MRI CARDIAC EXERCISE DEVICE

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Outline

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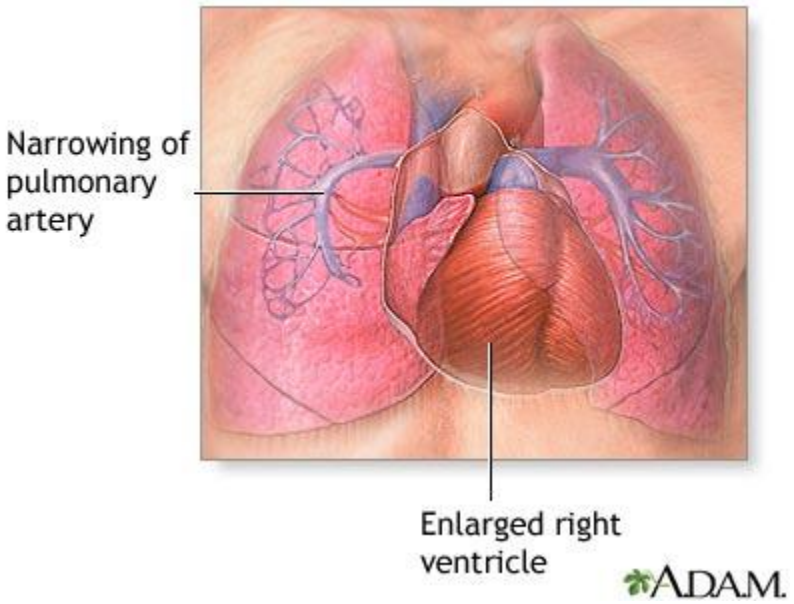
- Securing Patient to Device Designs
- Additional Design Improvements
- Future Work
- Acknowledgements / References

Problem Statement

- Design an exercise device to be used in cardiac MRI scans in order to diagnose and assess pulmonary hypertension
- Client requirements
  - MRI compatible materials
  - Exercise within the bore
  - Comfortable supine exercise motion
  - Minimal upper-body movement
  - Sufficient resistance to increase cardiac output
  - Adjustable workloads
  - Reasonable size and weight

Background Information

- Pulmonary Hypertension
  - Abnormally high blood pressure in pulmonary arteries
  - Decreased artery diameter
  - Enlarged right ventricle
  - Decreased systemic blood [O_2]
- Traditionally assessed with invasive procedure

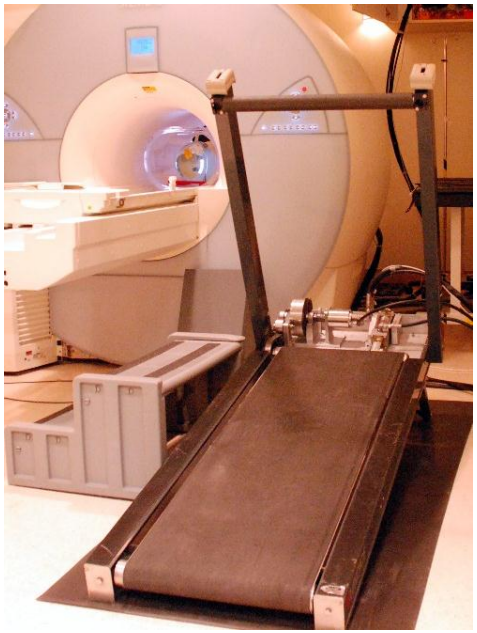


http://health.allrefer.com/health/primary-pulmonary-hypertension-primary-pulmonary-hypertension.html

Competition

- Lode B.V. MRI Ergometer
  - Expensive (> $28,000)
  - Cycling motion
  - Cannot exercise in bore during chest scans
- MRI-compatible treadmill
  - Developed at Ohio State University
  - Exercise occurs outside of the MRI tube
  - Less accurate results

