): Subject 1: Side plane movement to the reference angle comparison between good chair and bad (legs raised and sit lowered) chair

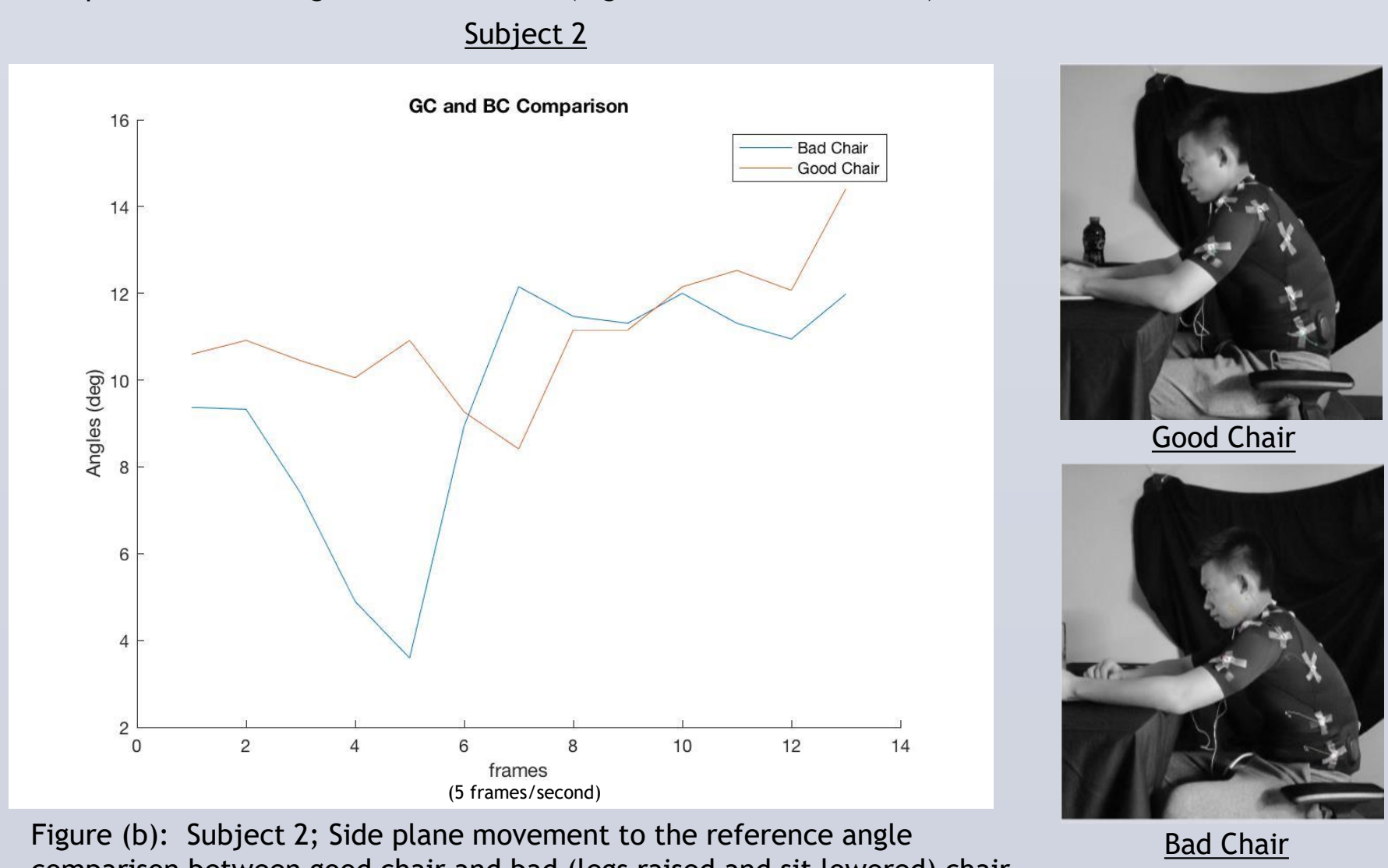


Figure (b): Subject 2: Side plane movement to the reference angle comparison between good chair and bad (legs raised and sit lowered) chair

### Phase 1 method:

- Identify all the significant side movements in each 30 min trial and isolate one movement to run analysis.
- Plot one significant movement from both trials comparing changes in angle with respect to time.

