Mechanical Hip Prosthetic Horizon Hip

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Design Requirements

Customer Requirements

- Stable leg supporting **90 kg user** (CR1)
- Enables **walking ability** (CR2)
- **Comfortable & easy to use** (CR3)
- **All-day battery life** (CR4)
- **Compatible** with existing prosthetics & sockets (CR5)
- Assists **sit → stand** (CR6) and **stand → sit** (CR7)

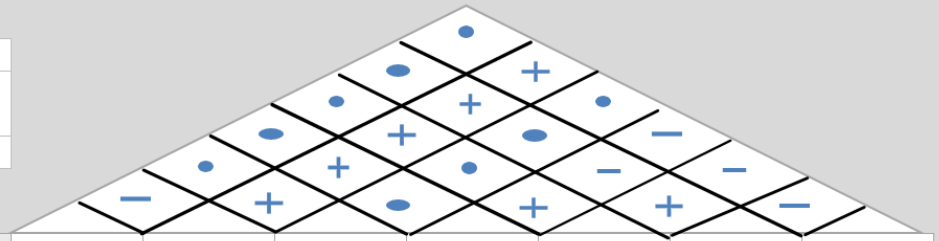
Engineering Requirements

- **Durable:** ≥ 18 load test cycles (ER1)
- **Lightweight:** < 15 lbs (ER2)
- **Compact:** ≤ 14 in length (ER3)
- **Range of Motion:** -20° to 135° (ER4)
- **Torque:** 66.2 Nm (ER5)
- **Cadence:** 1.25 steps/sec (ER6)
- **Energy:** Expends 28.8J (ER7)

QFD

Quality Function Deployment

Project title:	Horizon Hip
Team Members:	Aiden Camisa, Victoria Lyon, Matthew Martinez, Quinn O'Neill
Date:	3/20/2026



Correlation:

+	.	-
Positive	No correlation	Negative

Relationships:

9	7	3	1	0
Strong	Moderate	Intermediate	weak	none

		Desired direction of improvement (↑,0,↓)	0	v	v	^	^	^	^			
	1: low, 7: high	Engineering Requirements (How's) →	Structural integrity with use	Weight of >=15lb	Length of 14 in or less	ROM from -20 ° to 135°	Desired torque of 66.2Nm or greater	Cadence of 1.25 steps/sec or greater	Lasts for 1 hour of regular use		Competitive evaluation (1: low, 5: high)		
	Customer importance rating	Customer Requirements - (What's) ↓								Weighted Score	Satisfaction rating	Helix 3D	Unpowered Hinged Pylon
1	7	Support 90kg individual	9	1	0	0	7	0	0	119	5	5	5
2	4	Ability to walk	9	3	0	9	9	9	7	184	5	5	3
3	2	Ease and comfortability	1	9	9	7	0	7	7	80	4	4	2
4	1	Efficient battery life	0	1	0	1	7	3	9	21	3	-	-
5	6	Ensure standard attachment above and below	3	3	3	1	0	0	0	60	5	5	5
6	5	Sit to Stand	9	3	1	9	7	0	1	150	5	3	1
7	3	Stand to Sit	9	3	1	9	7	0	1	87	5	5	5
		Technical importance score	191	80	44	129	148	53	59	701			
		Importance %	27%	11%	6%	18%	21%	8%	8%	100%			
		Priorities rank	**1**	**4**	**7**	**3**	**2**	**6**	**5**				
		Difficulty	4	3	2	3	2	4	1	1: very easy, 7: very difficult			
		Cost and time	5	3	3	2	5	2	3	1: low, 7: high			
		Priority to improve	**2**	**1**	**6**	**4**	**3**	**7**	**5**	1: low, 7: high			

Testing Summary

Experiment/Test	Relevant DRs	Testing Equipment Needed	Other Resources
Exp 1 – Device Weight Check	ER2 – Less than 15 lb	Scale	NextStep Facility
Exp 2 – Attachment Verification	CR5 - Ensure standard attachment above and below	Lamination plate, female pyramid adapter	
Exp 3 – Power Usage Test	CR4 – Battery should last throughout the day ER 7 - Last 1 hour of use	Electrical System Lower leg prosthesis Secure Suspension System	
Exp 4 –ROM Test	ER4 - (- 20°) to 135° sagittal ROM	IMU OR Digital inclinometer OR Markers, paper, camera Mounting System	NextStep Facility
Exp 5 – Static Stand Test: With and Without Sound Leg	CR1 – Support 90 kg user	Bypass Support or rail for safety Scale Lower leg prosthesis	NextStep Facility
Exp 6 – Stand to Sit Test: With and Without Sound Leg	CR7 – Stand to sit	Chair Rail/Support Bypass Position Sensor Camera	NextStep Facility