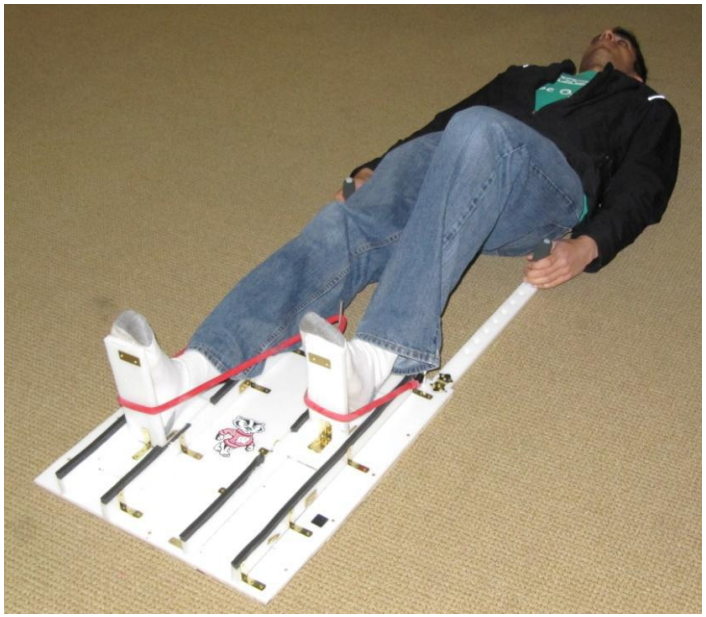
http://www.lode.nl/en/products/mri_ergometer



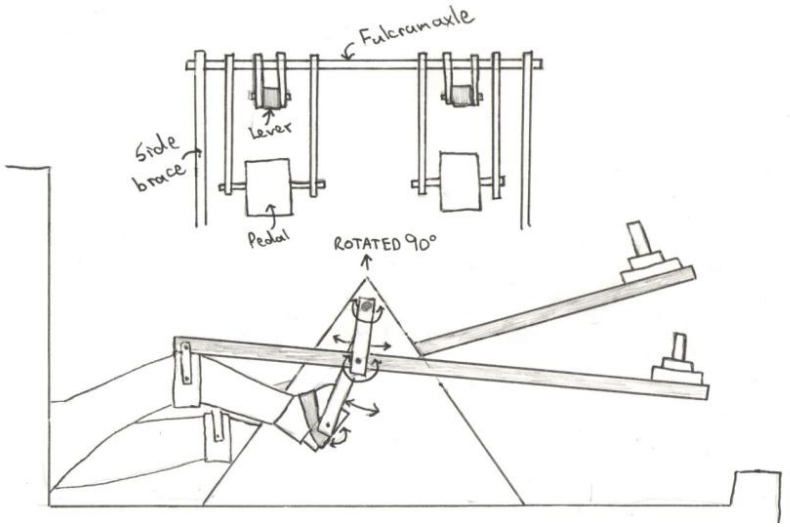
http://www.medcitynews.com/2009/05/commercialization-ramps-up-on-ohio-state-university-treadmill-used-for-mri-heart-tests/

