LOWER EXTREMITY STRENGTH TESTING DEVICE

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

Team Members: Hayley Raj, Eric Arndt, Sam Parmentier, Dan Wildner
Clients: Dr. Brian Heiderscheit & Dr. Rita Deering
Advisor: Dr. Darilis Suarez-Gonzalez

UW BME Design

Abstract

Pelvic instability, a common problem in women after pregnancy, can be assessed by measuring the maximum voluntary contraction (MVC) of the lower extremities during a straight leg raise. If not addressed, this condition can lead to lower muscle weakness and further damage. In order to obtain quantifiable results, Dr. Deering and Dr. Heiderscheit have requested a device capable of accurately gathering force data of the MVC of the hip flexor muscle. This data will provide quantitative results for a currently subjective and qualitatively diagnosed issue. The main goals of the semester were to successfully set up the electronics software that collects force data, conduct testing, and to decrease the overall weight of the device.

Motivation

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

Background/Current Methods

- Pelvic floor muscles are between the tailbone and sacroiliac joint (3).
- As the fetus grows, abdominal muscles separate to allow womb protrusion (3).
- Weakened pelvic floor muscles are associated with higher chances of pelvic organ prolapse (4).
- The rectus femoris, sartorius, and tensor fasciae contribute to hip flexor motion (5).
- Current methods for assessing pelvic instability include a patient dependent rating of difficulty of a straight leg raise. If the difficulty decreases with pressure placed on the sides of the hips, pelvic instability is diagnosed, which is a very subjective procedure (1).

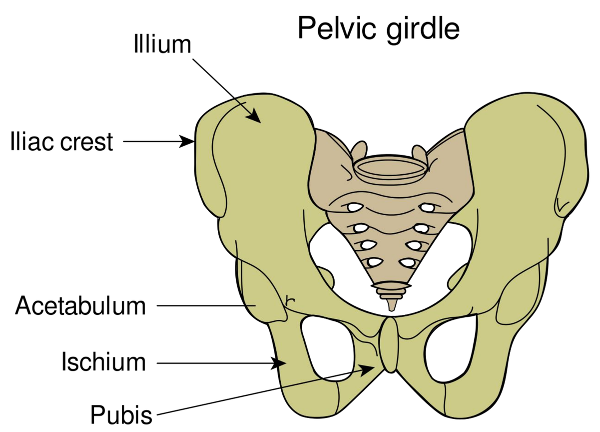


Figure 1: Pelvic Girdle

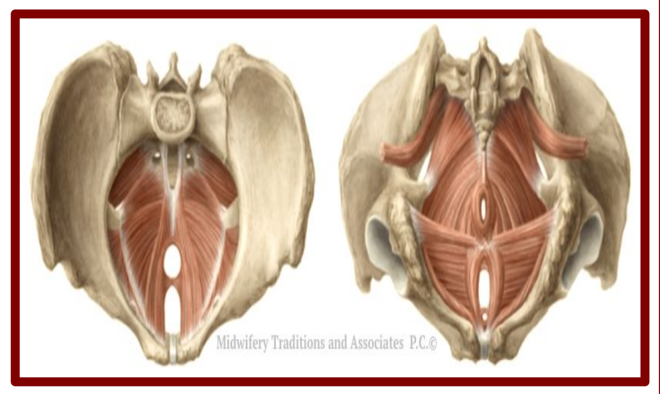


Figure 2: Pelvic Floor Muscles

Design Criteria

- Portable between SAPC and Marquette lab location.
- Must withstand a MVC (59.53 lb-f) of a straight leg lift from an adult female.
- Comfortable for client.
- $1000 Budget
- Height adjustable between 0-10 in.
- Able to measure forces in tension and compression
- Must remain stable and not shift during testing procedure.