Testing Summary [continued]

Experiment/Test	Relevant DRs	Testing Equipment Needed	Other Resources
Exp 7 – Sit to Stand Test	CR6 – Sit to stand	Chair Rail/Support Bypass Position Sensor Camera	NextStep Facility
Exp 8a – Motor Torque Performance Check: Constant Velocity	ER5 – Torque of 66.2Nm	Mounting System Weight-tension system Camera	NextStep Facility
Exp 8b – Motor Torque Performance Check: Oscillating Velocity	ER5 – Torque of 66.2Nm	Mounting System Weight-tension system Camera	NextStep Facility
Exp 9 – Motor Cadence Performance Check	ER6 – Cadence of 1.25 steps per second	Mounting System Weight-tension system Camera	NextStep Facility

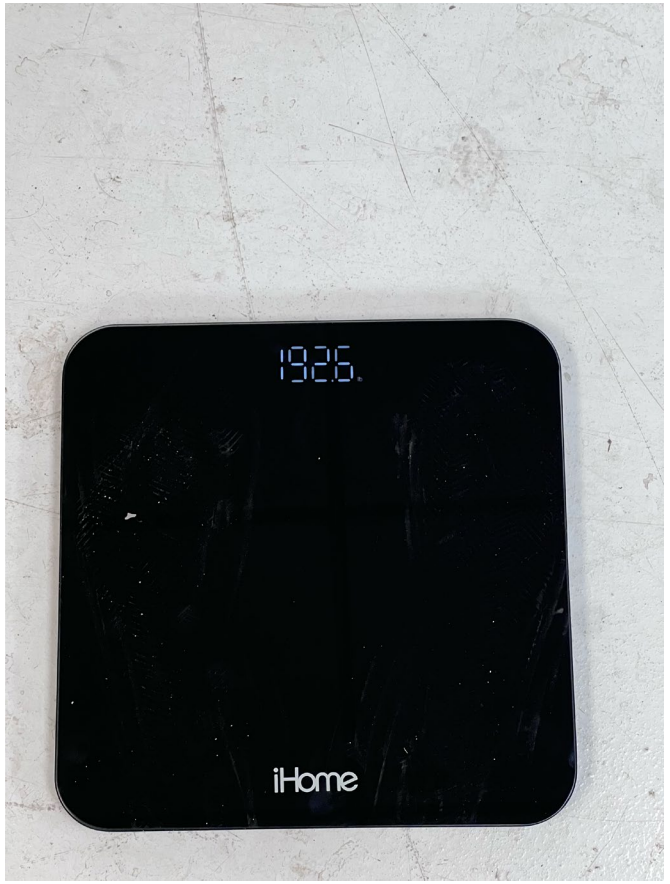
Testing Plans

Category	Experiment 1 – Weight Check (ER2) (Performed)	Experiment 2 – Attachment Verification (CR5) (Performed)
Goal	Verify device weight < 15 lbs	Verify compatibility with prosthetic components
Method	Measure using calibrated scale	Attach to lamination plate & pyramid adapter
Procedure (Short)	Weigh device, repeat 3×	Assemble components, check alignment
Results	8 lbs	Secure fit, no misalignment. Ease of assembly
Conclusion	Meets ER2	Meets CR5

Device Weight Check

(Initial weight = Teammate)
(Final weight = teammate holding prosthesis)

ER2 met!





Initial Weight: 192.6 lbs

Final Weight: 200.6 lbs

Prosthesis 8 lbs







Attachment Proof

Alignment is good, and the device attaches to the female pyramid adapter and the lamination plate

CR5 met!

