LOWER EXTREMITY STRENGTH TESTING DEVICE

Team Members: Brittany Glaeser, Kaitlin Lacy, Noah Nicol, Sam Parmentier, Dan Wildner

Client: Dr. Brian Heiderscheit & Dr. Rita Deering

Advisor: Dr. Wan-Ju Li

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

UW BME Design

Abstract

Pelvic instability, a common problem after pregnancy, can be assessed by measuring the maximum voluntary contraction (MVC) of the lower extremities in a postpartum female performing a straight leg raise. Pelvic instability, if not addressed, can lead to lower muscle weakness and further damage. In order to obtain quantifiable results, Dr. Deering and Dr. Heiderscheit have a requested a device to accurately gather the appropriate force data. In order to gather data, the subject will first perform a fatiguing task with one leg. Then, they will lay inside of the apparatus quickly after completing this task. The fatigued leg will perform a straight leg lift, and the MVC produced by that leg will be recorded near the ankle of that leg. Intended testing was unable to be completed due to significant electrical issues that were encountered. The LEST accuracy was going to be compared against the accuracy of force plates implemented the in the UW Health Research Park Clinic. The final goal was to create a design that was able to interface with the electronics setup used in this setting.

Motivation

A device is needed to quantitatively assess a maximal voluntary contraction (MVC) of the hip flexor and knee extensor muscles during a straight leg raise task. This can be analyzed to assess the loss of strength in the lower extremities of pregnant and postpartum women. The device must be portable, durabile, and adaptable to all locations for future studies.

Background/Current Methods

- Pelvic floor muscles consist of multiple layers of musculature between the tailbone and sacroiliac joint which connects the spine to the pelvis(3).
- As the fetus grows, the abdominal muscles have to separate to allow the womb to protrude, thus altering weight distribution of the mother(3).
- Weakened pelvic floor muscles are associated with higher chances of pelvic organ prolapse(4).
- During the straight leg raise, the rectus femoris, sartorius, and tensor faciae contribute to the motion of the hip flexor (5).
- Current methods for assessing pelvic instability include a straight leg raise with the patient rating their comfort on a scale from 0-5. If the number decreased with pressure placed on hip flexor, then pelvic instability is present (1).

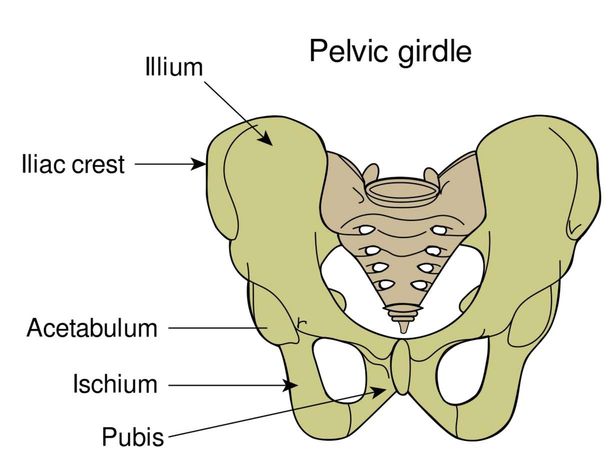

Figure 1: Pelvic Girdle

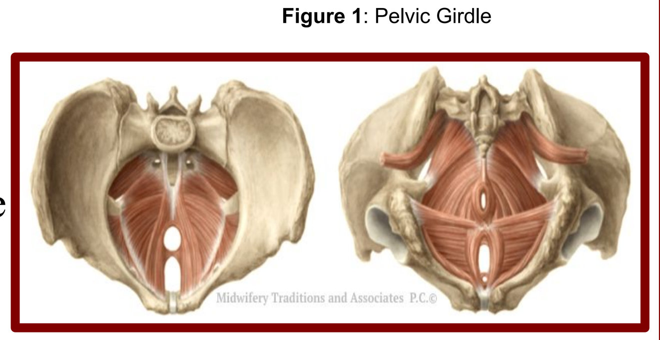

Figure 2: Pelvic Floor Muscles

Design Criteria

- Portable
- Strong enough to withstand a MVC of a straight leg lift from an adult female
- Comfortable
- $1000 Budget
- Easily height adjustable
- Able to measure forces in tension and compression
- Must work without fixturing to a specific testing location

Final Design

Figures 3-5: Measurement of MVC

Adjustment Steps

1. Lower the push plate to the ground by loosening the handles on the corner towers.

2. Perform a straight leg raise with the other leg resting on the push plate. The raised leg starts at 20 cm off the ground and the task is stopped when the leg is less than 10 cm from the ground.

3. Raise the push plate up to the designated height and perform a straight leg raise against the push plate with the fatigued leg.

Design Features

- Lightweight base with comfort padding.
  - Joint in middle allows for folding of base for easy transportation.
- Corner towers with EZ clamp for quick height adjustment.
  - Allows for various height settings during the testing process.
- Vertical supports with integrated load cells for force recognition.
- SST Transmitter allowing for setting adjustment.