Past BME Designs

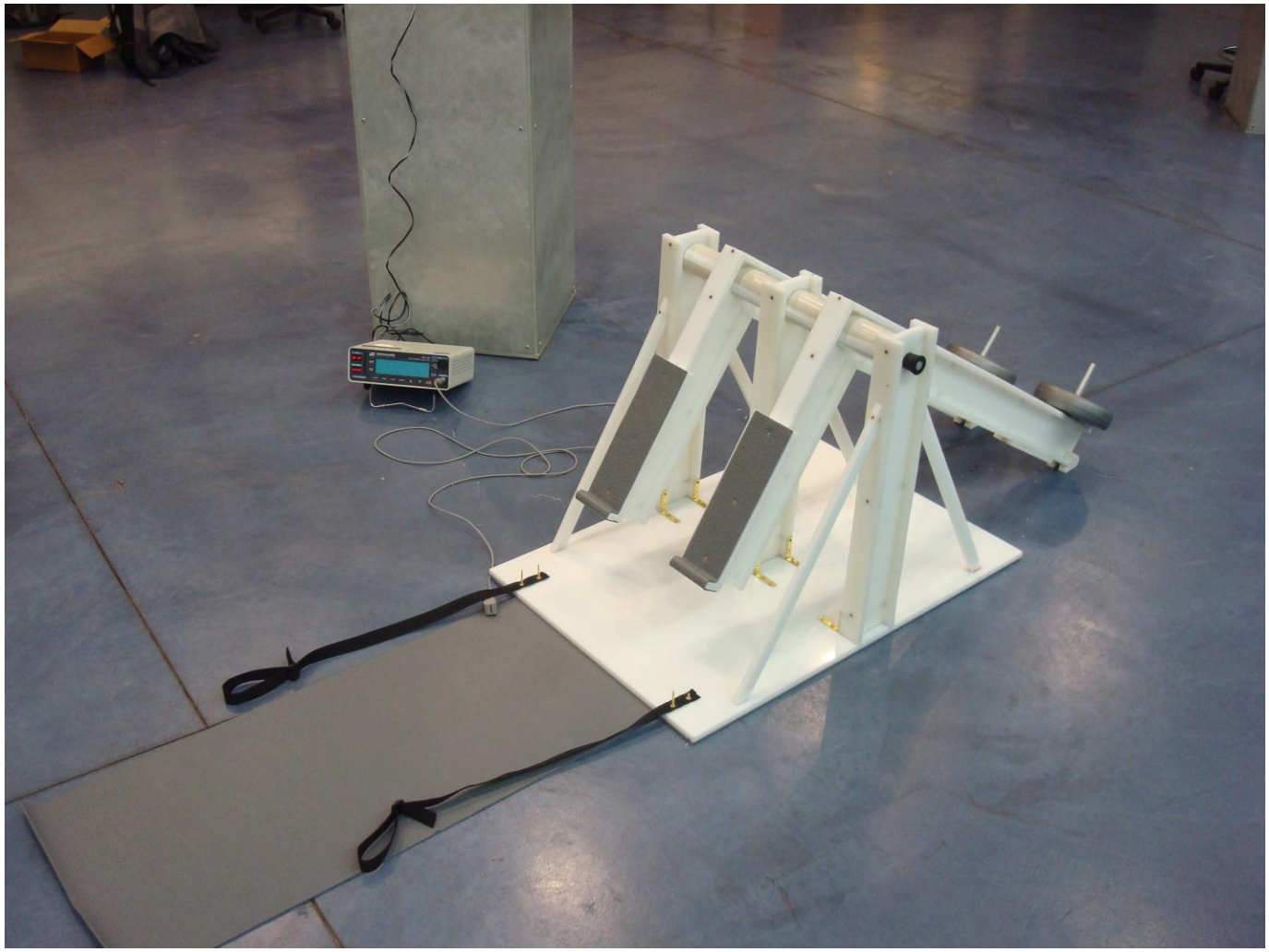
- MRI Lower Leg Exerciser
  - Spring 2010
  - Excess friction
  - Insufficient workload



- MRI Leg Exercise Device
  - Fall 2010
  - Unnatural loading
  - Bulky



Previous Prototype: Design



Previous Prototype: Testing

- Used 6.77 kg additional mass per leg
- Worked at a cadence of ~130 steps/min
- Equivalent to ~62 Watts
- Tests lasted 10 minutes
    - Maximum heart rate measured via pulse oximeter

Subject	Resting HR (bpm)	Exercising HR (bpm)	% Max. HR
1	65	130	65.33
2	62	128	64.32
3	62	118	59.30
4	58	146	73.37
Average	**61.75**	**130.50**	**65.58**

Previous Prototype: Problems

- Durability of the prototype
- Lateral lever arm stability
  - Lateral foot movement
  - Bearings
- Compatibility with the sliding MRI couch
- Device and subject movement
- Size
- Sliding weights

Lateral Lever Arm Stability Design: Track-Guided

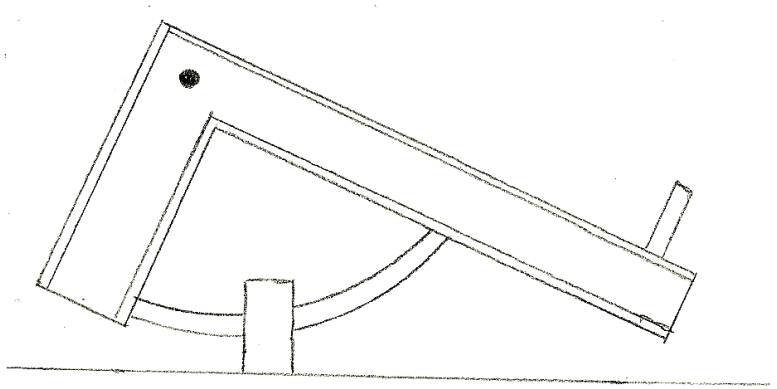
- Extension on arm moves through external track