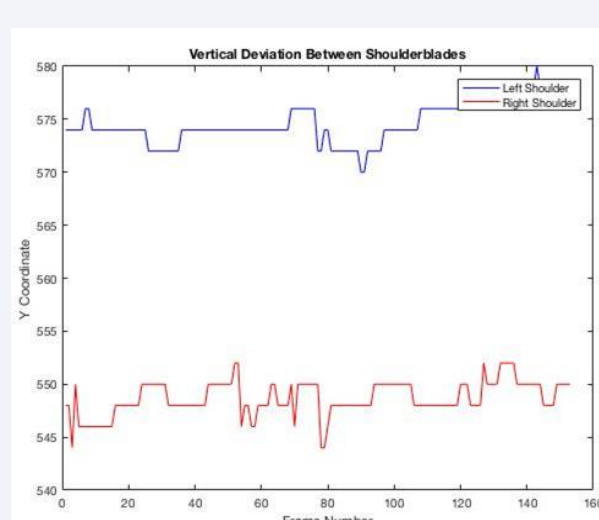
### Phase 1 results:

- The difference in range of motion indicates that the bad chair needs a larger range of motion to adjust.
- Motion pattern varies from subject to subject.

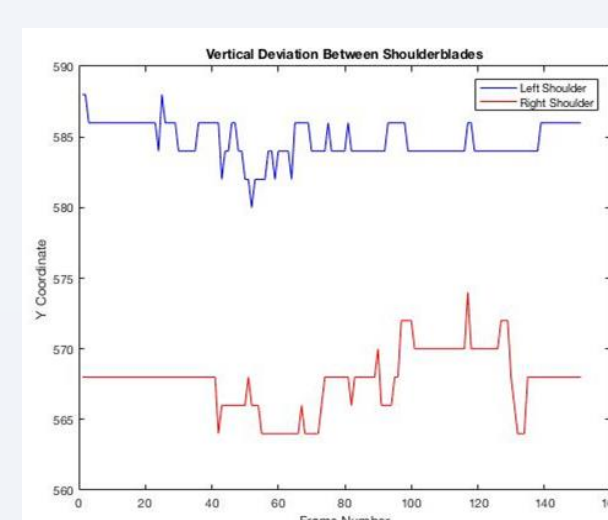
## Motion Tracking Analysis: Continued

### Phase 2

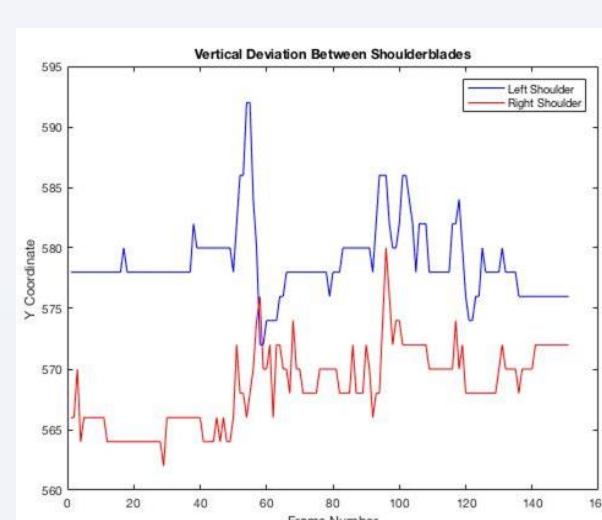
At time: 5 minutes



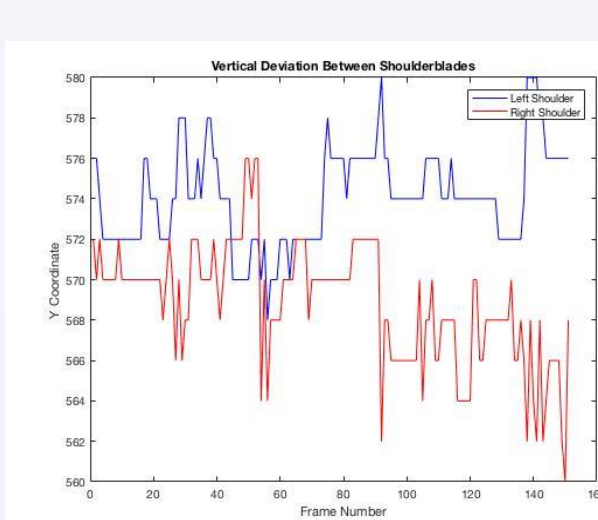
10 minutes



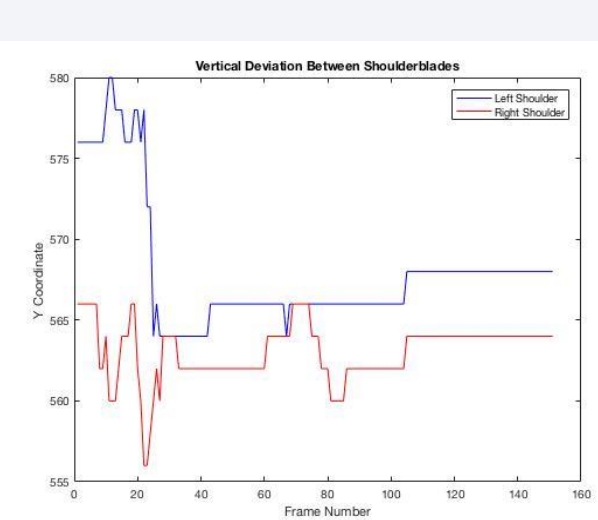
15 minutes



20 minutes



25 minutes



30 minutes

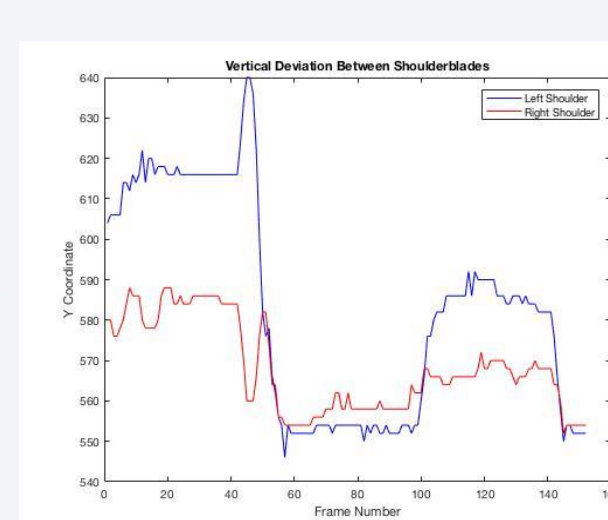


Figure (c - h): Subject 1; Sequence of back plane movement on good chair of vertical deviation between shoulder blades; 1.5 frames/second

### Phase 2 method:

- Analyze 30 sec video segment of every 5 min video time interval

### Phase 2 results:

- The sequence shows motion on back plane, specifically vertical deviation between left and right shoulders
- The frequency and range of fluctuation indicates the motion of the back
  - As time goes by, fatigue can be identified by the increase in range of motion and frequency of fluctuation
- Phase 2 suggests that even on a good chair, fatigue can be experienced and quantified.