Final Design

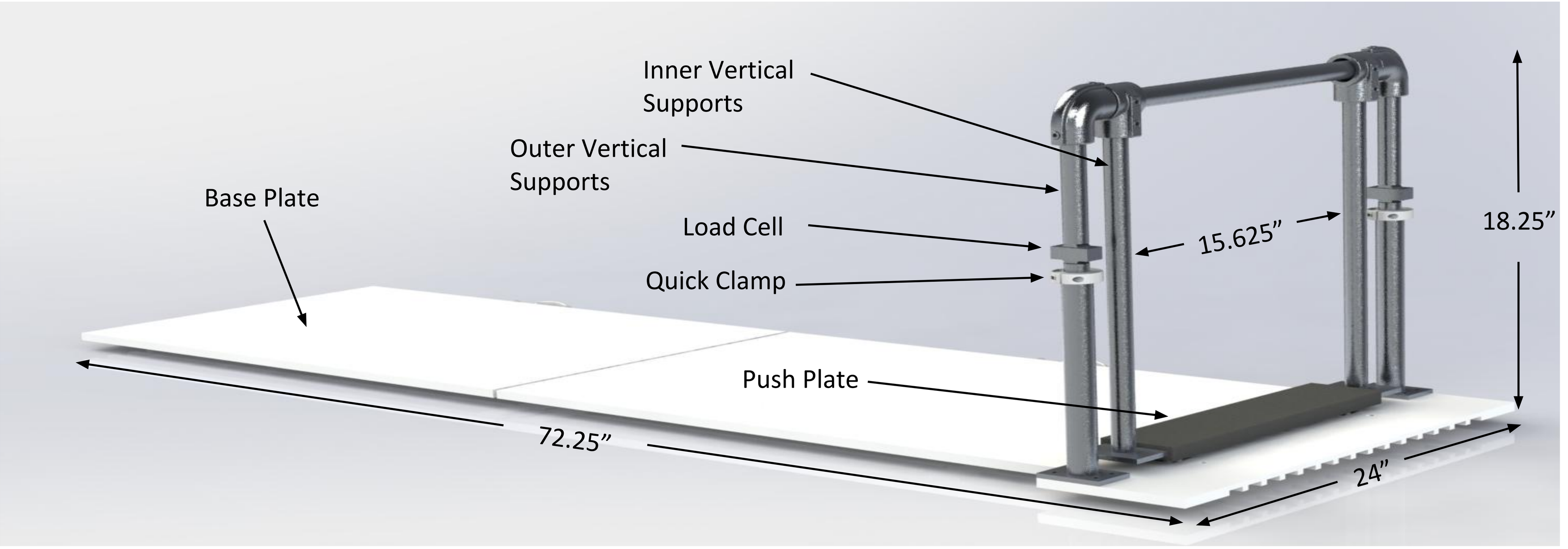


Figure 3: CAD Model of LEST apparatus.

Design Features

- Lightweight base with comfort padding.
  - Both joint in middle for folding of base and side handles allow for easy transportation.
  - Vacuum cups on bottom for added stability.
- Corner posts with quick adjust clamps for easy 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 and force recognition.

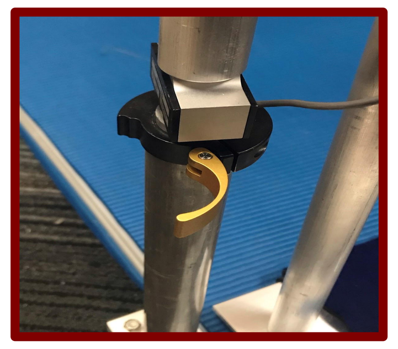


Figure 4: Open quick clamp.

Figure 5: Push plate in the lowered position for step one of testing.

Figure 6: Push plate in the upright position.

Formal Testing Procedure

1. While laying down with their feet between the inner vertical supports, the subject will first perform an unassisted leg raise with one leg to fatigue it.
   - The push plate will be in its lowest position with the quick clamps locked in place..
   - 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).
2. The push plate will be raised to an appropriate height to fit the subject's ankle by releasing the quick clamps, raising the vertical assembly, and retightening the quick clamps.
3. The fatigued leg will immediately perform a straight leg lift on the bottom face of the push plate. 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 base plate of the design, which does not interact in any way with components fixed to the load cells.
4. This process will then be repeated with the opposite leg on a separate day.