Testing Plans

Category	Experiment 3 – Energy Usage (ER7, CR4) (Performed)	Experiment 4 – Range of Motion (ER4) (Performed)
Goal	Compare energy used by prosthetic to that used by sound leg	Verify ROM from -20° to 135°
Method	Measure Energy used during a sit to stand demo, and compare	Controlled motion testing with IMU
Procedure (Short)	Use torque test protocol to simulate 10 sit to stands and measure the Energy through wattage using a recorded frame by frame analysis	Rotate through full angle range until collision
Result Criteria	Within 5J of the desired 28.8J of sit to stand	-20° to 135°
Conclusion	If the used energy is under 33.8J per sit to stand, ER& and CR4 are met	Meets ER4 if goal met

Energy Test Results

Using this formula to find the necessary loading to

simulate sit to stand for desired 28.8 J

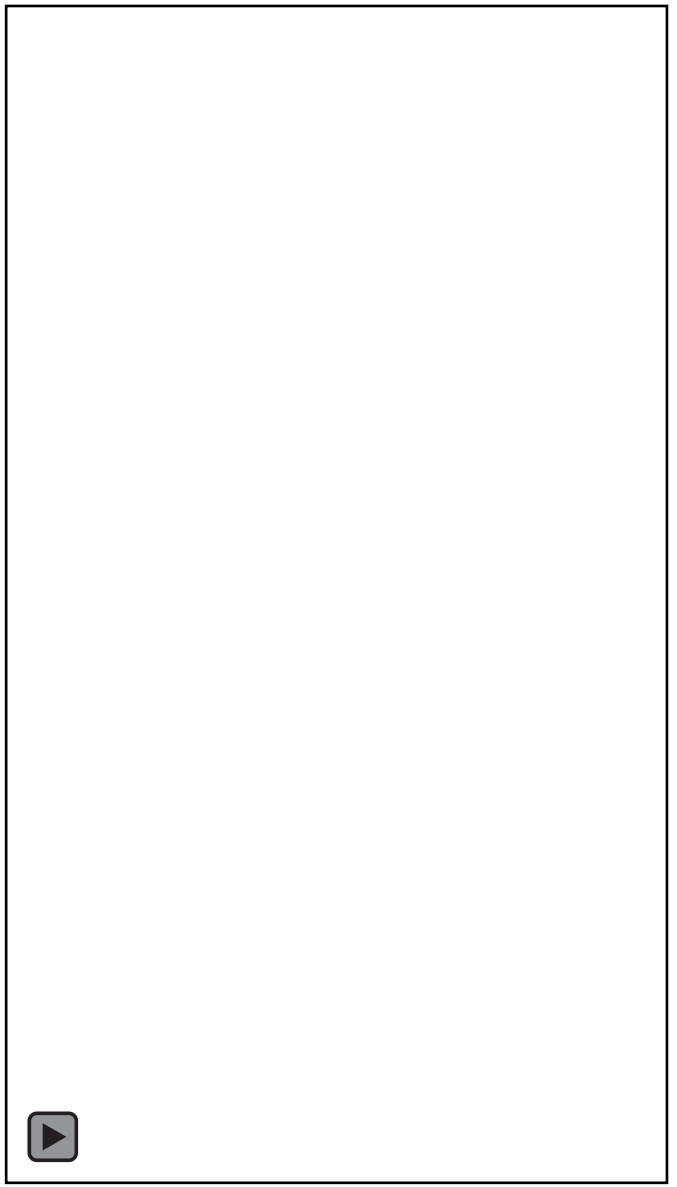
$$E = (\Theta_{max} - \Theta_{min})Fd \int_{\Theta_{min}}^{\Theta_{max}} \sin(\Theta)\, d\theta$$

A required load of 10.6357 lbs at.3785 m for a range of 0-90 degrees

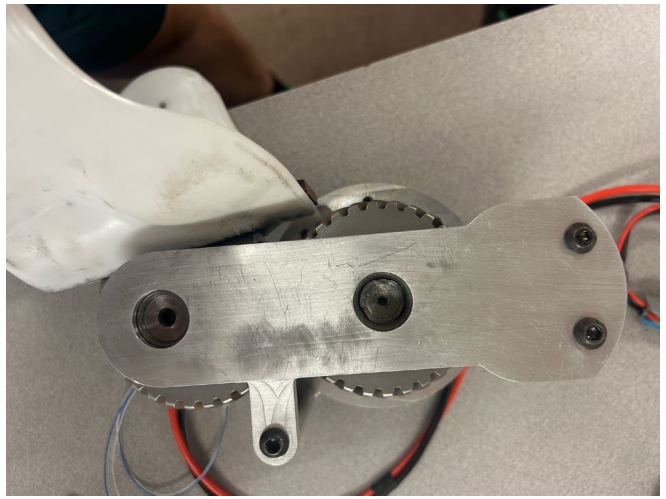
- Each of the 10 trials had 43 frames recorded at 30fps for 1.433 s
- The found average Power was 22.41 W
- The found average Energy was 32.12J
- We were within our goal of < 33.8J