Formal Testing Procedure

While laying down with their feet inside this device, the subject will first perform an unassisted leg raise with one leg to fatigue it. The push plate will be in its lowest position, and both feet will be within the bars of the push plate while one leg uses the area in between them to perform the fatiguing task. The leg not performing the fatiguing task will remain on top of the push plate so that the load cells can record in compression how much force that foot pushes down with. This fatiguing task will be performed until failure, which is achieved once the foot drops beneath 10 cm or excessive lumbopelvic motion occurs (measured by an air bladder underneath their lower back). Then, the push plate will be raised to an appropriate height and the fatigued leg will immediately perform a straight leg lift. The MVC produced by that leg will be recorded near the ankle of that leg. The leg that did not partake in the fatiguing exercise will rest on the bottom plate of the design, which does not interact in any way with components fixed to the load cells. This process will then be repeated with the opposite leg on a separate day.

Materials

- -Tee Through-Hole Connector for 1" Pipe
- -90 Degree Elbow Connector for 1" Pipe
- -Aluminum Round, 1 " DIA (Frame)
- -2" x 3" Aluminum Bar (Corner towers)
- -Brass Surface Mount Hinges
- -Zinc Adjustable Position Handle
- -.25" x 3" Aluminum Bar (Push Plate) with Foam
- - HDPE Base Plates

Electronics

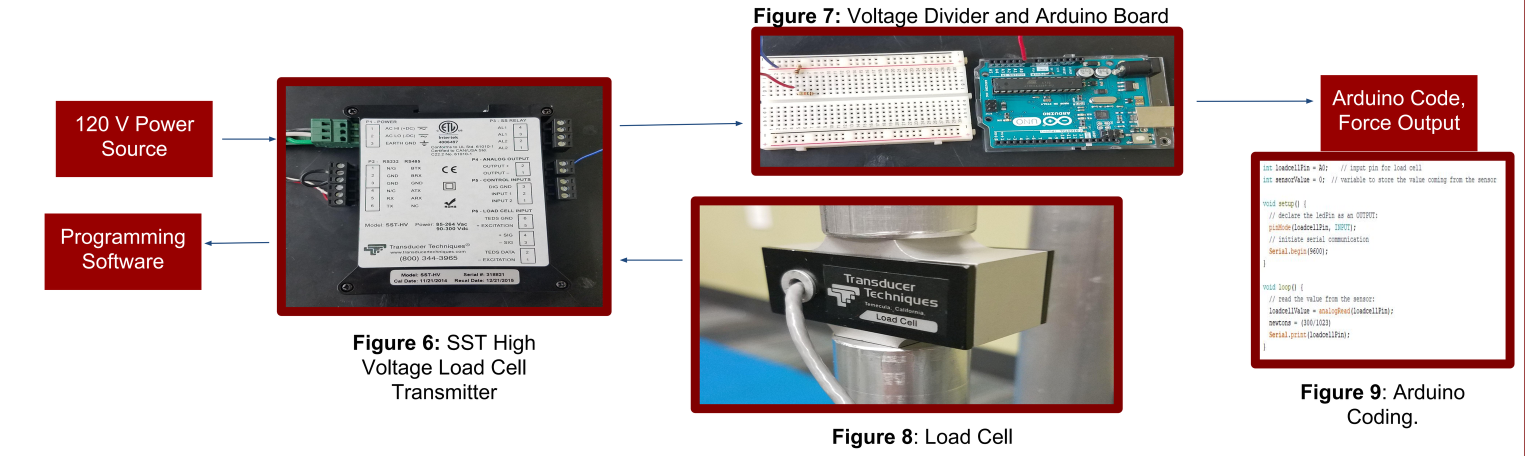

Figure 6: SST High Voltage Load Cell Transmitter

Figure 7: Voltage Divider and Arduino Board

Figure 8: Load Cell

Figure 9: Arduino Coding.

Load cell

- Input goes to SST High Voltage Load Cell Transmitter, essentially a "middle man" between the load cell and Arduino Board.

Programming Software

- Establish connections with SST Transmitter, adjust settings of baud rate, input/output and high/low reading limits.

SST Transmitter

- Powered by a 120 V power source, sends +/- 10 V excitation to load cell, receives a voltage signal back from it based on load recognized and outputs a 0-10 V signal.
  - Wheatstone bridge inside SST.

Voltage Divider and Arduino

- Output from SST runs through voltage divider to reduce signal to 0-5 V range that Arduino is capable of receiving.
- Arduino coding refines signal and produces a live plot of load recognized by load cell.

Planned Testing

Testing plan: use weights (5, 15, 25, 45 and 60 lbs) to check accuracy of devices below and compare forces measured with trusted scale. This would determine whether the LEST device reasonably could replace a pre-existing method.

- Existing force tester - Research Park force plate error ≤ 0.2% (6)
- LEST device

Future Work

- Add handles to the side of the device for easier transportability.
- Order replacement SST transmitter.
- Adapt electronics to interface with client's setup.
- Further reduce weight, primarily in corner towers and support beams.

References/Acknowledgements

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