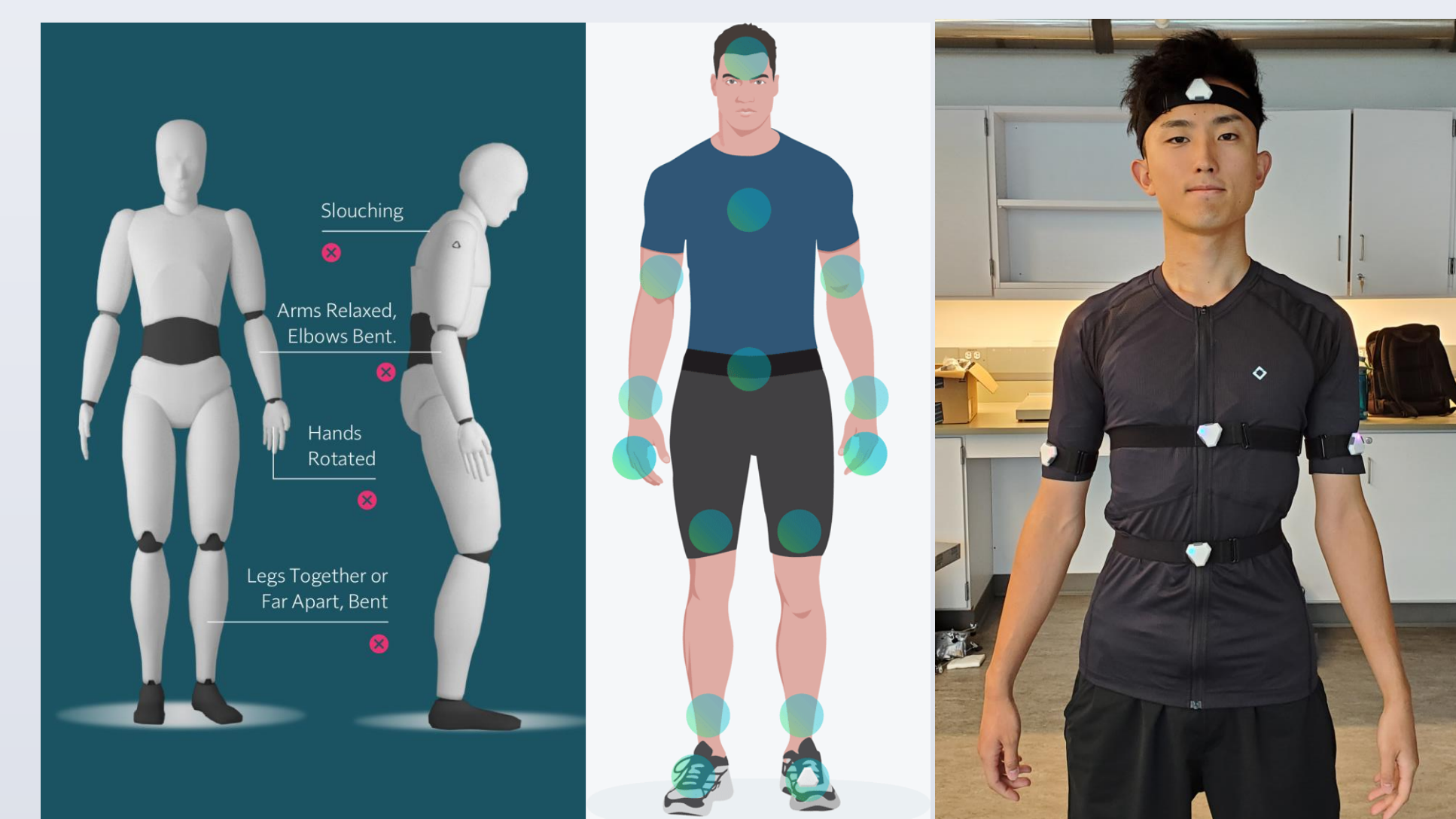


Figure (j): Wearnotch working diagram for posture correction (left); Sensors installment position (middle); test participant wearing Wearnotch sensors (right)

### Phase 4 method:

- Conduct usability test using IMU sensor system, Wearnotch© for higher data resolution and to simplify experiment process.

## Design: Exosuit Prototype



Figure (j): Exosuit first Prototype (front)

### Front:

- Silicone Friction Pad was designed to fit tightly on the inside of the EMG shirt against user's front chest to exert frictional force, as reminder and help straighten upper body.
- EMG shirt was used as prototype base to provide constrains (compressive exterior fabric). Electrodes embedded in different parts of the shirt can give a comprehensive reading of upper body EMG signal.

### Back:

- Pneumatic artificial muscles were designed as actuators of the system. When the air pressure is regulated by fluidic control board from air compressor, horizontal expansion of the rubber tube is constrained by the geometric shape of the braid on the exterior, thus pulling the light strings.
- Fluidic Control Board regulates the pressure in the system using Pulse-width modulation, and pressure sensors provide feedback of the system.
- Stability strap is secured around the waist to provide stability to the air muscles.