Materials

- -Aluminum Connectors for 1" Pipe
- -1.25" Hollow Aluminum Tubes
- -Aluminum Round, 1 " DIA (Frame)
- -Industrial Vacuum Cups
- -Brass Surface Mount Hinges
- -Quick Adjust Shaft Collar
- -.25" x 3" Aluminum Bar (Push Plate) with Foam
- - HDPE Base Plates

Electronics

Figure 8: Voltage-force calibration settings for SST software

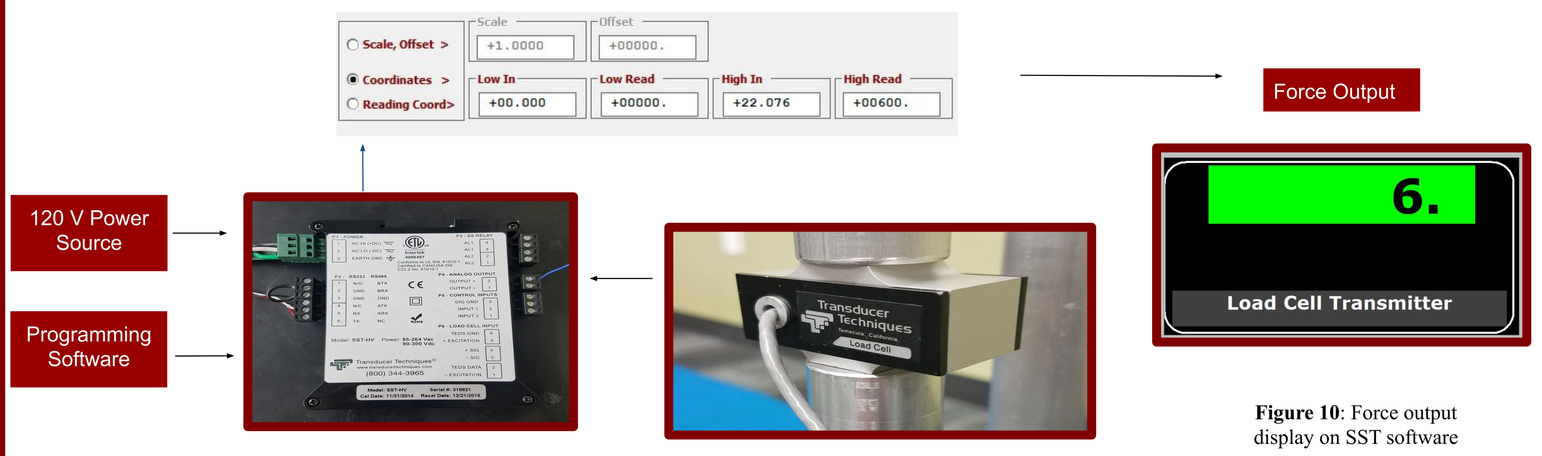


Figure 7: SST High Voltage Load Cell Transmitter

Figure 9: Load Cell

Figure 10: Force output display on SST software

Load cell

- Input goes to SST High Voltage Load Cell Transmitter.
- Wheatstone bridge inside load cells to convert changes in strain to changes in voltage

SST Transmitter

- Takes voltage input from load cells and interfaces with software

Programming Software

- Establish connections with SST Transmitter, adjust settings of baud rate, input/output and high/low reading limit, converts voltage to force reading

Testing

By using increasing increments of weights (5 lb, 15 lb, 25 lb, 35 lb, 45 lb), the accuracy of the LEST device was measured using the accompanying SST software. To begin, exercise plates were placed on top of the push plate and the load cell accuracy was measured. Then, the LEST device's push plate was flipped and hung off the edge of a table. Similar to the procedure mentioned previously, the load cell accuracy was then measured in tension.