The additional power can be explained by electronics and the

slight imperfection of loaded weight

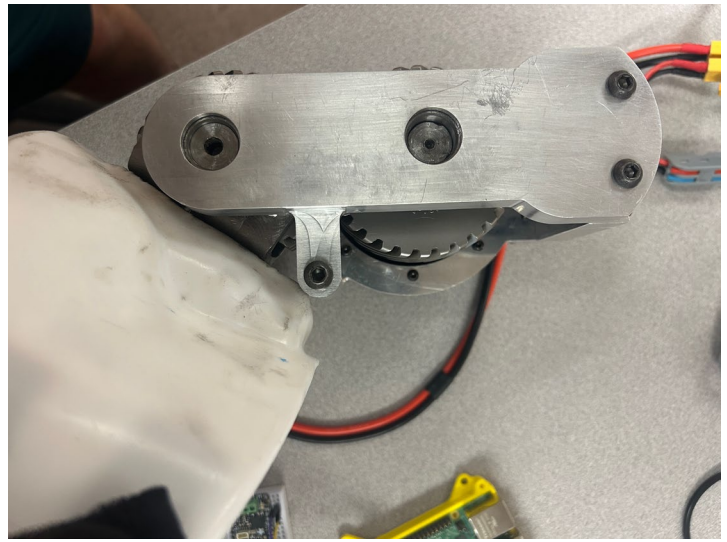


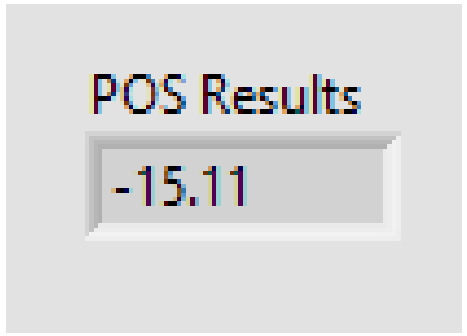
Range of Motion Test Results

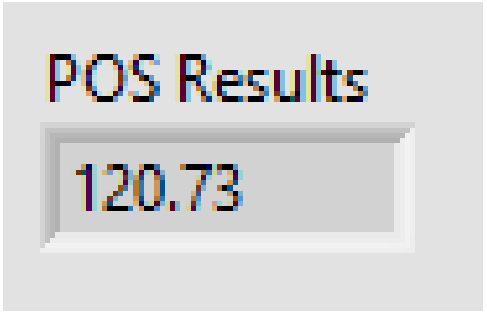


Maximum range of motion of 135 degrees (Measurements in degrees)

ER4 not met







Testing Plans

Category	Experiment 5 – Static Stand (CR1) (Performed)	Experiment 6 – Stand-to-Sit (CR7) (Performed)
Goal	Support 90 kg user	Controlled sitting motion, impedance control
Method	30s standing tests, each foot on a scale to measure force	Motion tracking with position sensors
Procedure (Short)	Timed standing trials	Perform sit motion, record data
Result Criteria	Holds weight for 30s, >15% loading difference	Smooth, stable descent. Range of motion meets anatomical stand-to-sit (~100° flexion)
Conclusion	Meets CR1 if criteria met	Meets CR7 if action is performed

Testing Setup for Wearing Device



Hip restricting bypass





COVER!

Static Stand

- Trial 1: Left = 114lbs, Right = 82.4lbs
  - 27.7% loading difference
- Trial 2: Left = 105lbs, Right = 95.2lbs
  - 9.3% loading difference