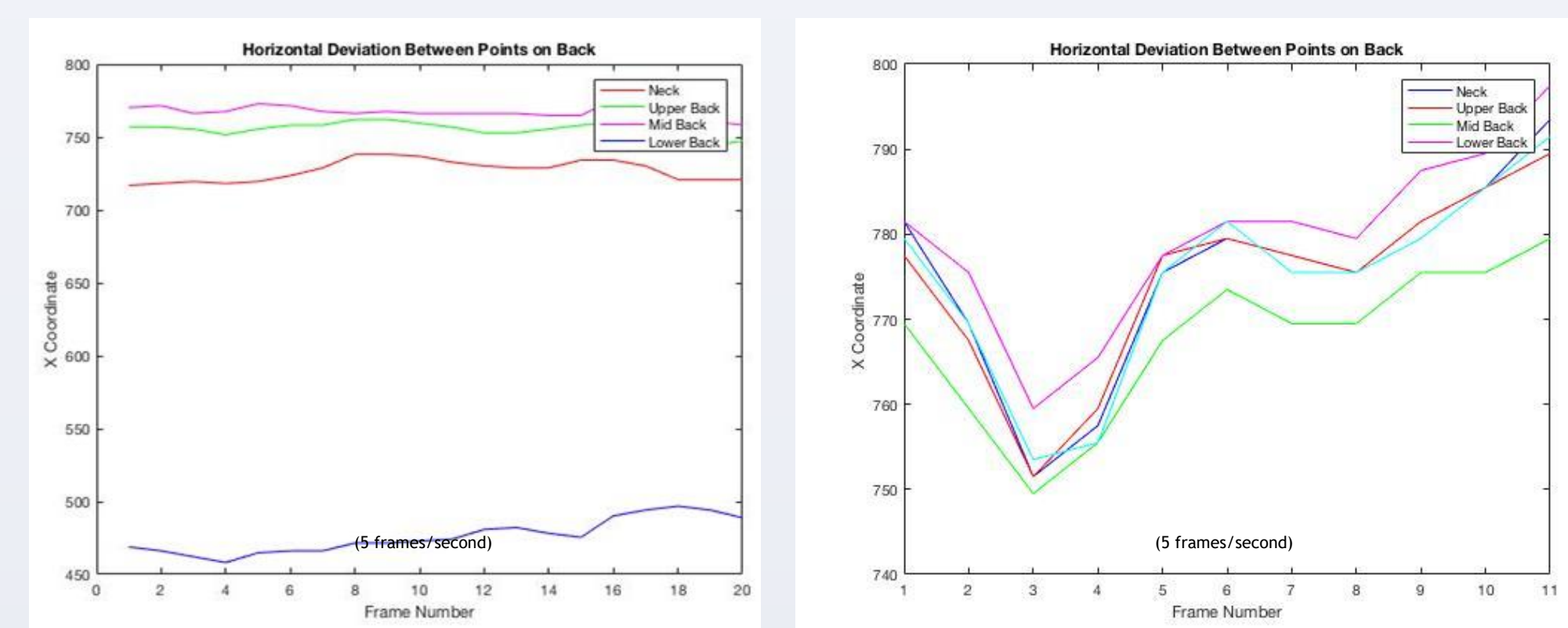


Figure (i): Subject 2; Back plane movement on good chair (left) and back chair (right) of each dots, which represent different vertebral segments

### Phase 3 method:

- Identify all the significant back movements in each 30 min trial and isolate one to run analysis

### Phase 3 results:

- The graphs show motion on the back plane, specifically horizontal deviation between each dot along the spine
- In comparison, the motion of subject 2 sitting on good chair is relatively stable, with far less range of motion
- The overall trend is consistent and the relative motion of different dots could indicate the start of a corrective motion

### Phase 4 results:

- The research team is still in the process of adapting previous motion tracking methods to the new sensor system.
- Current results have shown improvement in accuracy, duration of length for each trial. It also requires less restriction on test surroundings.