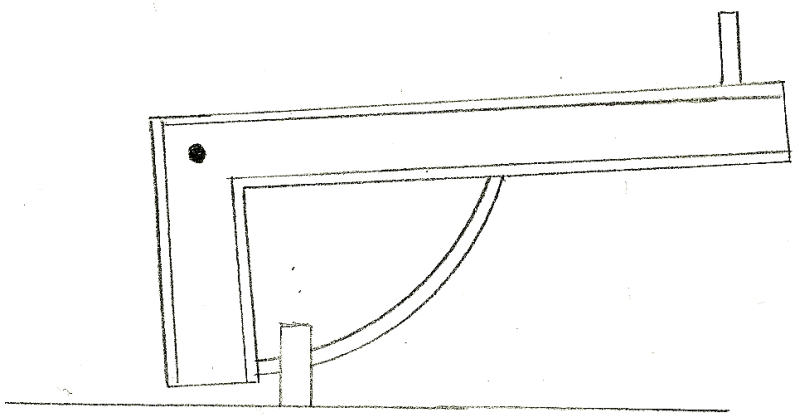
Pros:

- Cost-effective

Cons:

- Friction
- Indirect solution





Lateral Lever Arm Stability Design: Block

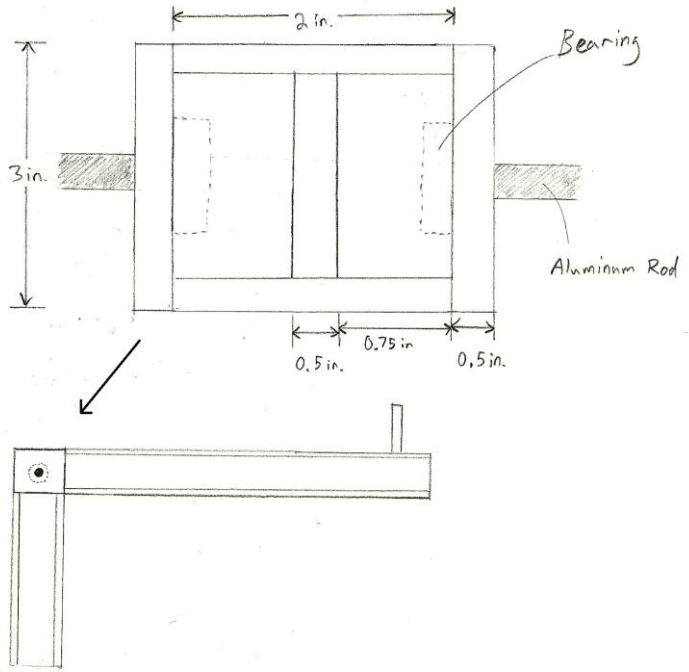
- Two bearings housed in block
  - Provides even support
  - Secures bearings

Pros:

- Reduces friction/wear
- Limits lateral motion

Cons:

- Additional bearings



Lateral Lever Arm Stability Design: Arc-Support

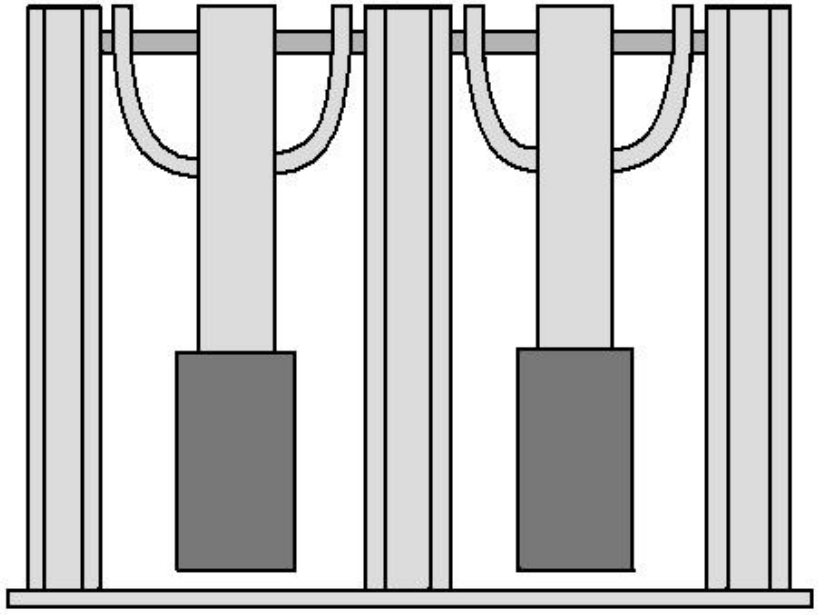
- Support arms provide increased interface with bar

