Biometric Neurorehabilitation and Mobility Assessment System

BME 200/300 Design

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Aidan Burich
Nial Donohoo
Nicolas Maldonado
Carolyn Randolph
Henry Salita

Advisor: Dr. Duc-Huy Nguyen
Client: Dan Kutschera

Background

Fig. 1: Walking assessment [1].

Tracking TBI Patient Walking Progress

- Current Methods
  - Timer and tape measure for speed and distance
  - No commonly available way to track pressure on walker
- Past BME Design Iterations
  - Compromised structural integrity of walker
  - Not easily replicable

[1] https://emsci.org/index.php/project/the-assessments/functional-test

Client Introduction and Requirements

Daniel Kutschera

- Physical Therapist
- Acute Stroke Clinic - ThedaCare, Fitchburg, WI

Fig. 2: Client Dan Kutschera [2].

Client Requirements:

- Real-time data on distance traveled, speed, and pressure applied to walker in U.S customary units
- Do not alter structure of walker
- $500 budget

[2] https://www.linkedin.com/in/daniel-kutschera-239a8492/

Competing Designs

Camino Smart Walker

- AI equipped, auto-braking and boosts
- Expensive - $2,999
- Not designed for clinical settings

Fig. 3: Camino product photo.

[3] "Camino : The World's First Smart Walker." Camino Mobility, caminomobility.com/. Accessed 2 Oct. 2025.

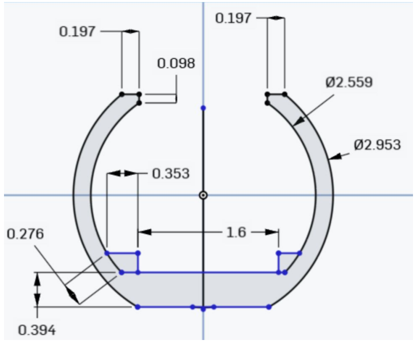
Problem Statement

Current methods of tracking the progress of TBI patient progress calculate speed and distance after trials are complete and exclude pressure. Real-time data on these metrics will reduce documentation time and increase immediate objective feedback of patient readiness for discharge.

Design Specifications

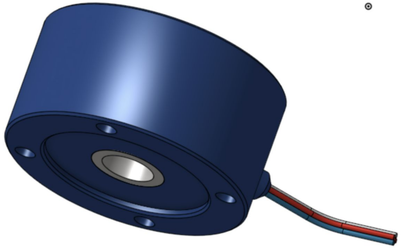
- Tracks pressure, speed, and distance
  - Accuracy: within ±10%
  - Reliable over distance of 10m and period of 30 minutes.
- Compact, removable attachments
  - <u>No impact on walker usability</u>
  - Compatible with existing 2-wheel walkers
  - Easy to clean between patients
- Supports patient weight up to 140 kg
- Designed to meet FDA/ISO safety standards
- Budget: ~ $500

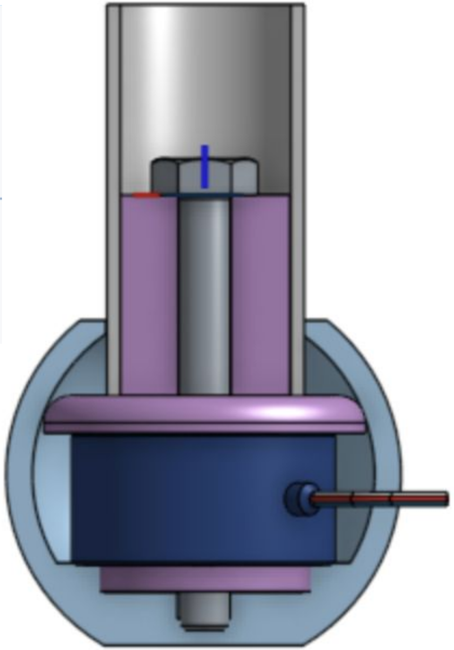
1. Tennis Baller



Components:

- Pancake load weighing cell
- 3D printed custom piece
- Larger base for additional stability