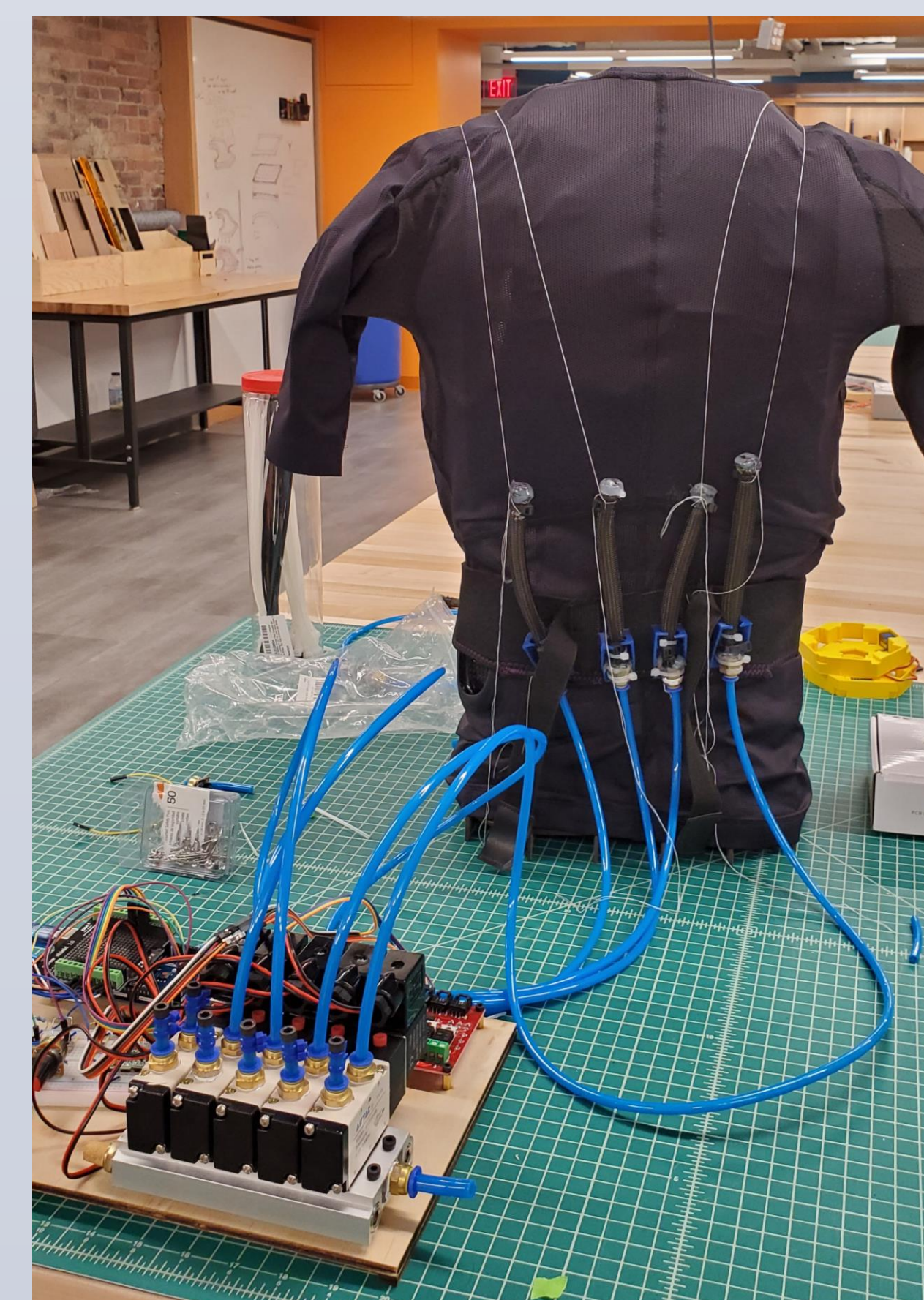


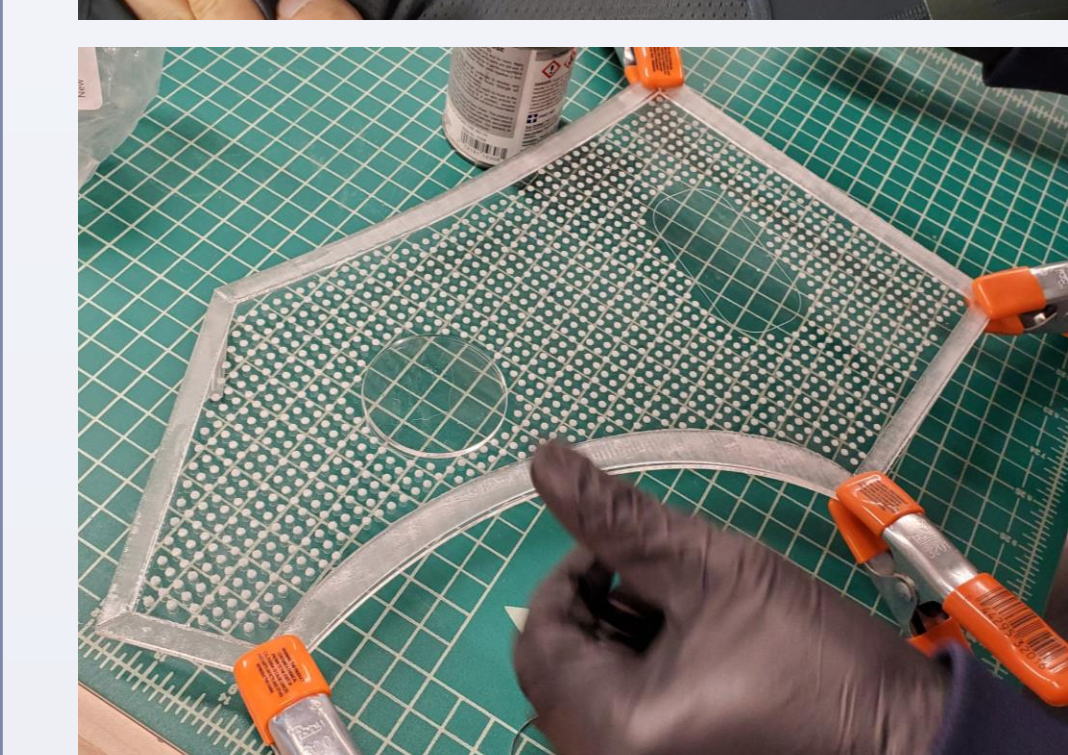
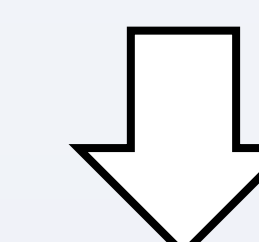
Figure (k): Exosuit first Prototype (back) and fluidic control board

