Below the Knee Exoskeleton

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ER’s and CR’s

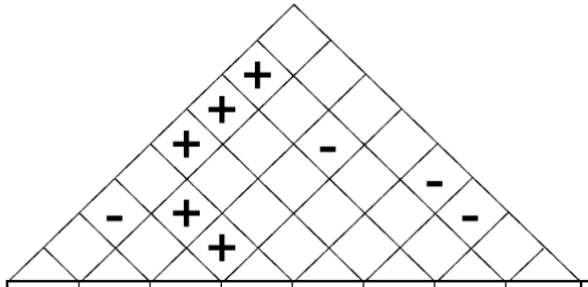
CR’s

- CR1: Durable
- CR2: High range of motion
- CR3: Comfortable
- CR4: High battery life
- CR5: Adjustable
- CR6: Lightweight
- CR7: Affordability

ER’s

- ER1: Energy efficient
- ER2: Accommodate different shoe size
- ER3: High Torque
- ER4: Supports users of all weight
- ER5: Under 3 kg
- ER6: Temperature of motor
- ER7: Battery Capacity
- ER8: Ingress Protection

QFD



Design Requirements / Customer Requirements		Importance (1-5)	Energy efficient	Accommodate different shoe sizes	High torque	Support users of all weights	Under 3 kg	Temperature of motor	Battery Capacity	Ingress Protection
Durable		3		3		6	6	6		9
High range of motion		5			9					
Comfortable		4		3		3	3	3		
High battery life		3	9		6			9	9	
Adjustable		3		3		6				
Lightweight		5			3		9			3
Affordability		5							3	3
Technical Importance: Absolute			27	30	78	48	75	57	42	57
Technical Importance: Relative			7%	7%	19%	12%	18%	14%	10%	14%
Design Competitive Assessment	**Worst: 1**								B	C
	2					C		B	C	B
	3		AB		B		C	C		
	4				C	A	B			A
	Best: 5		C	A	A		A			
Target Value			90	0.3	1000	90	2	70	1000	54
USL			60	0.27		120	3	155		68
LSL			30	0.22	500	30	1.5		500	52
Units			mins	m	mNm	kg	kg	C	mAh	IP

Improvement Direction					
Customer Competitive Assessment					
1 Worst	**2**	**3**	**4**	**5 Best**	
	C	AB			
		B	AC		
			A		
			B		
				C	A
				B	AC
	C	B			

A	Caplex Exo
B	Utah Knee
C	ETM Motor

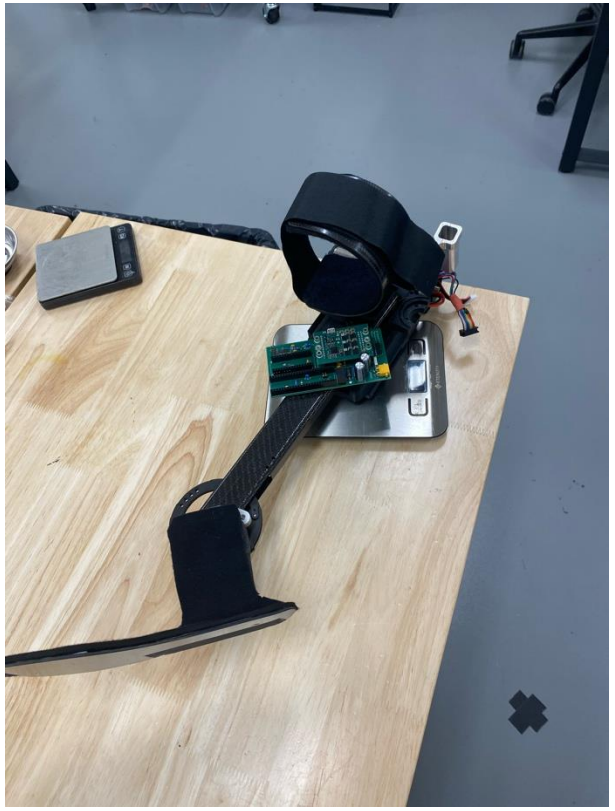
Testing Plan

2 Top Level Testing Summary

Experiment/Test	Relevant DRs	Testing Equipment Needed	Other Recourses
Exp1: Weight and COM	ER5: Under 3kg CR6: Lightweight	Scale	Access to device from Lerner's Lab
Exp2: Initial run of device	ER1: Energy Efficient ER3: High Torque ER7: Battery Capacity CR4: High Battery Life	Device, PCB, Battery, Motor	Programmed PCB
Exp3: Ingress Test	ER8: Ingress Protection	Motor and PCB/battery housing, water	Probe, Spray bottle, determined by target IP rating
Exp3: Ingress Test	ER8: Ingress Protection	Motor and PCB/battery housing, water	Probe, Spray bottle, determined by target IP rating
Exp4: Thermal Test	ER6: Temperature of Motor	Arduino, DAQ, motor & housing	Alternate motor housings
Exp5: Final test on human	ER2: Accommodate Different Shoe Size ER4: Supports Users of All Weight ER1: Energy Efficient ER6: Temperature of Motor CR1: Durable CR2: High range of motion CR3: Comfortable CR5: Adjustable CR6: Lightweight	Assembled device, treadmill	Test Lab