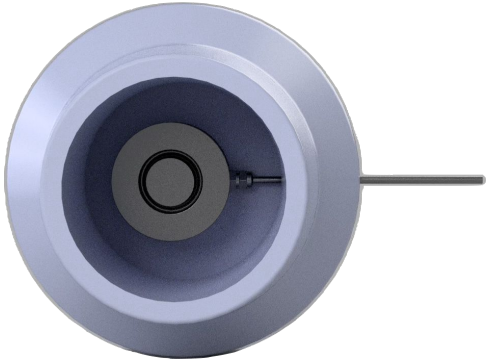




How it is used:

- Device is placed on the end of the back legs of the walker, replacing the normal end cap
- When the patient puts weight on the walker, the device will measure the ground reaction force

2. Endcape 2.0

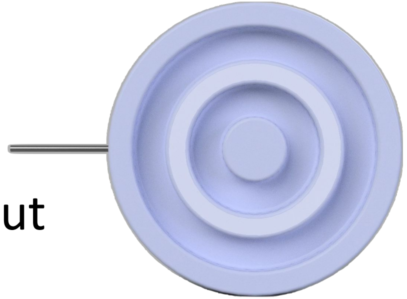


Components:

- 3D printed Custom End Cap
- Load Cell

How it is used:

- Device is placed on the end of the back legs in the place of a normal end cap
- As a patient puts their weight on the walker, the device will measure the ground reaction force in order to measure the weight being put on the walker



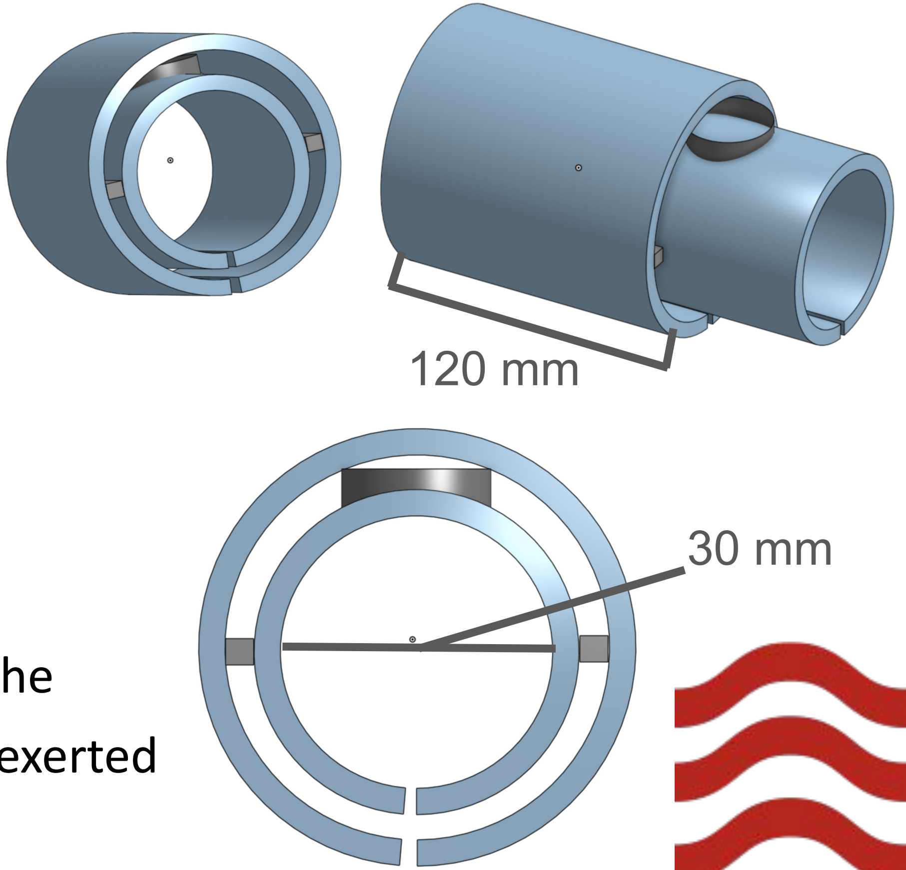
3. Hand Gripper

Components:

- 3D Printed Double Shell
- Load Cell

How it is used:

- Device is put on handles of walker
- When a patient puts pressure on the handles, load cell tracks the force exerted



Design Matrix Load Cell Housing

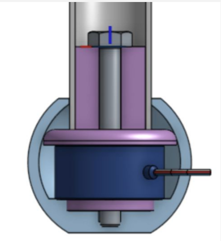
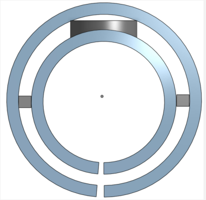
		 1. Tennis Baller		 2. End-Cap 2.0		 3. Hand Gripper	
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accuracy of Data	25	5/5	25	5/5	25	3/5	15
Simplicity	25	4/5	20	5/5	25	4/5	20
Usability	20	5/5	20	5/5	20	3/5	12
Safety	15	4/5	12	5/5	15	3/5	9
Ease of Set-up	15	3/5	9	3/5	9	5/5	15
Total (Out of 100):		86		94		71	

Table 1: Design Matrix.

1. Infrared Sensor

Fig. 4: Infrared Sensor

Components:

- Infrared Sensor
- Wheel Color Modification

How it is used:

- Wheel has a white strip of tape
- Every time sensor sees white tape, a rotation is tracked
- Sensor is mounted at the base of the leg pointed at the wheel

2. Rotary Encoder

Fig 5: Rotary Encoder Attached to Wheel

Components:

- Rotary Encoder
- Wheel attachment
- Band that connects wheel to Encoder

How it is used:

- A band will be attached to the wheel and encoder
- Encoder measures the rotations of the wheel to determine distance traveled

3. Lidar Sensor

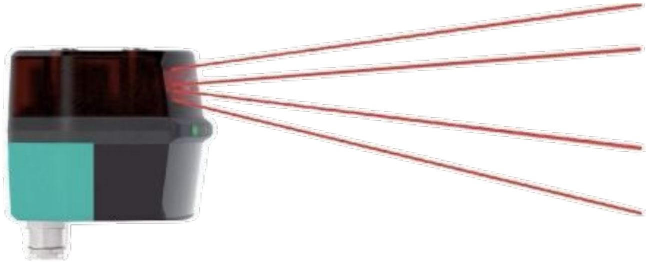


Fig 6: Lidar Sensor

Components:

- Lidar Sensor
- Component Housing

How it is used:

- Lidar will be pointed at a wall and measure how quickly and far a patient walks towards that wall
- The lidar will update at 2 MHz ensuring no gaps in the data

Design Matrix Movement Sensors

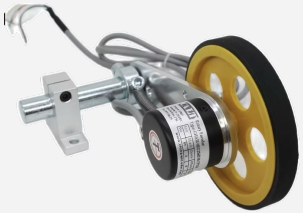
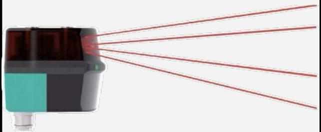
		 1.Infrared Sensor		 2. Rotary Encoder		 3. Lidar Sensor	
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accuracy of Data	25	3/5	15	5/5	25	4/5	20
Structural Impact	20	4/5	16	1/5	4	5/5	20
Safety	15	5/5	15	3/5	9	5/5	15
Reliability of Sensors	15	3/5	9	5/5	15	4/5	12
Ease of Set-up	15	3/5	9	1/5	3	4/5	12
Cost	10	5/5	10	3/5	6	2/5	4
Total (Out of 100):		74		62		83	

Table 2: Design Matrix Movement Sensors.

Final Design

- Lidar Sensor
  - Stick down from front bar
  - Facing wall
- Load Cells
  - bottom of end cap add on
  - Hat/lego mechanism
- Electrical components
  - Through legs
  - Batteries in attached box