Pros:

- Limits lateral motion
- Cost-effective

Cons:

- Durability concerns
- Friction



Lateral Lever Arm Stability Design: Design Matrix

Weight	Criteria	Track-Guided	Block	Arc-Support
0.4	Effectiveness	4	8	9
0.4	Durability	5	9	6
0.1	Ease of Assembly	7	8	6
0.1	Cost	8	6	8
	Weighted Total:	**5.1**	**8.2**	**7.4**

Securing Patient to Device Design: Extended Base

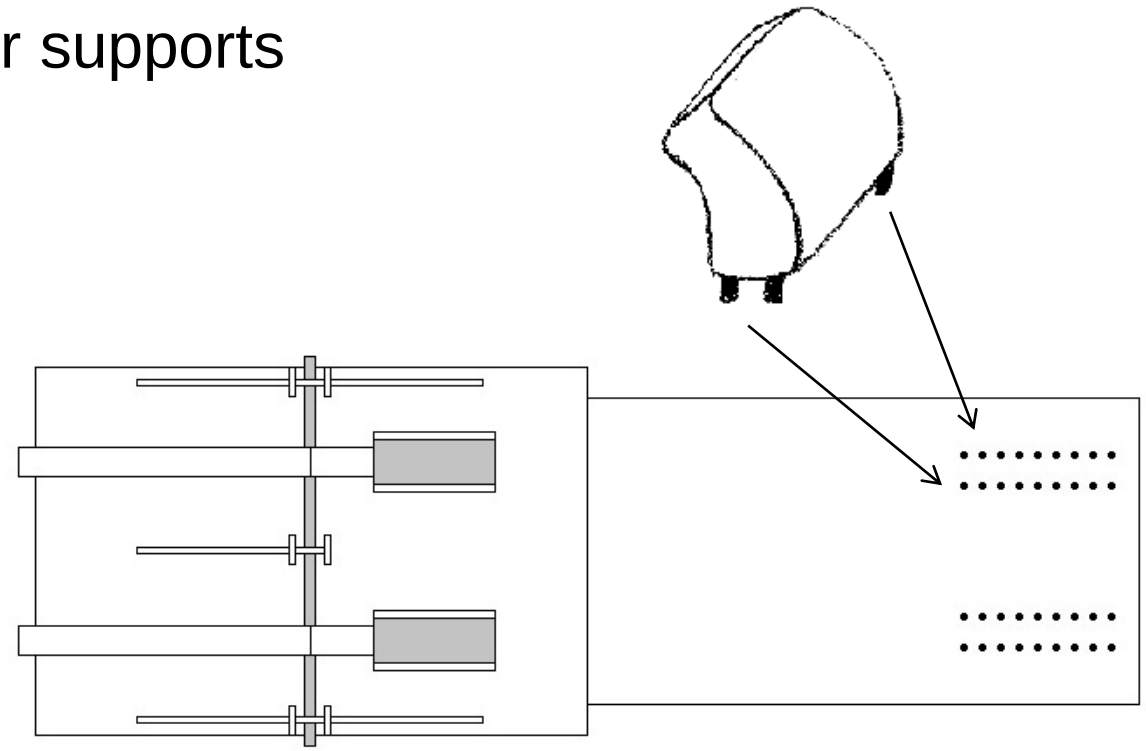
- Elongated base with padded shoulder supports

Pros:

- Effective

Cons:

- Bulky
- Expensive



Securing Patient to Device Design: Backpack Straps

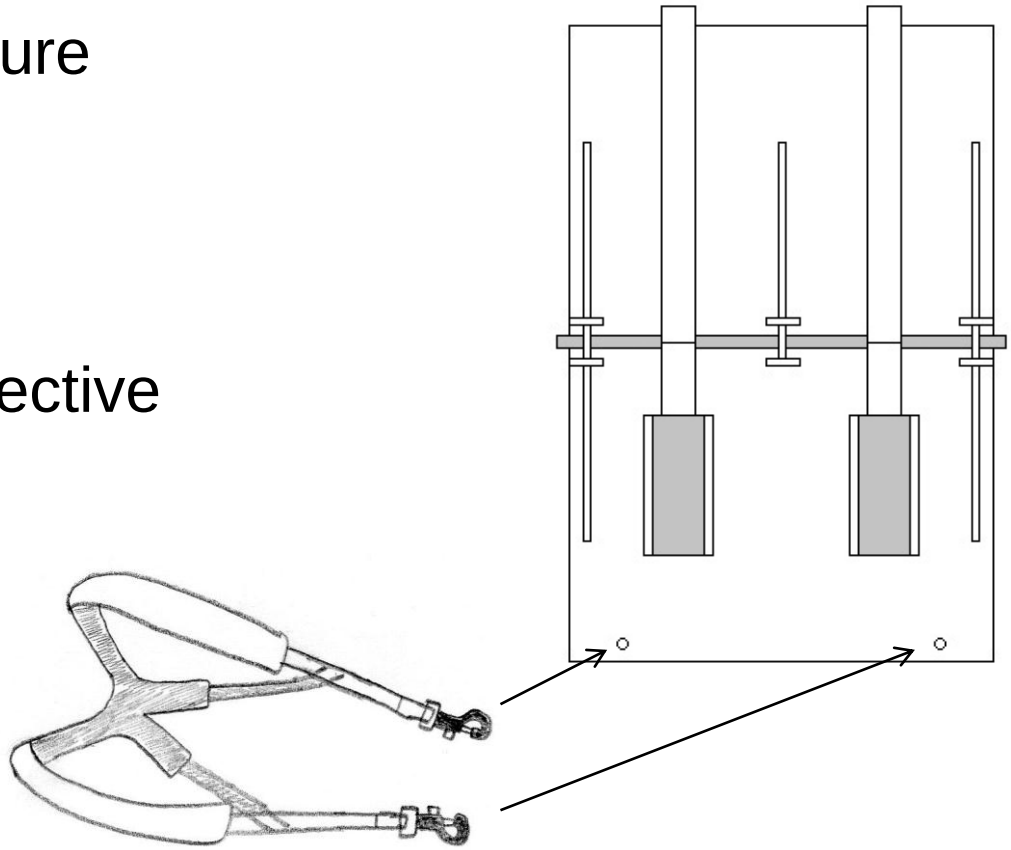
- Shoulder straps secure patient to device

Pros:

- Comfortable and effective
- Light-weight

Cons:

- Restrictive



Securing Patient to Device Design: Velcro Yoga Mat

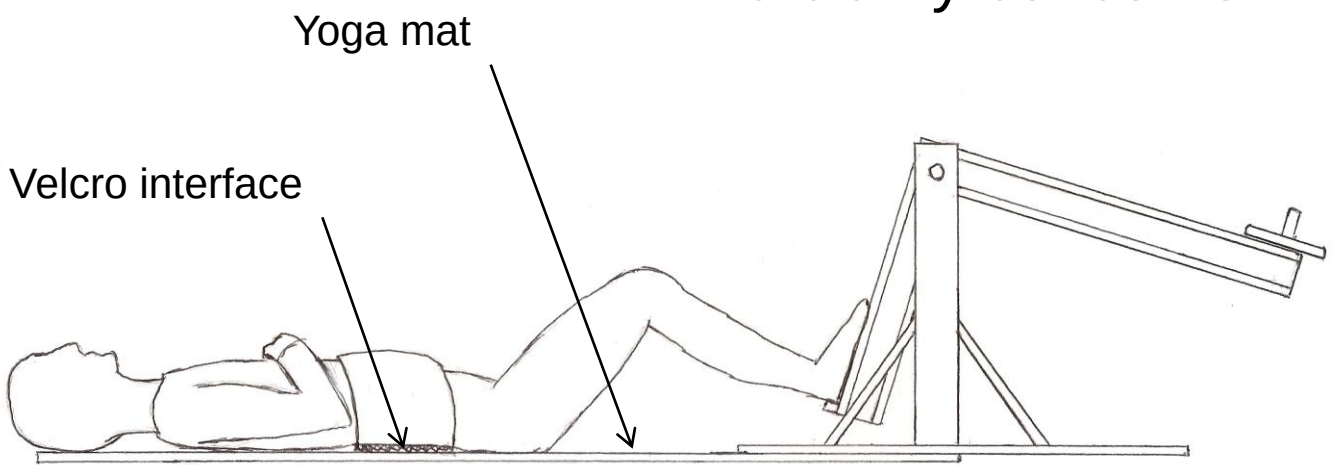
- Velcro belt attaches to underlying yoga mat