Testing Images

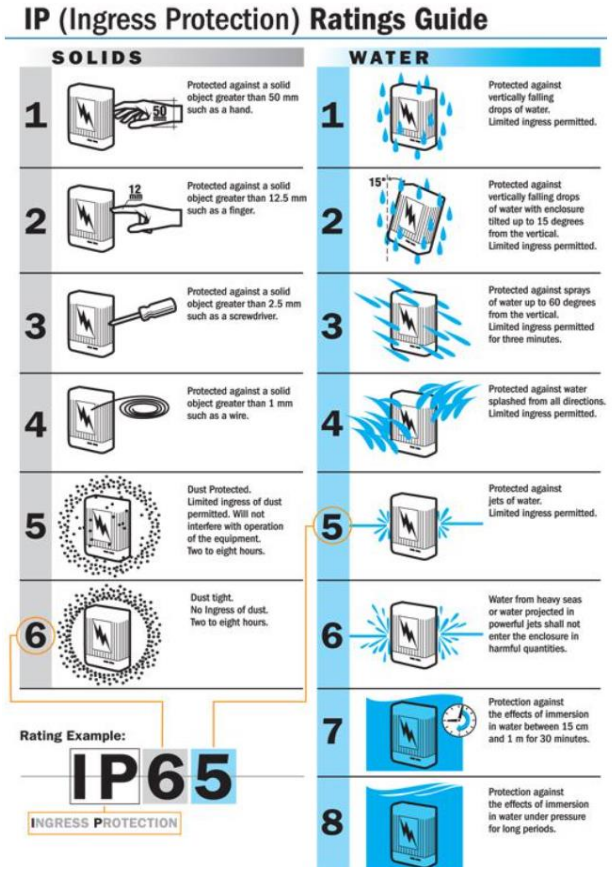
Exp 1: Weight and COM



Exp 1: Comfortability and use.