  Up to 106.8lbs !
  Funky scales would turn off mid test
  :/

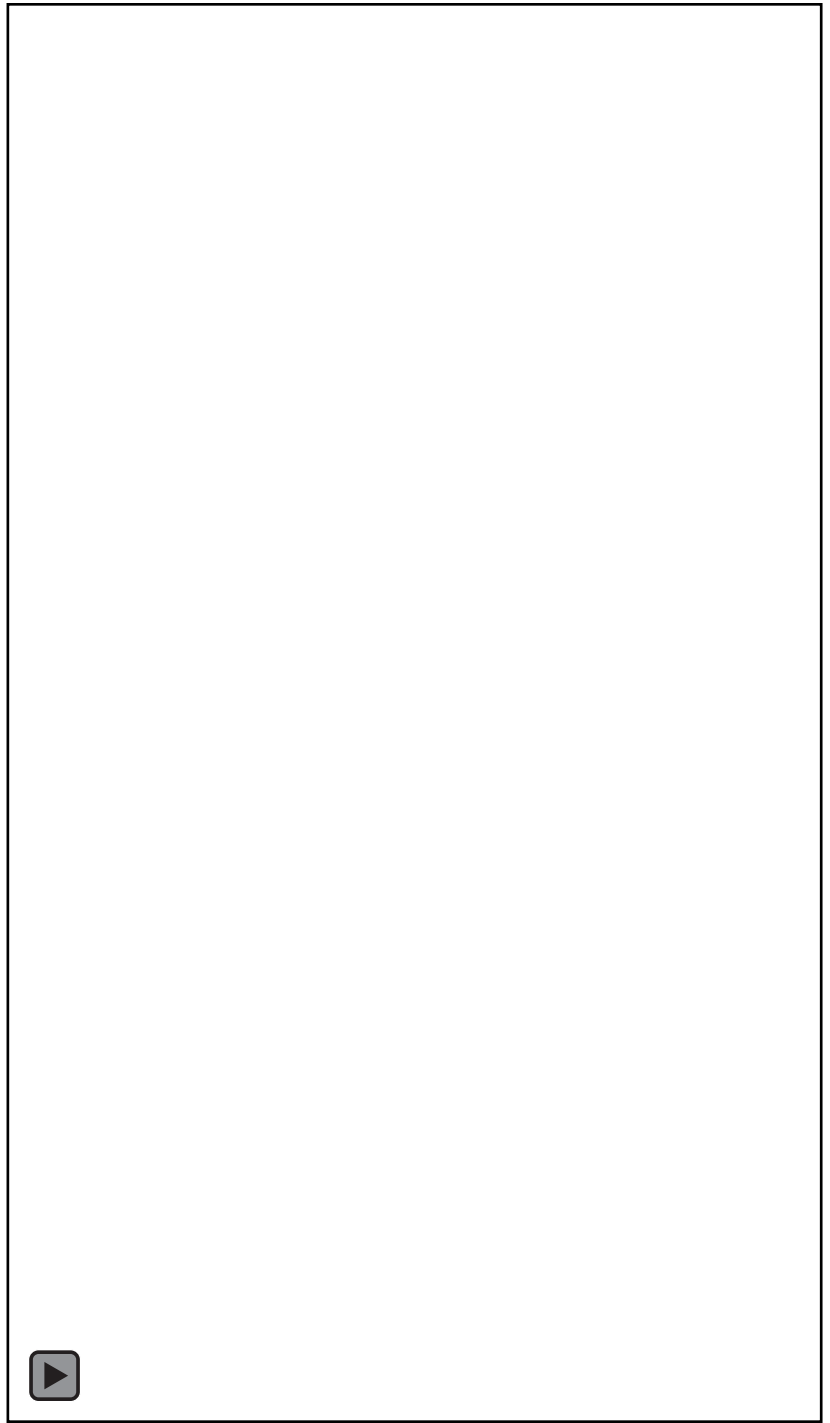






Stand-to-Sit [V1]

- Range of motion met and is repeatable
- Testing setup needs further improvement
  - Fixing foot in place
  - Additional upper body support
  - Bypass fixes