Pros:

- Light-weight

Cons:

- Less comfortable
- Durability concerns

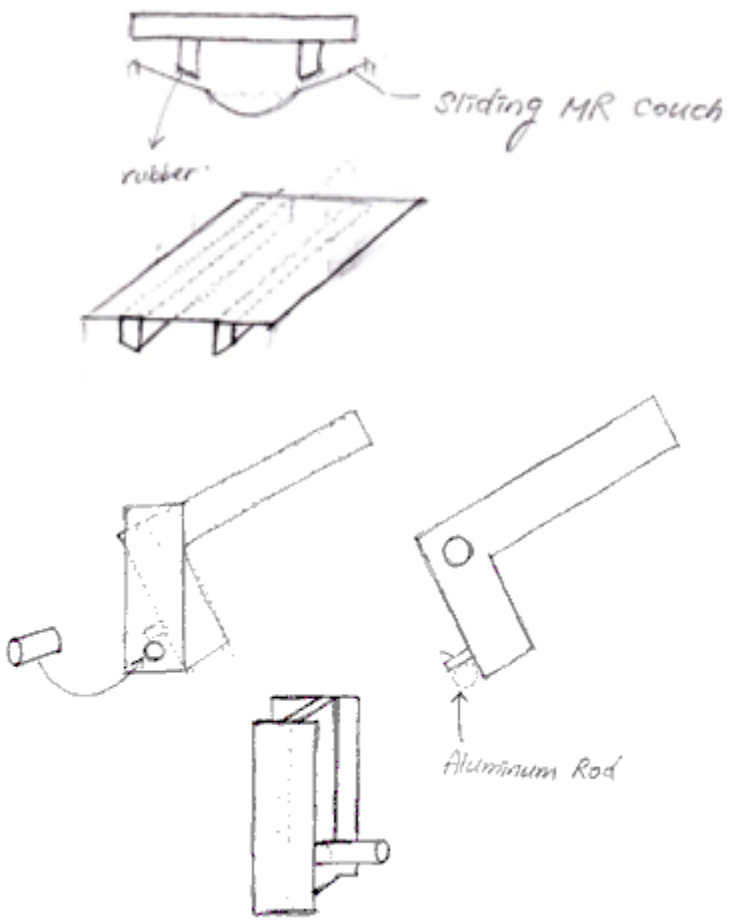


Securing Patient to Device Design: Design Matrix

Weight	Criteria	Extended Base	Backpack Straps	Velcro Yoga Mat
0.25	Effectiveness	9	9	6
0.2	Patient Comfort	7	8	6
0.15	Size/Weight	3	9	8
0.15	Durability	7	7	5
0.15	Safety	10	8	7
0.1	Cost	5	7	6
	Weighted Total:	**7.15**	**8.15**	**6.3**

Additional Design Improvements

- More comfortable hand straps
- Foot straps
- Decreased lever arm length
- Tracking under base
  - Compatible w/ couch movement
- Stopping mechanism
- Threaded aluminum rod
- Improved weight interface



Future Work

- Order new materials
- Salvage/recycle older components
- Construct and assemble new prototype
- Test effectiveness of prototype
- Test compatibility of prototype with MRI
- IRB approval
- Acquire pulmonary arterial blood pressure data through MRI scans before, during, and after exercise
  - Varied subject demographics

Acknowledgements

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- Prof. Willis Tompkins
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- Previous BME Design Teams

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