MRI CARDIAC EXERCISE DEVICE

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Outline

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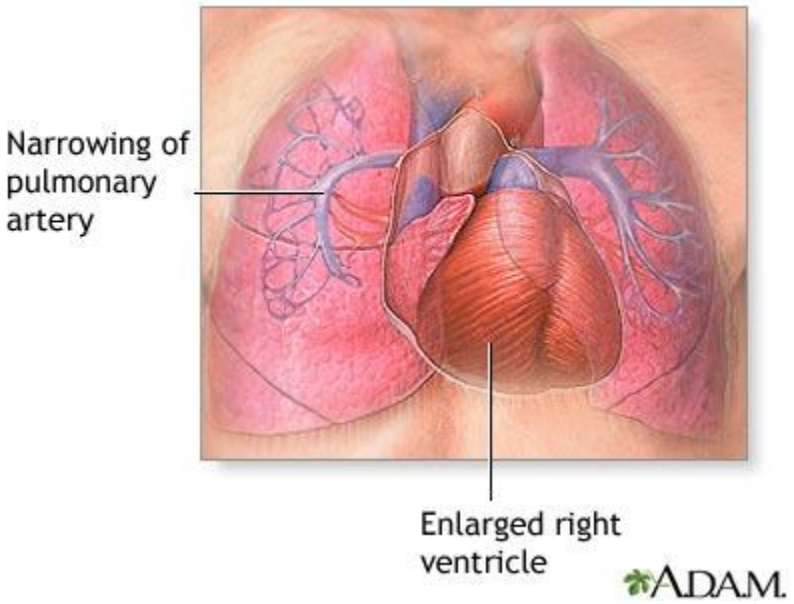
Problem Statement

- 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
  - Measurement of power and cadence

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

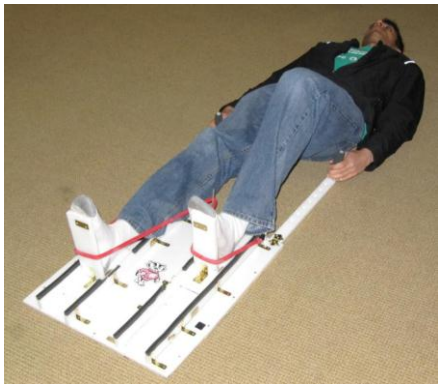


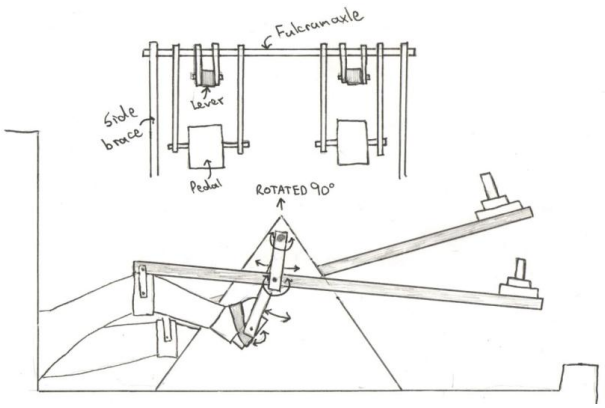
http://health.allrefer.com/health/primary-pulmonary-hypertension-primary-pulmonary-hypertension.html

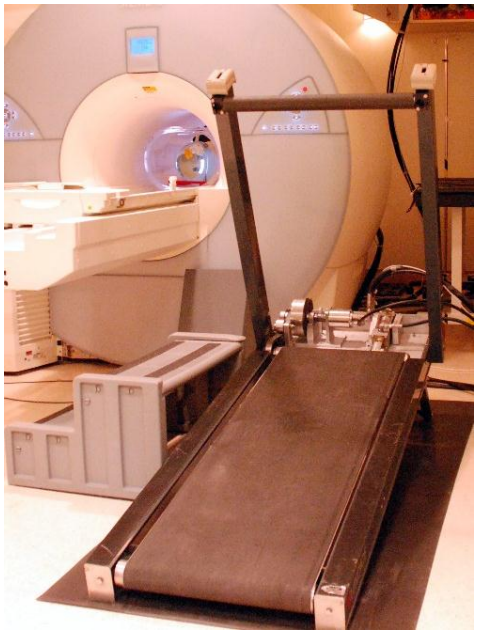
Competition

- Lode B.V. MRI Ergometer
- MRI-compatible treadmill
- Past BME design projects
  - Spring 2010
  - Fall 2010