## Fabrication: Cast-molding Silicone

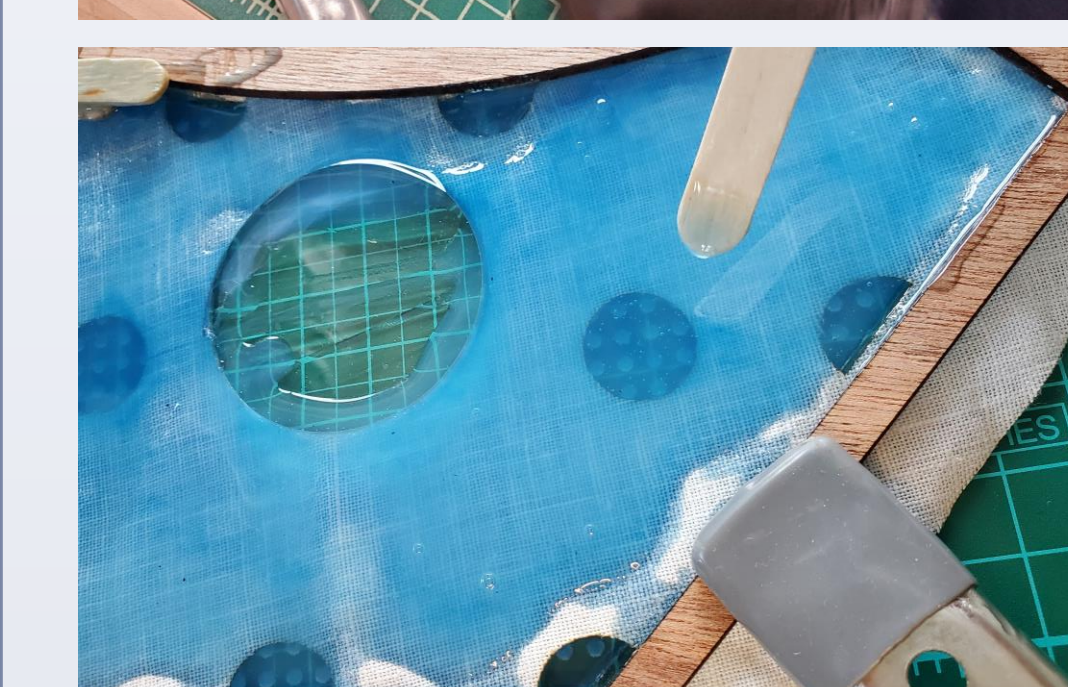
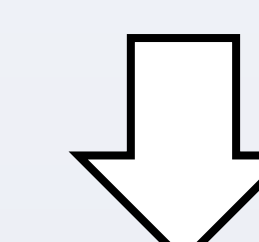


Method of customizing silicone-based material:

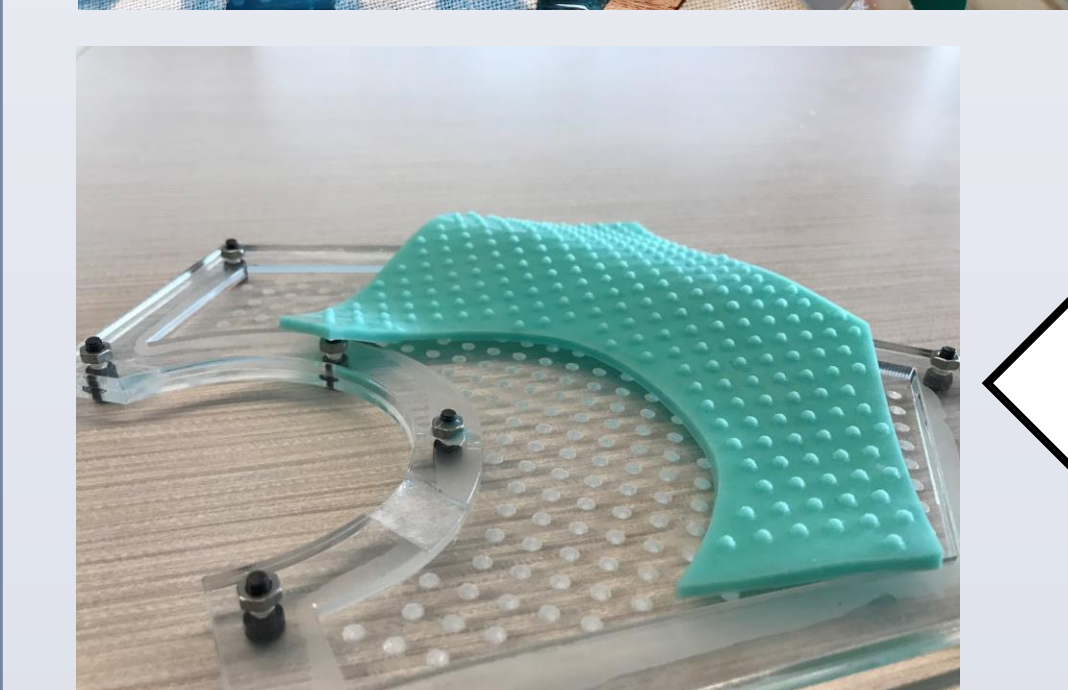
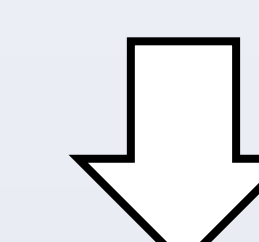
Take dimension of the EMG shirt around the electrodes



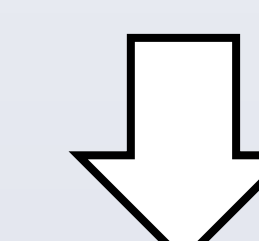
Laser Cut acrylic as silicone mold



Pour in first layer silicone



Evenly submerge the thin fabric in uncured silicone



Pour in second layer silicone; wait for curing

Figure (l): Silicone pad fabrication process

## Conclusions and Future Directions

Over the course of Fall semester and summer, the research team was able to determine the scope and viability of the development of this system. We will continue our motion tracking studies to gather broader data sets using new IMU system on movement while sitting. Additionally, we will analyze additional sensors, such as EMG signal captured by EMG shirt, to gather data on muscle fatigue that can be correlated with captured position data.

The research on Pneumatic artificial muscles will extent to different structural designs and their resultant of different directional bending or contracting. Different silicone-based material and different design of the friction pad will also be tested.

Through an iterative design process including actual test wear, we will continue to refine both our measurements and the Exosuit system.

## Acknowledgements

We would like to thank Professor James Intriligator and Professor Hoda Koushyar for their tireless support and guidance throughout this project. Also credit goes to all the research team members: Yufeng Wu, Amelia Coffey, Maya Kurzman, Ali Brodeur, Julia Sakalus, Ian Jones, Ginga Sato, James Liao, Isobel Smith, Judy Charamund, Belén Farias, Charley Sun.

## References

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3. "Fluidic Control Board", Soft Robotics Tool Kit, Zheng Wang, Panagiotis Polygerinos, Ali Alazmani, Alexandre Campo https://softroboticstoolkit.com/book/control-board