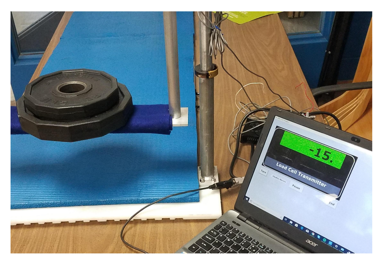
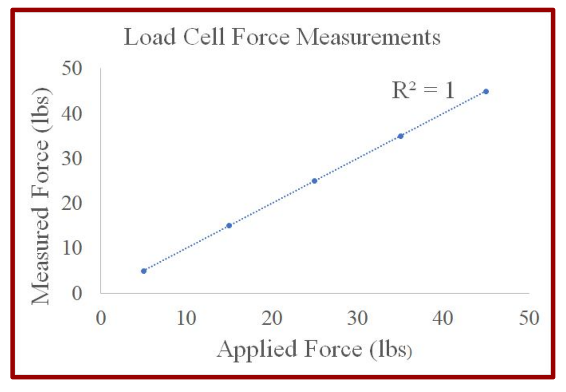


Figure 10 (left): An image of the testing procedure done with the LEST device, utilizing the SST software.

Figure 11 (right): The force measured by the load cells was 100% accurate to two significant figures for both tension and compression.



Future Work

- Make vertical assembly detachable.
- Ensure LEST integrates with lab software.
- Design case to carry electronics.
- Increase the resolution on the display.

References/Acknowledgements

[1] Deering, RE et al (2018). Fatigability of the lumbopelvic stabilizing muscles of women 8 and 26 weeks postpartum. Journal of Women's Health Physical Therapy. In press.
[2] Mens, J., Vleeming, A., Snijders, C., Koes, B. and Stam, H. (2001). *Reliability and Validity of the Active Straight Leg Raise Test in Posterior Pelvic Pain Since Pregnanc*. 26th ed. [ebook] Rotterdam, The Netherlands: Erasmus University of Rotterdam, pp.1167-1171.
[3]Therapeutic Associates Physical Therapy. (2018). *Lumbopelvic Stability - Therapeutic Associates Physical Therapy*. [online]
[4] Keane, D., Sims, T., Abrams, P. and Bailey, A. (1997). Analysis of collagen status in premenopausal nulliparous women with genuine stress incontinence. *BJOG: An International Journal of Obstetrics and Gynaecology*, [online] 104(9), pp.994-998.
[5] Thompson, N. (2017). *Muscles That Move the Leg*. [online] Acefitness.org
[6] [1]*BP400600 Force Platform*. 176 WALTHAM STREET WATERTOWN, MA: ADVANCED MECHANICAL TECHNOLOGY, INC., 2018.

Thank you to our ever-helpful clients and our advisor for the continued advice and support! Also, thank you to the TEAM Lab staff and parts vendors for their design aid..

Sam Notes

Features

- Lightweight HDPE base with dado cuts made to reduce weight.
- Vacuum cups on the bottom help fix the base plate to the floor to increase stability during testing.
- Hinged base and side metal handles help to increase portability of the design between multiple location.
- Vertical Assembly comprised entirely of aluminum components.
  - An outer corner tower assembly made of an aluminum base and aluminum tubes is fixed to the base plate. Quick adjust shaft collars are welded to the top of the corner towers for easy height adjustment of the base plate.
  - Load cells integrated into the outer vertical supports recognize forces produced during testing.
  - Aluminum pipe fittings fix the outer vertical supports to the inner vertical assembly and aluminum push plate.
  - The base plate and push plate have foam coverings for added comfort.

Testing Procedure

1. While laying down with their feet between the inner vertical supports, the subject will first perform an unassisted leg raise with one leg to fatigue it.
   - The push plate will be in its lowest position with the quick clamps locked in place..
   - 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).
2. The push plate will be raised to an appropriate height to fit the subject’s ankle by releasing the quick clamps, raising the vertical assembly, and retightening the quick clamps.
3. The fatigued leg will immediately perform a straight leg lift on the bottom face of the push plate. 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 base plate of the design, which does not interact in any way with components fixed to the load cells.
4. This process will then be repeated with the opposite leg on a separate day.