Impact of Fat Spectrum Model on Skeletal Muscle Fatty Infiltration Quantification

SCHOOL OF MEDICINE
CASE WESTERN RESERVE UNIVERSITY

DEPARTMENT OF POPULATION AND QUANTITATIVE HEALTH SCIENCES

Ria Tilve[1]; Brendan Eck, PhD[2]; Xiaojuan Li, PhD[2]

[1]Department of Population and Quantitative Health Sciences, Case Western Reserve University;
[2]Department of Biomedical Engineering, Program of Advanced Musculoskeletal Imaging (PAMI), Cleveland Clinic

Cleveland Clinic

PAMI Program of Advanced Musculoskeletal Imaging

QR Code and Link to Presentation:
https://youtu.be/XcXeSO1sFal

Background

- Fatty infiltration may indicate altered muscle morphology and reduced physical ability. In knee osteoarthritis, muscle fat fraction (FF) is associated with severity, whereas muscle size was not [1].
- 6-Point Dixon MRI is a noninvasive method used to measure muscle FF. It captures multiple images where fat and water are in- or out-of-phase. Prior knowledge can then be used to compute proportions of MRI signal to distinguish fat and water.
- Dixon MRI was primarily developed for liver imaging, and muscle fat analyses typically assume the liver fat spectrum model.
- A muscle fat spectrum model may improve FF quantification measurements in skeletal muscles.

Objectives

Study Aims
- Determine if changing fat spectrum models changes first, the fat fraction quantification, and second, measurement reproducibility
- Evaluate impact of changing fat spectrum model in patient data

Learning Objectives
- Evaluate differences in fat-water separation between measurement techniques and modify algorithms used to assess fatty infiltration
- Analyze performance in patient data to characterize muscle fat
- Identify and communicate with patients for study recruitment

Methods

- **MRI Protocols** (3T Siemens Skyra Fit)
  - Used a monopolar 6-point Dixon MRI acquisition with first echo time (TE) of 1.23 ms and echo spacing of 1.23 ms.
  - Phantoms scanned at 70mm right/left of isocenter to mimic thigh position. Human subjects scanned with high-resolution T1-weighted (T1w) turbo spin echo sequence.Thighs captured using large field-of-view for bilateral imaging.
- **MRI-based FF Quantification**
  - Magnitude images processed with vendor-independent method [4].
  - T1w images from human data were used for segmentation of hamstring, quadriceps, and other muscle groups.
  - All data processed extract mean FF across 4 center slices.
- **Fat Spectrum Models**
  - Default (liver fat), Peanut oil (for phantoms) and Skeletal Muscle (for controls and patients) spectra were used.

Table 1. *Chemical structures in fat spectrum models and corresponding relative peak heights.*

Chemical Structure	Peak Location (ppm)	Default (Liver)	Peanut Oil	Muscle Fat
-(CH2)n-CH3	0.9	0.087	0.087	0.089
-(CH2)n-	1.3	0.693	0.5809	0.598
-CO-CH2-CH2	1.60	—	0.0611	0.047
-CH2-CH = CH-CH2-	2.05	0.128	0.0986	0.077
-CO-CH2-CH2	2.26	—	0.0581	0.052
-CH = CH-CH2-CH = CH-	2.76	0.004	0.0083	0.011
-CH2-O-CO-	4.22	0.039	0.0388	0.035
-CH = CH-	5.3	0.048	0.0556	0.066

Study Population

- Patients ages 22-45 enrolled in the 'MOON 10-Year Onsite Study' who had ACL reconstruction 10 years ago [3].
  - **Phantoms** (N=5): Fat-water vials of varying fat compositions (5%, 10%, 15%) created using peanut oil, water, and agar.
  - **Controls** (N=1): Healthy participants that did not undergo an ACL reconstruction (ACLR) procedure.
  - **Patients** (N=9): Participants at 10-Year follow-up post-ACLR.

Results

- **Image Analysis**
  - Default and peanut oil spectra used to obtain FF in phantoms, and default and muscle fat spectra used to obtain FF in control/patients.
  - Differences between scan-rescan data in phantom and in control subjects was used to assess reproducibility.