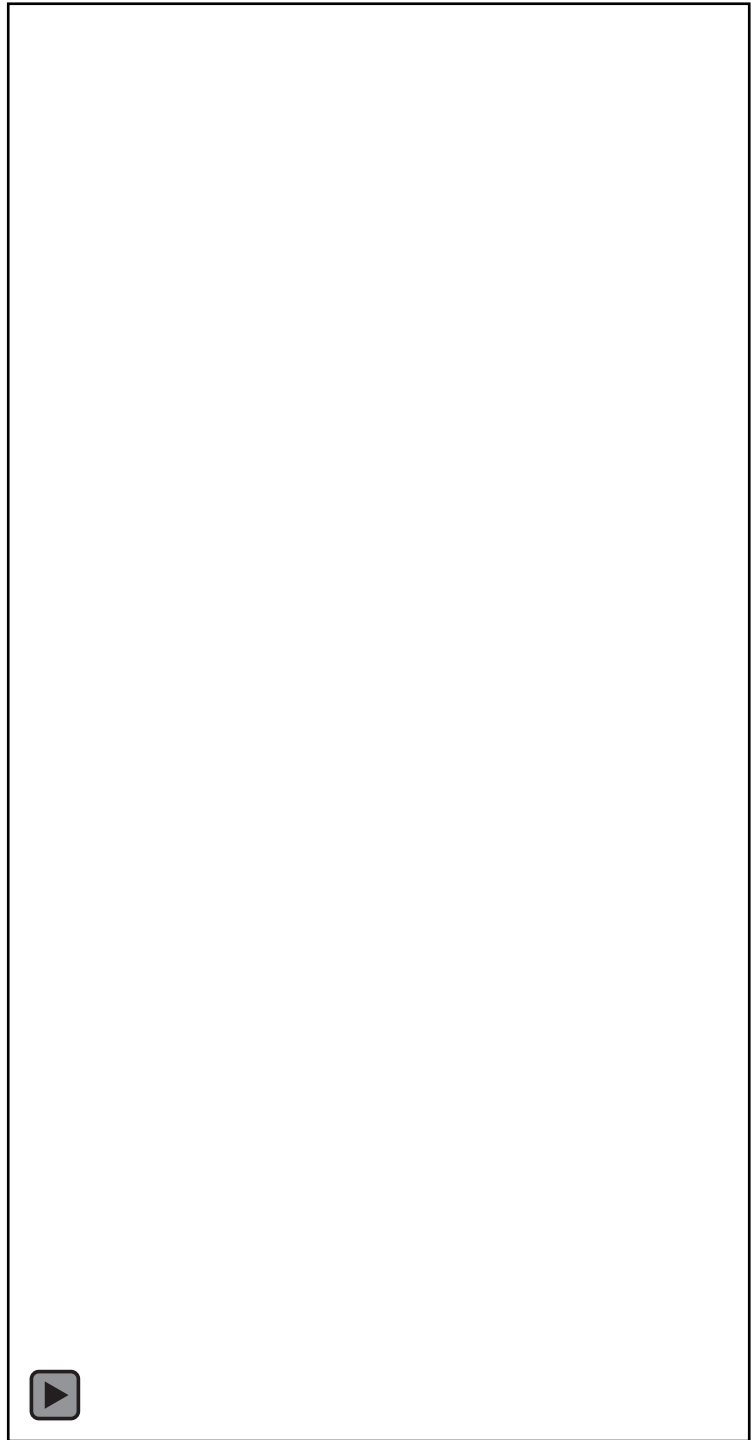


Testing Plans

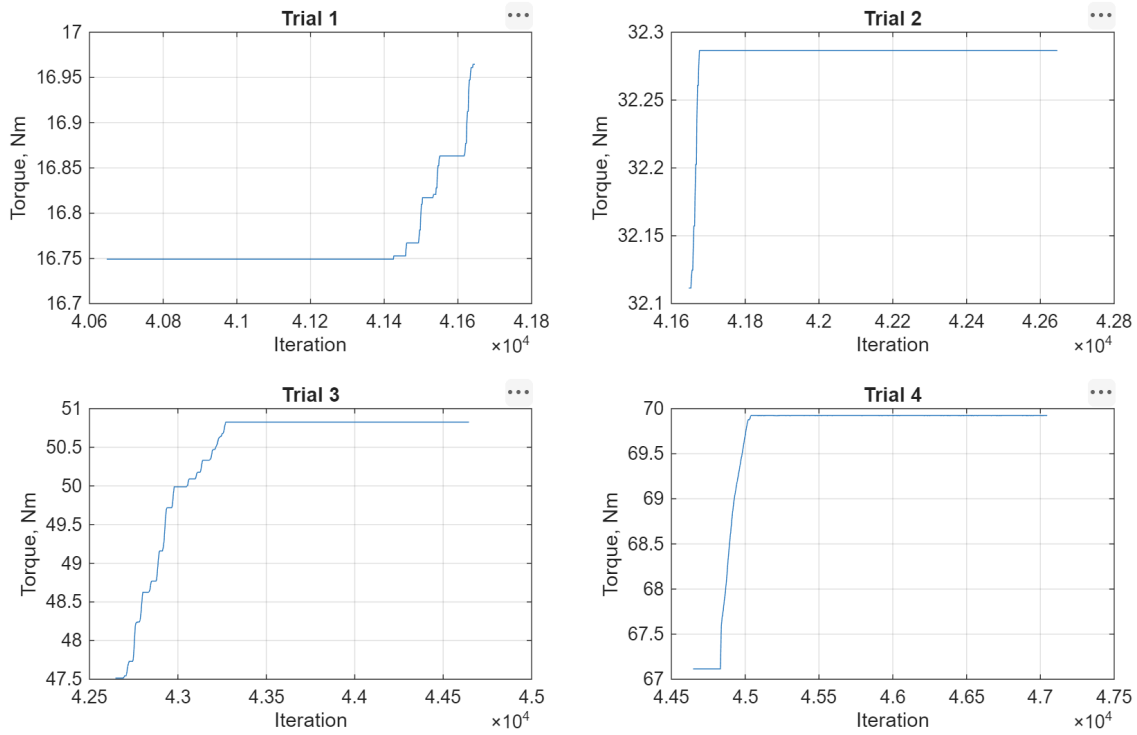
Category	Experiment 7 – Sit-to-Stand (CR6) (Performed)	Experiment 8 – Torque Test (ER5) (Performed)
Goal	Assist user to stand	Achieve 66.2 Nm torque
Method	Motion tracking with position sensors	Pulley system with weight moving at constant/ oscillating velocity
Procedure (Short)	Perform stand motion, repeat trials	Add weight until 66.2Nm reached
Result Criteria	Smooth, repeatable motion. Range of motion meets anatomical sit-to-stand (~100° flexion)	Meets required torque
Conclusion	Meets CR6 if action is performed	Meets ER5 if torque produced ≥ 66.2 Nm

Sit-to-Stand [V1]

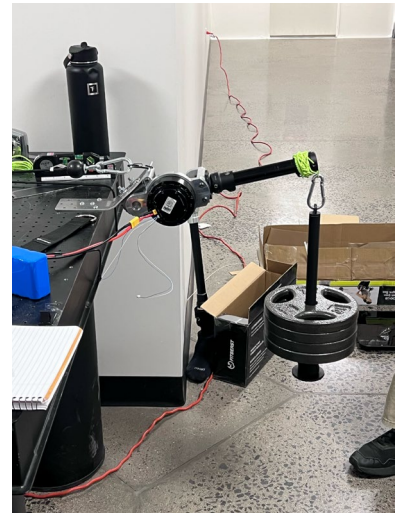
- Range of motion met and is repeatable
- Testing setup needs further improvement
  - Fixing foot in place
  - Additional upper body support
  - Bypass fixes



Motor Torque



- Device + pylon = 15.2 in
- Determined necessary force = 38.42lbs → 40lbs
  - 10lbs added each trial
- Angle from motor position sensor
- Result: 69.95 Nm
- $T = L * F * \sin(\theta)$