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



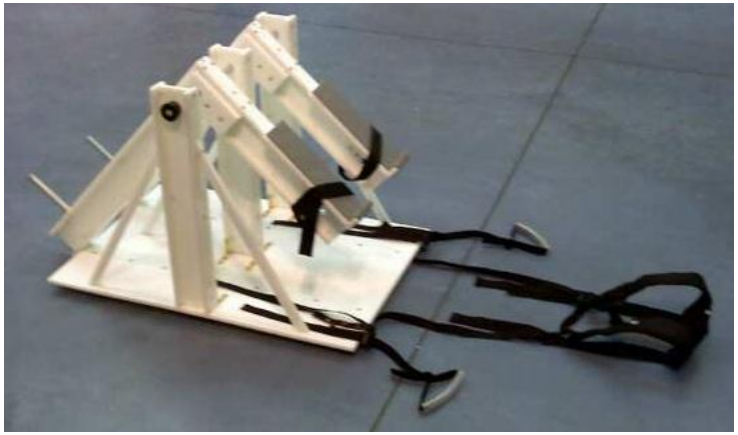




http://www.medcitynews.com/2009/05/commercialization-ramps-up-on-ohio-state-university-treadmill-used-for-mri-heart-tests/

Previous Prototype: Design

- Utilizes stepping motion
- User pushes on foot pedals which raise weights at the ends of the lever arms
- Materials:
  - High density polyethylene (HDPE)
  - Glass and acetal bearings
  - Brass screws
  - Aluminum rods
  - Nylon hand and shoulder straps



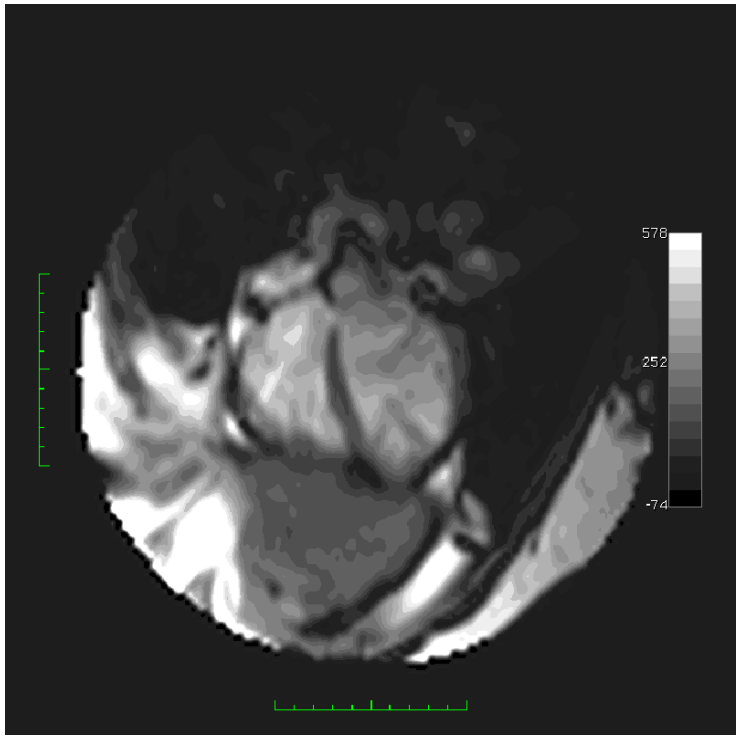
Previous Prototype: Testing

- Performed outside bore to find maximum attainable HR
- Exercised w/ maximum weight according to fitness levels
- Cadence of ~110 steps/min for 10 min
- Heart rate measured with digital pressure monitor and manually on carotid artery

Subject	Resting HR (bpm)	Post Exercise HR (bpm)	% Max. HR
1	73	119	59.80
2	74	143	71.86
3	70	122	61.31
4	68	110	55.28
Average	**71.25**	**123.50**	**62.06**