Figure 1. *Representative processed images of Phantom, Control, and Patient data.*

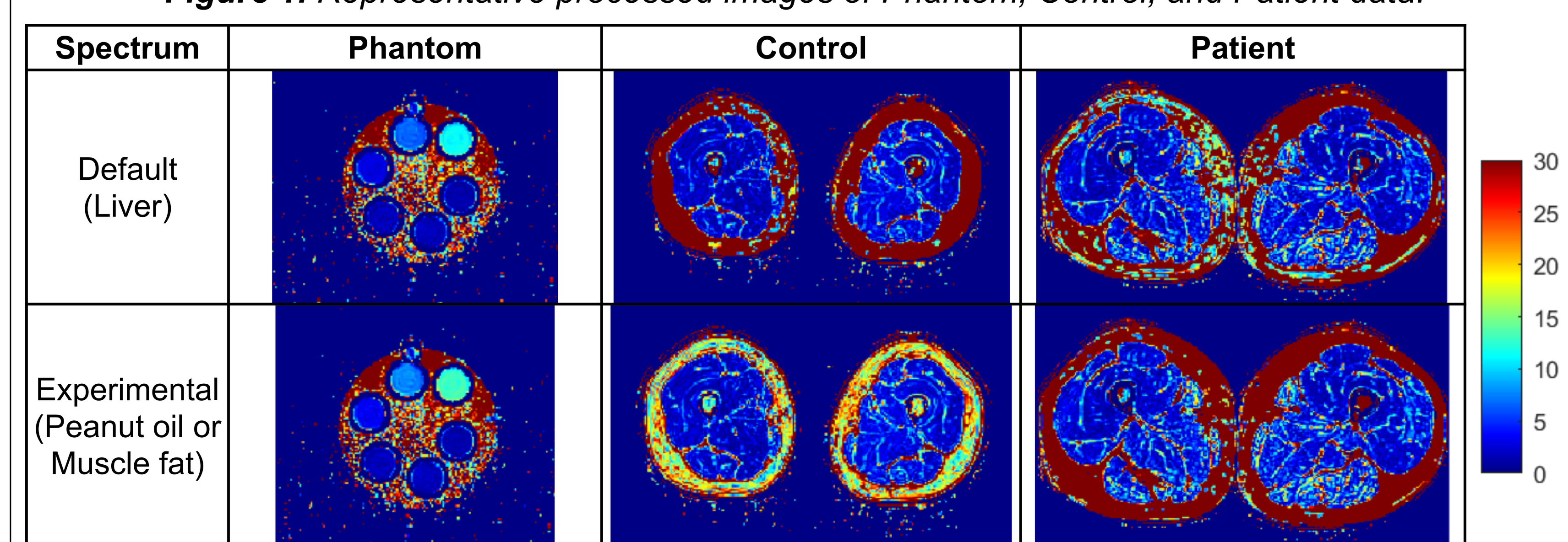
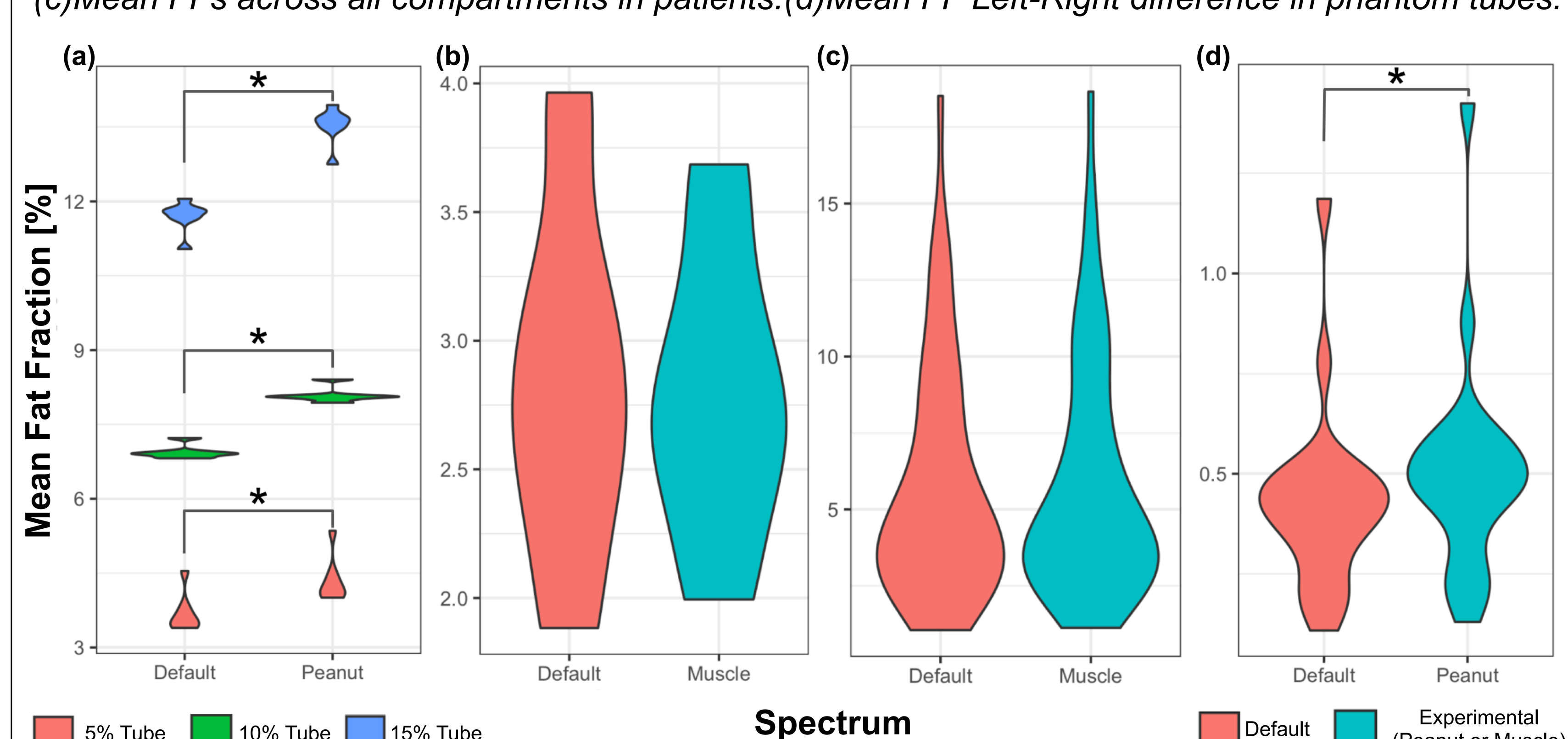


