JOHNSON HEALTH TECH: ADAPTIVE INDOOR ROWER FOR WHEELCHAIR USERS

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BACKGROUND & MOTIVATION

Benefits of Rowing Machines:

- Rowing exercise targets arm, shoulder, and back muscles [1]

Importance of Adaptive Equipment:

- 5.5 million wheelchair users in the U.S. [2]
- Consistent upper body exercise can alleviate shoulder pain, which is common among wheelchair users [3]
- 81% of individuals with disabilities feel uncomfortable in fitness centers due to lack of adaptive exercise equipment [4]
- Existing devices permanently change functionality of the rower (AROW) [5]

Figure 1. AROW Rowing Machine [5]

PROBLEM STATEMENT

Individuals with lower extremity disabilities/injuries who require the use of wheelchairs have trouble utilizing typical workout machines due to a lack of accessible exercise equipment. The majority of exercise machines are not wheelchair accessible, and thus exercise options for these individuals are limited. To solve this issue, modifications were made to a standard Matrix Rower [6] to accommodate individuals in wheelchairs while maintaining safety and preserving the rowing motion. This unique design addresses the lack of exercise equipment available for individuals who require the use of a wheelchair and helps to improve their wellbeing.

DESIGN CRITERIA

Criteria:	Specification:
User Stability / Safety	Pulley mechanism and antlers withstand maximum 400 N force [7]; zero tipping / displacement
Ease of Fabrication	Easy to fabricate; all materials available to order
Ease of Use / Ergonomics	Accessible to individuals in wheelchairs; no external assistance required
Adjustability	Fit wheelchairs 60-70 cm in width, 45-50 cm in seat height, 90-125 cm in depth [8]
Versatility	Easily convertible from standard to adaptive mode; adaptations extend a maximum 0.6 m from the rower
Durability	10 year lifespan / 8 million meters [9]
Budget	~$500 for development

SOLIDWORKS MODELS

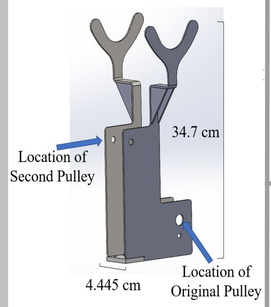


Figure 2. Pulley Plates & Antlers

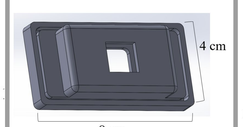


Figure 3. Resistance Display Cover

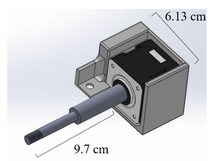
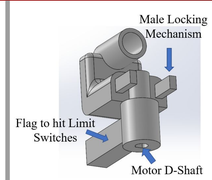


Figure 4. Resistance Adjustment Mechanism



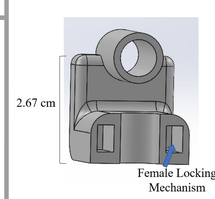


Figure 5. Console Field Goal Posts

FINAL DESIGN

Section Note: All labeled components were either fabricated or altered by the design team.