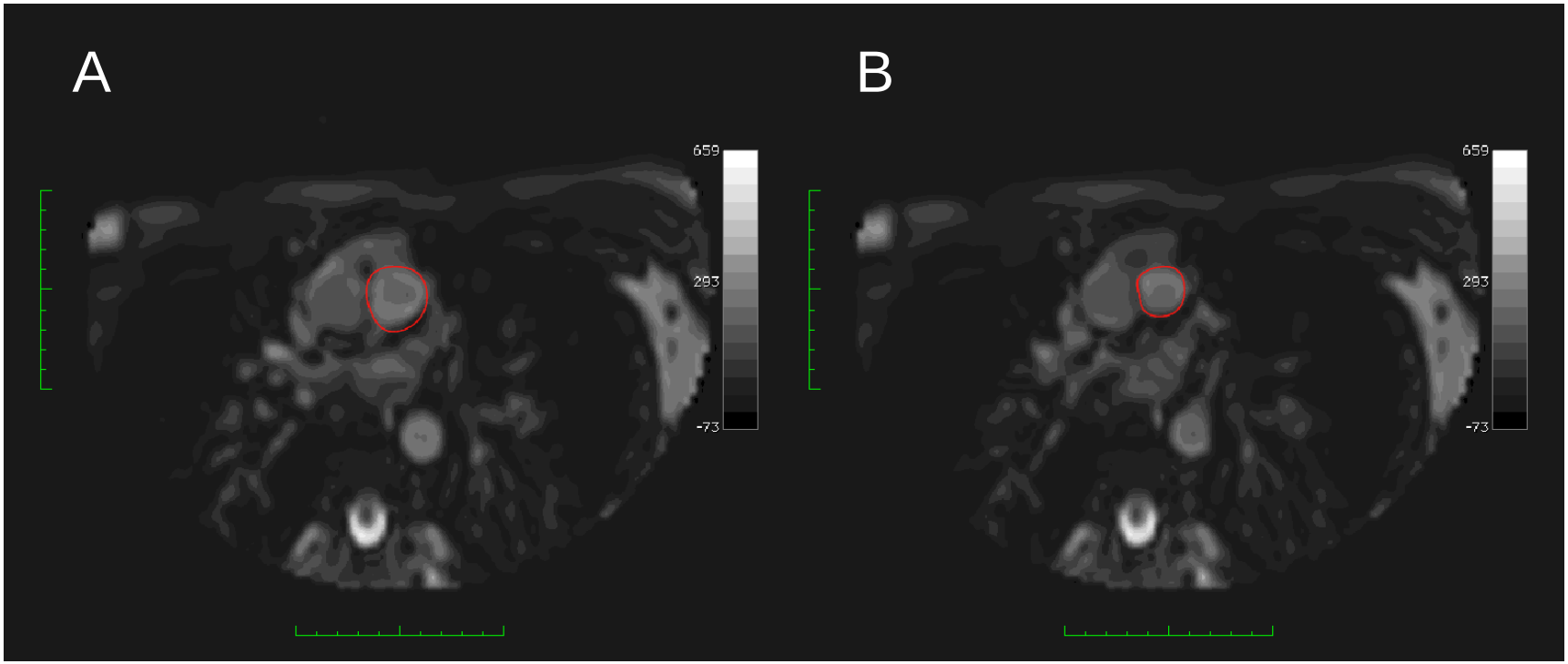
Previous Prototype: MRI Testing

- Obtained cardiac MR images from one subject
- Real-time imaging during exercise
  - Continuously scans
- Allows for assessment of:
  - Right ventricle function
  - Pulmonary artery area
    - Systolic vs. diastolic
  - Arterial distensibility (stiffness)



Real-time MRI four-chamber view of the subject's heart

MRI Testing Images



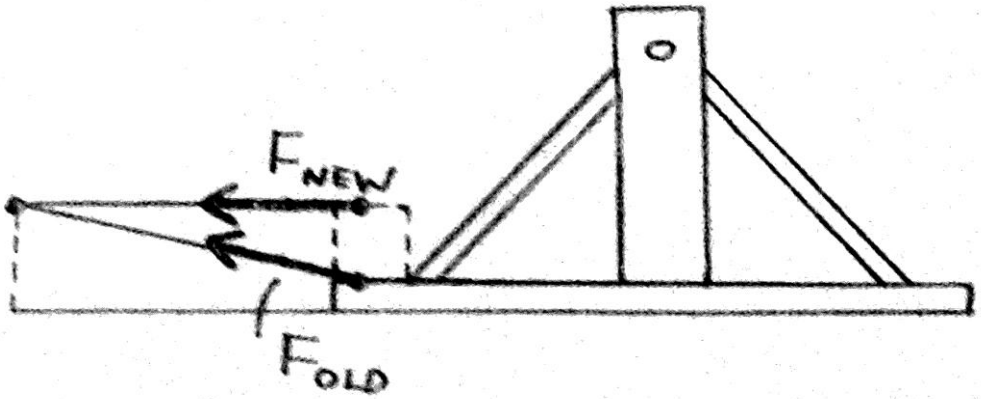
Real-time MRI images of the heart during systole (A) and diastole (B) while exercising; red circles indicate the pulmonary artery