Figure 2. *(a) Mean FFs for phantom tubes. (b) Mean FFs across all compartments in control. (c)Mean FFs across all compartments in patients.(d)Mean FF Left-Right difference in phantom tubes.*



Public Health Implications

- Non-invasive tool for assessing muscle composition, sarcopenia, and changes in muscle composition related to injury or aging
- Myosteatosis predicts higher mortality and co-morbidity rates
- Monitor trends in fat infiltration to identify patients at risk for poor health outcomes who can be potential targets for interventions

Discussion

- Changing the fat spectrum model changed quantification values
  - Significant changes seen in phantom data ($p<0.05$)
  - No clear trend in how measurements changed in control/patient data
  - Worsened reproducibility seen with muscle fat spectrum
- Future studies will use more control/patient cases and assessing alternate and patient-specific muscle fat spectra.

Conclusions
- Using a muscle fat spectrum model did not always produce more desirable results and may not be the most optimal spectrum model.
- Skeletal muscle fat fraction measurements are weakly affected by the fat spectrum model chosen, but further evaluation is warranted.
- This quantification method can be applied to various populations to assess skeletal muscle fatty infiltration.

Experiences

Activities
- Explored fat spectrum models in MRI algorithms in MATLAB
- Descriptive statistics and hypothesis testing to evaluate measurements and assess disease burden in patient population
- Screened, approached, and recruited patients through education

Deliverables
- Written report of results to share the project's primary findings
- Oral presentation to MSK MRI research group at Cleveland Clinic
- Tidied collection of written code and sorted data from project

Lessons Learned

- Importance of sorting and storing data to facilitate analysis
- Utility of documentation and reproducible code that others can understand and implement for future uses
- Practice of building and describing meaningful results and figures that address objectives and share primary conclusions
- Empathy and communication skills required to speak with patients

Acknowledgements

I would like to thank the rest of the Li Lab for providing me with guidance, feedback, and support, and the SOURCE office and the NIH Grant R01AR075422 for providing financial support to complete this project.

References

1. Kumar D, et al,2014,"Quadricep intramuscular fat fraction rather than muscle size associated with knee osteoarthritis," Osteoarthr Cartil, 22(2):226-34.
2. Eck B, et al., 2021, "Evaluation of Dixon MRI Methods for Quantitative Assessment of Thigh Muscle Fatty Infiltration in Post-Traumatic Osteoarthritis," Poster presented at: ISMRM 2021 Annual Meeting and Exhibition.
3. The Cleveland Clinic. MOON Onsite MRI 10 Years After ACL Reconstruction (MRI). ClinicalTrials.gov identifier: NCT04660955.
4. Smith DS, et al, 2012, "Optimization of Fat-Water Separation Algorithm Selection and Options Using Image-Based Metrics with Validation by ISMRM Fat-Water Challenge Datasets," Poster presented at: ISMRM Scientific Workshop - Fat-Water Separation.
5. Popescu R, et al., 2015, "Discrimination of vegetable oils using NMR spectroscopy and chemometrics," Food Control, 48:84-90.
6. Triplett WT, et al., 2014, "Chemical shift-based MRI to measure fat fractions in dystrophic skeletal muscle," Magn Reson Med, 72(1):8-19.
7. Damon BM, et al., 2016, "Quantitative Magnetic Resonance Imaging of Skeletal Muscle Disease," J Vis Exp., (118):52352.