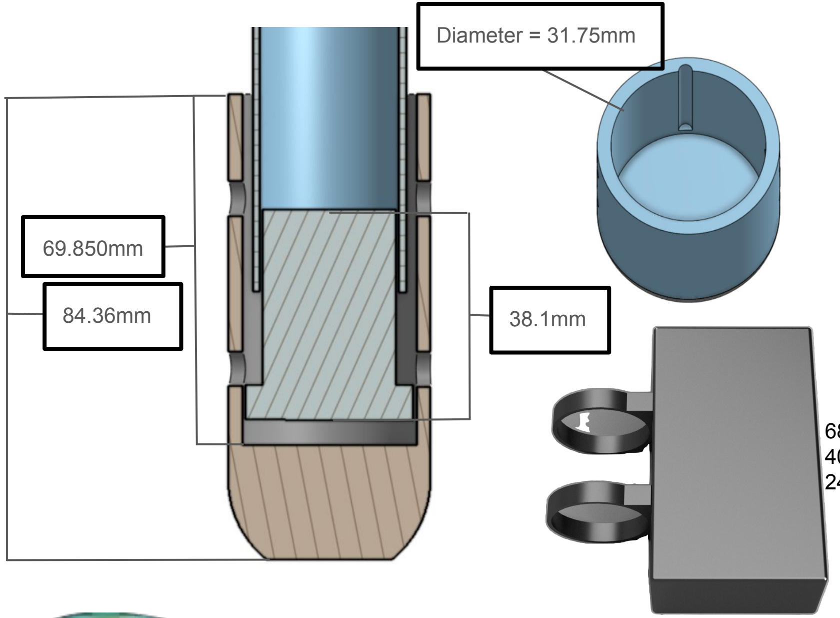


Figure 7: Lidar Sensor [7]

Testing

- Load Measurement Testing: Compare walker load sensor readings against in-ground force plates while a subject applies weight through the handles.
- Speed Testing: Validate both average and instantaneous velocity by timing walker movement over marked distances and comparing to device-reported values.
- Distance Testing: Set a pre measured distance to walk

Future Work

- Order electronic components
    - Best type of load cell and lidar sensor
- Begin prototyping with 3D printed parts
- Electronics
    - Code
    - Wiring
    - Bluetooth

References and Acknowledgements

Thank you Dr. Duc-Huy Nguyen, Dan Kutschera, and Dr. Puccinelli

[1] https://emsci.org/index.php/project/the-assessments/functional-test

[2] Linkedin, https://www.linkedin.com/in/daniel-kutschera-239a8492/

[3] “Camino : The World’s First Smart Walker.” Camino Mobility, caminomobility.com/. Accessed 2 Oct. 2025.

[4]Https://Www.Radwell.Com/Buy/ANALOG%20DEVICES/ANALOG%20DEVICES/EVAL-ADXL345Z-S?adlclid=deca88278ee21666662ee0f89c1f1f58&msclkid=deca88278ee21666662ee0f89c1f1f58&utm_source=bing&utm_medium=cpc&utm_campaign=%5BLegacy%5D%20%5BDSA%5D%20SC%20-%20DSA%20-%20All%20Webpages%20-%20Bing&utm_term=%2Fbuy%2F&utm_content=Dynamic%20Ad%20Group.

[5]“Encoder Linear Measuring Systems.” AutomationDirect, www.automationdirect.com/adc/overview/catalog/sensors_-z-_encoders/linear_position_sensors/encoder_linear_measuring_systems?utm_source=msn+cpc&utm_medium=cpc&utm_term=%2Fadc%2Foverview%2Fcatalog%2Fsensors_-z-_encoders%2Flinear_position_sensors&utm_campaign=DSA+-+All+Searchers&utm_adgroup=Process+Sensors&msclkid=97db9d89f4e11bae1a8cf556e0f39ea2&utm_content=Process+Sensors. Accessed 2 Oct. 2025.

[6]“Sick 1055376 LMS531-11100 2d Lidar Sensor.” Southern Electronics, southernele.com/sick-1055376-lms531-11100-2d-lidar-sensor/?msclkid=9adb4ef6daa21e663a792629ce399e17&utm_source=bing&utm_medium=cpc&utm_campaign=%2A%2ALP+Shop+-+Top+Brands+-+Catch+All&utm_term=4577816667621016&utm_content=Catch+All. Accessed 2 Oct. 2025.

[7] “Garmin LIDAR-Lite Optical Distance Sensor – V3.” Adafruit, https://www.adafruit.com/product/4058
. Accessed 2 Oct. 2025.