Problems with Previous Prototype

- Base of device lifting during exercise
- Diagonal support bending
- Incompatibility of weights with MRI
- Weight interface
- Lack of electronic power and cadence measurement system

Prototype Modifications

- Reinforced diagonal supports
  - 1” thickness vs. ½” thickness
  - Increase compressive strength
- Raised straps
  - Strap forces become more horizontal
  - Reduce lifting of patient-end of the device

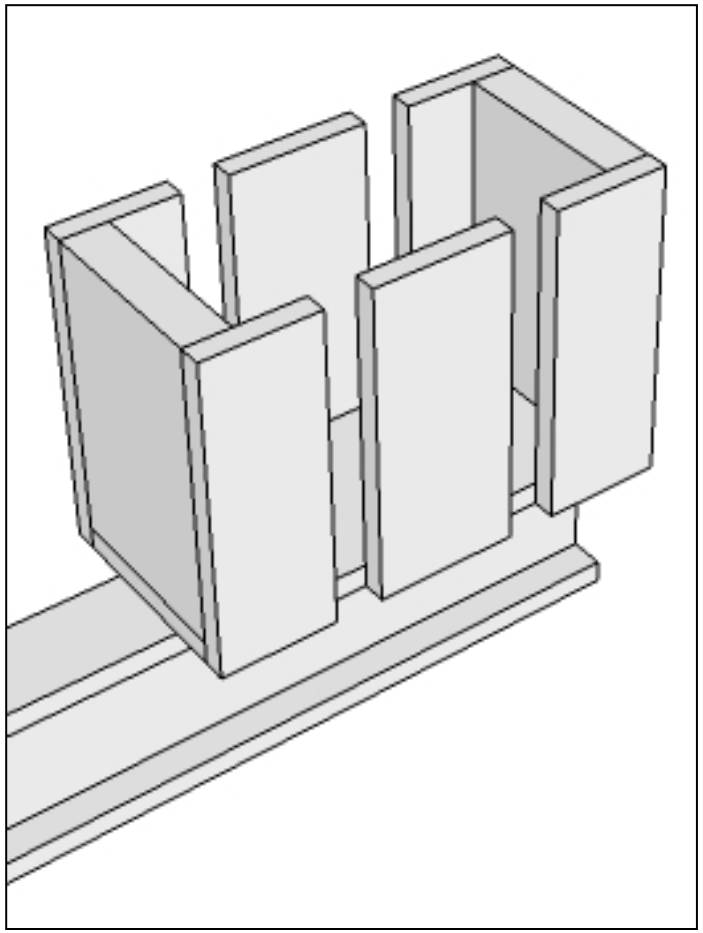


New Weights

- DuPont™ Zodiaq® Tiles
  - Completely MRI-compatible
  - Density of 2.4 - 2.5 g/cm³
  - Free sample tiles
    - (4” x 4” x ¾”)
    - 1.04 – 1.08 lb/tile
- Up to 16 tiles/lever arm

http://www.hllmark.com/downloads/newcolors2011.jpg

HDPE weight interface:



Electronic Measurement System

- Infrared proximity sensor
  - Range: 20-150cm (~8” – 4’11”)
- Records dynamic position of one lever arm during exercise
- Cadence and power continuously calculated by an Arduino Microcontroller
- Data relayed to control room via USB
- Verbal feedback to user

http://www.sparkfun.com

Future Work

- Complete weight interface
- Employ the electronic measurement system
  - Order components
  - Develop code
  - Test
  - Install onto device
- Test prototype on patients with varying heights to determine patient size limitations

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- Previous BME Design Teams

References

- Blaivas, A.J. (2010, April 27). *Pulmonary hypertension*. Retrieved from http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0001171/
- Lode B.V. (2008). *MRI Ergometer*. Retrieved from http://www.lode.nl/en/products/mri_ergometer
- McGuire, J., et. al. (2010, December 10). *MRI exercise device.* Retrieved from http://bmedesign.engr.wisc.edu/websites/project.php?id=332
- Murray, A. (2009, May 14). *Ohio state team creates new company based on university invention*. Retrieved from http://www.osu.edu/news/newsitem2425
- Yagow, D., et. al. (2010, May 6). *An MRI-compatible lower-leg exercising device for assessing pulmonary arterial pressure.* Retrieved from http://bmedesign.engr.wisc.edu/websites/project.php?id=29

Questions?