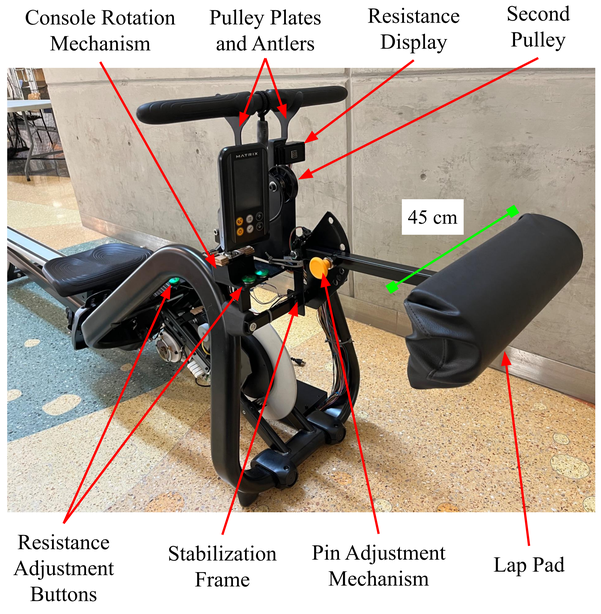


Figure 6. Full Assembly Isometric View

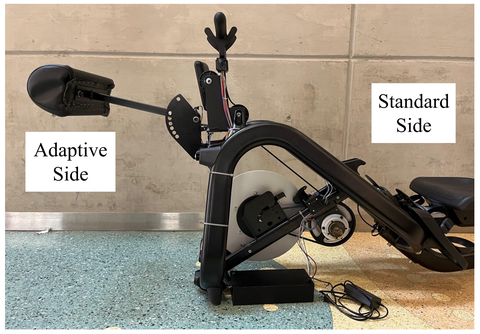


Figure 7. Full Assembly Side View

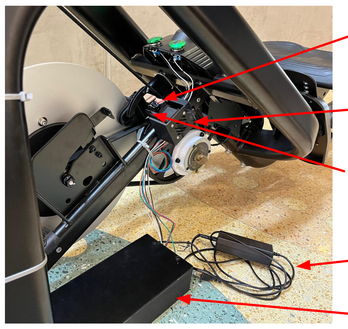


Figure 8. Resistance Adjustment Mechanism

TESTING & RESULTS

SolidWorks Simulations:

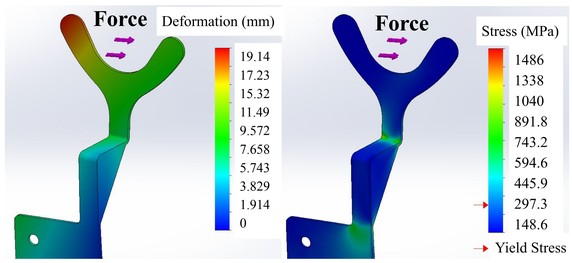


Figure 9. Antler Simulation Testing

- Fixed at neck support cavity to mimic actual loading
- 400 N load applied with safety factor of 2
- Max Displacement: 19.14 mm
- Max Stress: 891.8 MPa > Yield Stress: 220.6 MPa

Electromyography (EMG) Analysis:

- Data recorded on biceps, rear deltoids, and latissimus dorsi on standard and adaptive sides at resistances 1, 3, 5, 7, 9
- Average wave form and accompanying amplitude was calculated (larger amplitude = more activation)
- No major difference in the activation profiles for the biceps or rear deltoid on either side for respective resistance levels
- The latissimus dorsi had slightly increased activation levels on the standard side compared to the adaptive side

Usability Survey Testing:

Standard and Adaptive Side Survey Results (10 Testing Participants without Physical Disabilities)		
Standard Side	Average Score (Out of 5)	Standard Deviation
Overall Ease of Use	4.22	1.02
Overall Safety	4.80	0.42
Comfort	4.60	0.52
Adaptive Side	Average Score (Out of 5)	Standard Deviation
Overall Ease of Use	4.72	1.35
Overall Safety	4.75	0.44
Comfort	4.50	0.52
Standard and Adaptive Comparison	Average Score (Out of 5)	Standard Deviation
Workout Comparability	4.38	0.50
Console Use and Transition	4.89	0.33
Likelihood of Future Use	4.50	0.53
Ease of Resistance Adjustment	4.90	0.32

Adaptive Side Only Survey Results (3 Testing Participants with Physical Disabilities)		
Adaptive Side	Average Score (Out of 5)	Standard Deviation
Overall Ease of Use	4.80	0.41
Overall Safety	4.83	0.41
Comfort	4.33	1.15
Likelihood of Future Use	4.67	0.58

Figure 10. Survey Results

- Move console & buttons closer on each side
- Increase number of lap pad adjustability levels

DISCUSSION

Design Achievements:

- Rower converts between standard and adaptive sides without assistance since handlebar can be reached from both sides
- Resistance can be adjusted from both sides via push buttons
- Lap pad secures wheelchair user in place and prevents excessive movement of wheelchair
- Stabilization frame adjusts for different sized users / wheelchairs
- Console automatically rotates to side currently in use so that user can view the metrics of their workout

Areas for Improvement:

- Improve reliability of the resistance mechanism
- Increase adjustability of the stabilization frame

FUTURE WORK

Future Design Iterations:

- Fabricate console motor holder and resistance motor box out of steel
- Connect stabilization frame to pulley plates to increase rigidity
- Increase the number of adjustability levels for stabilization frame by using ratchet mechanism
- Utilize motor with stronger holding torque for resistance adjustment mechanism such that it does not slip during high impulse strokes
- Investigate methods for improving resistance increment consistency
- Cover all wires with insulated tubing
- Permanently attach limit switches via screws
- Increase accessibility to handlebar from adaptive side

Future Testing:

- Recruit more participants to complete usability and EMG testing
- Conduct more extensive EMG testing with more controls to promote consistency
- Include more muscle groups for EMG testing to determine differences in activation between standard and adaptive sides
- Conduct comprehensive design verification tests

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- UW-Madison TEAMLab
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