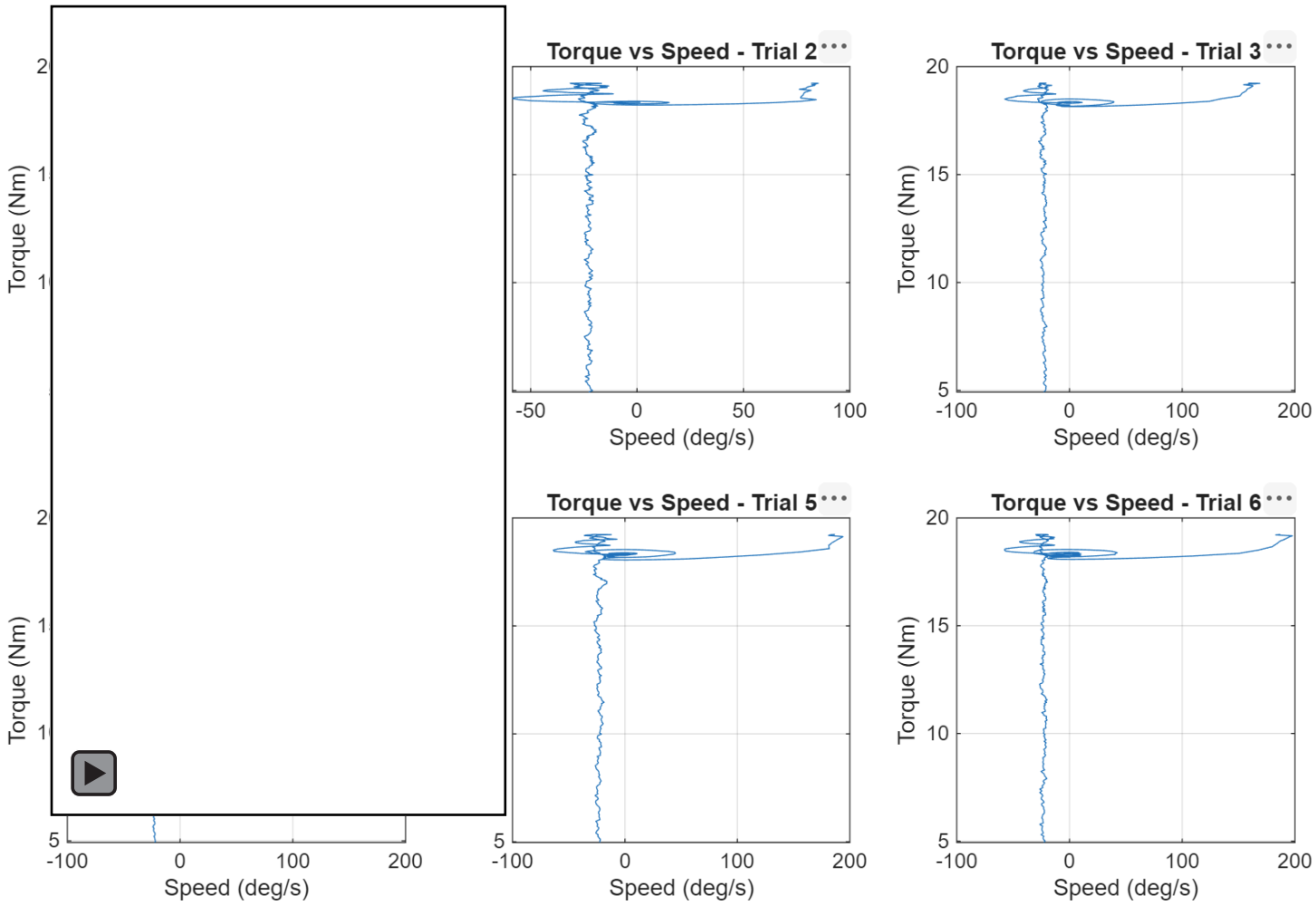


Testing Plans

Category	Experiment 9 – Cadence Test (ER6) **(Performed)**
Goal	Maintain 1.25 steps/sec
Method	Measure swing speed under load
Procedure (Short)	Increase weight, track cadence
Result Criteria	Consistent step rate
Conclusion	Meets CR2 and ER6 if cadence is maintained

Cadence Simulation

- Motor speed for trials 1 & 2 = 85 deg/s
- Motor speed for trials 3 & 4 = 172 deg/
- Motor speed for trials 5 & 6 = 200 deg/
- Added weight = 10lbs



Specification Sheet Preparation | Customer

Customer Requirement	CR Met? (Yes/No)	Client Acceptable (Yes/No)
CR 1 - Support 90kg individual	✓	✓
CR 2- Ability to walk	⊘	✓
CR 4 - Efficient battery life	✓	✓
CR 5 - Ensure standard attachment above and below	✓	✓
CR 6 – Sit to Stand	✓	
CR 7 – Stand to Sit	✓	

Specification Sheet Preparation | Engineering

Engineering Requirement	Target	Tolerance	Measured/Calculated Values	ER Met (Y/N)	Client Acceptable (Y/N)
ER 1 – Durability of device	Zero structural failure across 18 testing experiments	+5.56% Failure	0	✓	✓
ER 2 – Weight of Device	< 15lb	+2 lbs		✓	
ER 3 - Length of Device	< 14 in	± 1 in	7.1 in	✓	✓
ER 4 – Range of Motion	-20 ° to 135°	± 5°	-15 ° to 120°	⊘	✓
ER 5 – Desired torque of device	66.2 Nm	-2 Nm	69.96 Nm	✓	✓
ER 6 –Cadence	1.25 steps/s	0.5 step	1.25 steps/s	✓	✓
ER 7 – Energy	28.8J	± 5 J	32.12J	✓	

Thank you