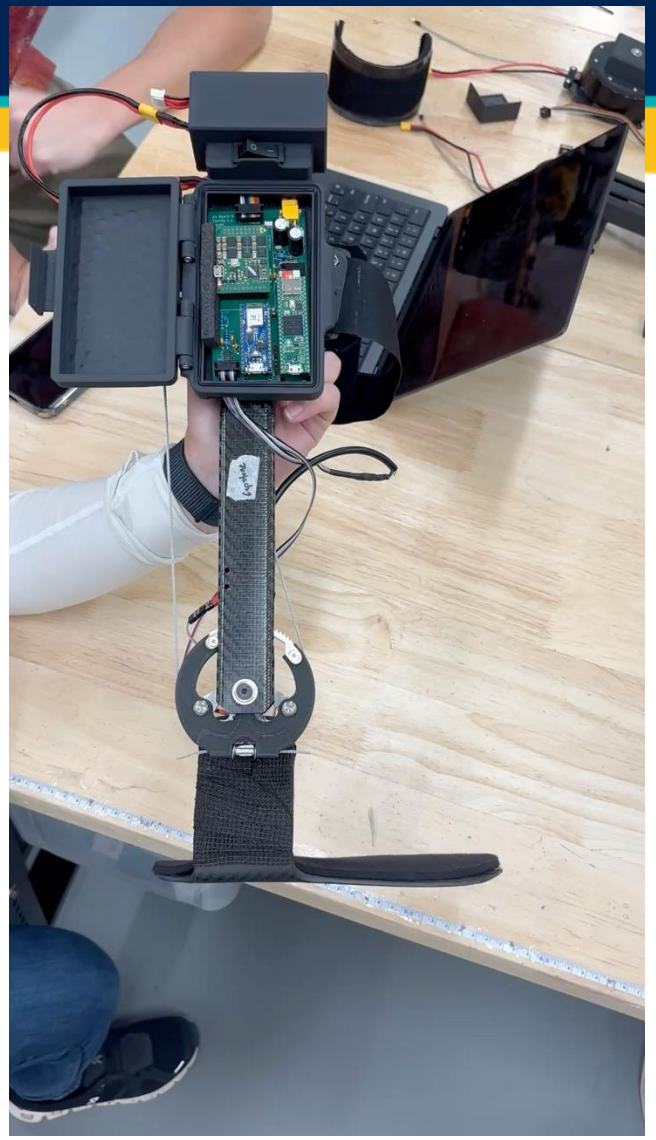
Testing Images

Exp 3: Ingress Protection



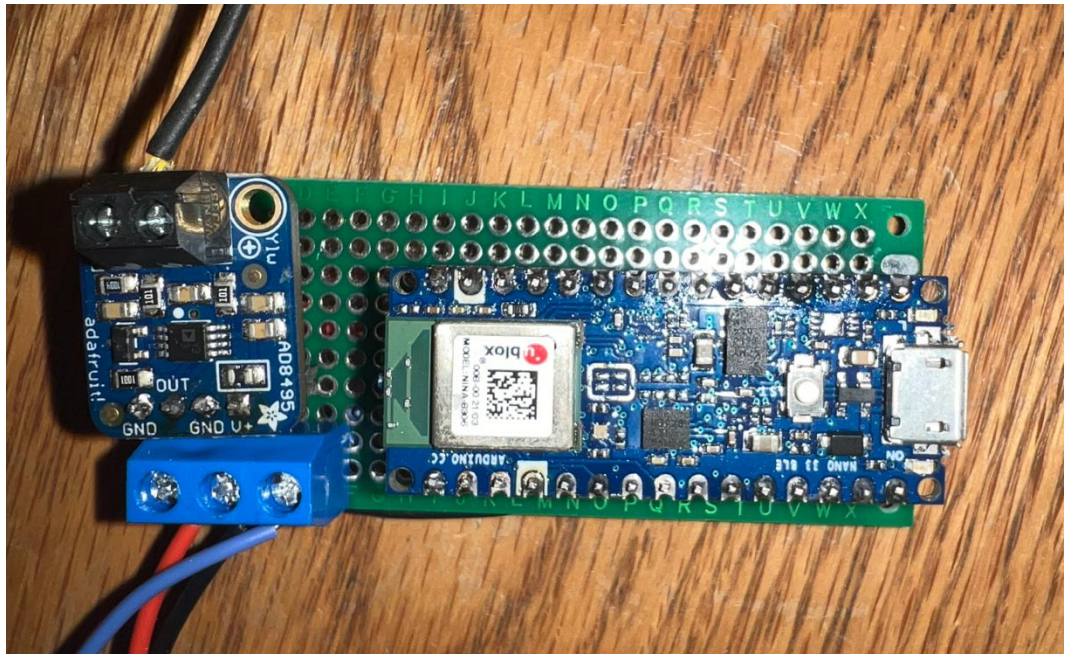
Testing Images

Exp 2: Initial Run of device



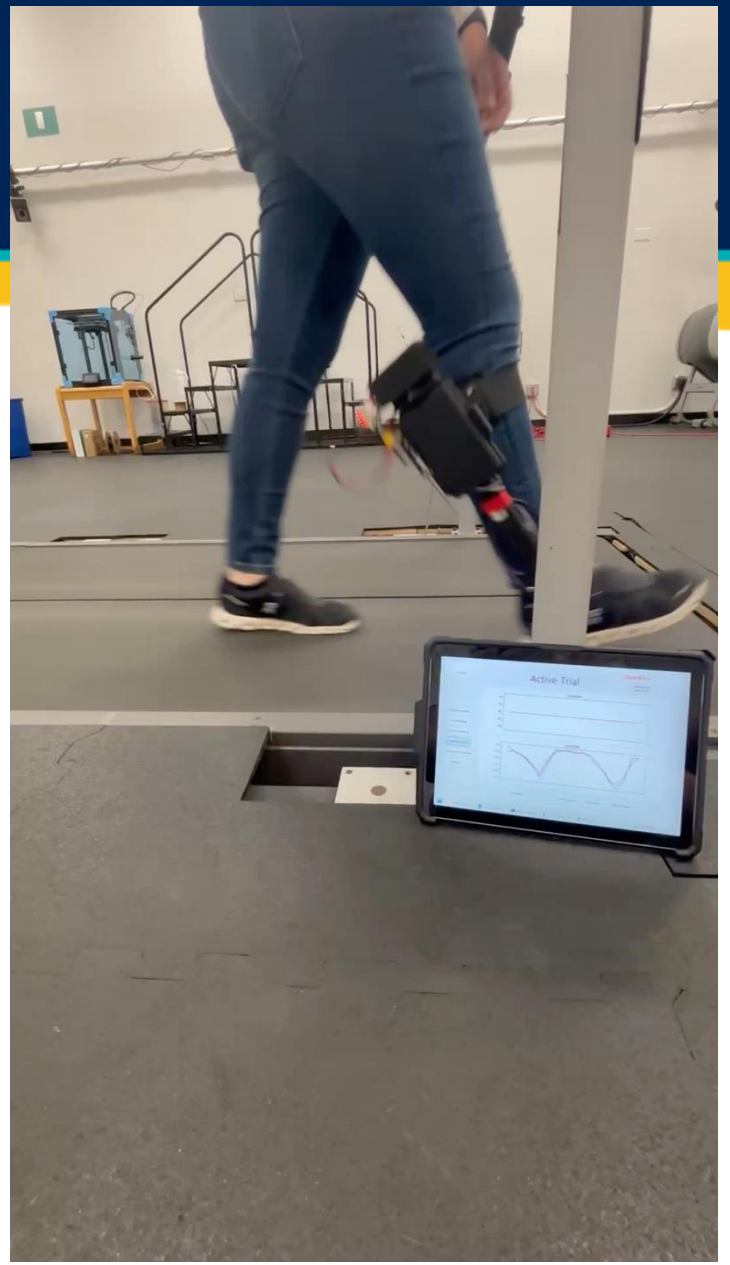
Testing Images

Exp 4: Thermal Test



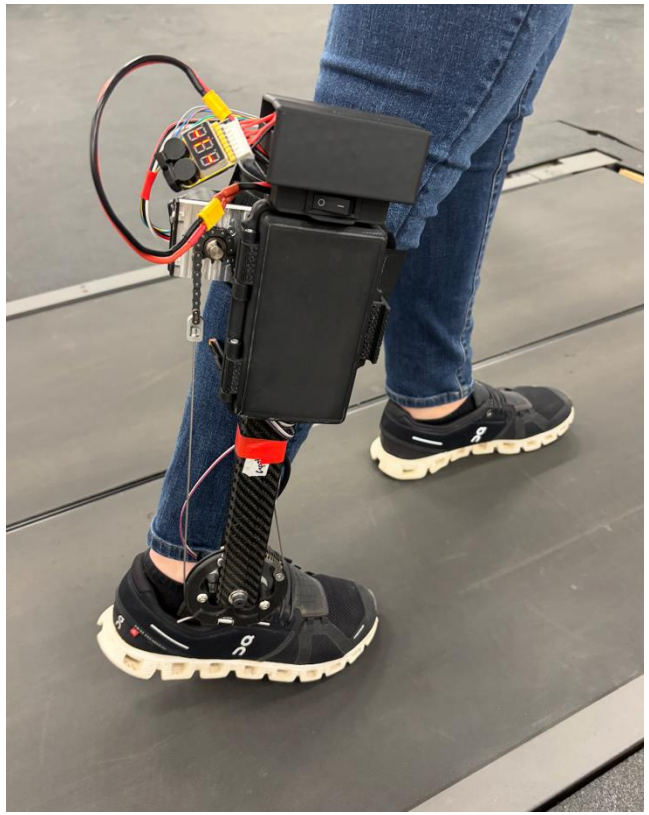
Testing Images

Exp 5: Final Test on human



Testing Images

Exp 5: Final Test on human



Specification Sheet

4.1 CR Summary Table

Customer Requirement	CR met? (✓ or X)	Client Acceptable? (✓ or X)
CR1: Durable	✓	✓
CR2: High Range of Motion	✓	✓
CR3: Comfortable	✓	✓
CR4: High battery life	✓	✓
CR5: Adjustable	✓	✓
CR6: Lightweight	✓	✓
CR7: Affordability	✓	✓

4.2 ER Summary Table

Engineering Requirement	Target	Tolerance	Measured/ Calculated Value	ER met? (✓ or X)	Client Acceptable? (✓ or X)
ER1: Energy efficient	60 mins	± 30 mins	53 mins	✓	✓
ER2: Accommodate shoe size	.27 m	± .05 m	.22m	✓	✓
ER3: High torque	10 N-m	± 5 N-m	12.5 N-m	✓	✓
ER4: Supports users of all weights	90 kg	± 30 kg	90kg	✓	✓
ER5: Under 3 kg	3 kg	± 1 kg	1.168 kg	✓	✓
ER6: Temperature of the motor	>70° C	± 70° C	54.5 ° C	✓	✓
ER7: Battery Capacity	1000 mAh	± 500 mAh	650 mAh	✓	✓
ER8: Ingress Protection	IP45	IP44, IP67	IP45	✓	✓

Percent Complete

Customer Requirements	Engineering Requirements
100% - Adjustable - Lightweight - Affordability - High Range of Motion - Comfortable - High Battery Life - Durable	100% - Accommodate shoe size - Supports users of all weight - Under 3 kg - Ingress Protection - Energy Efficient - High Toque - Temperature of Motor - Battery Capacity

Thank You!