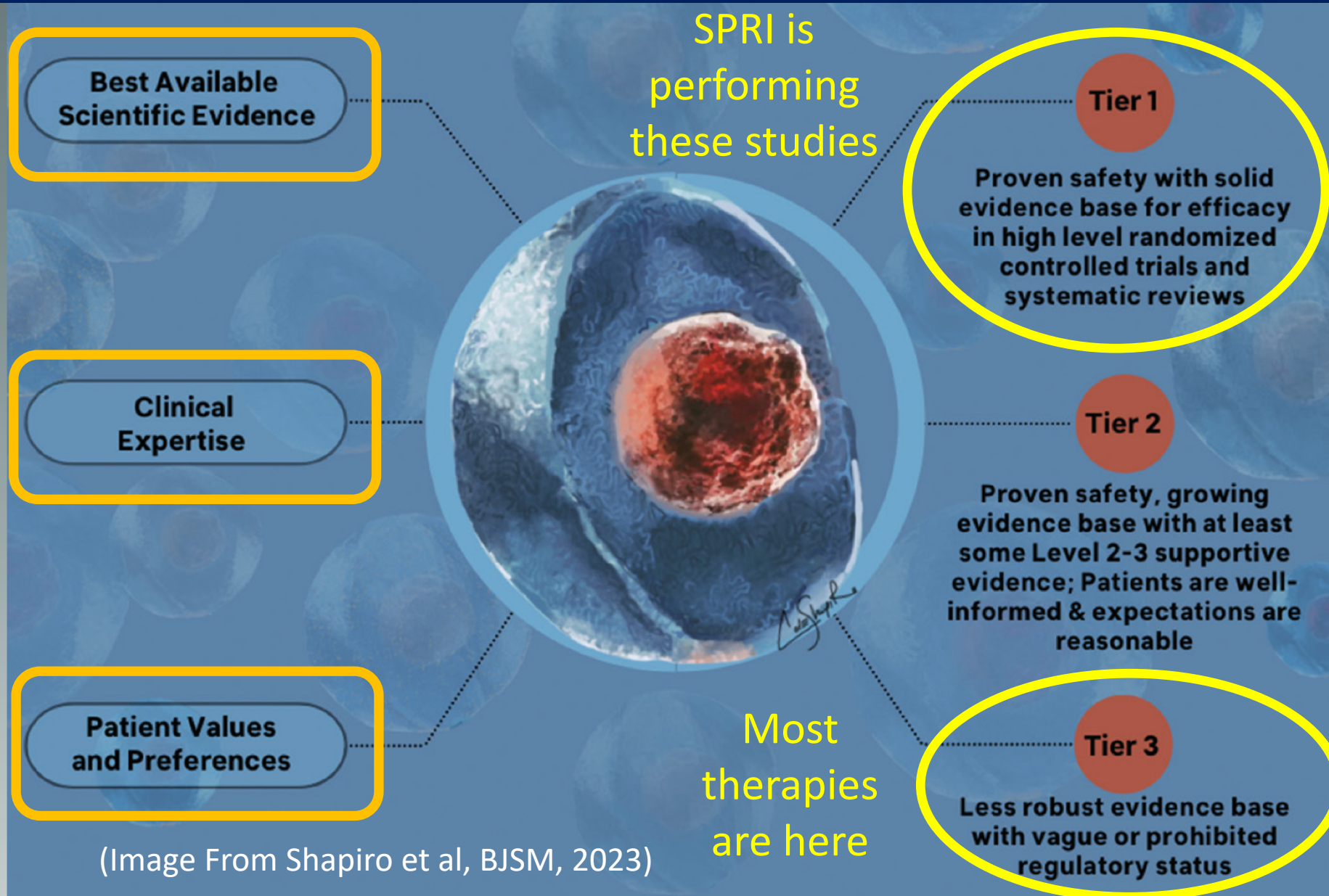


Evidence-based regenerative medicine: *How do we know what works?* Advanced imaging and biomechanical assessment of musculoskeletal function

Scott Tashman, PhD
Director, Biomedical Engineering
Steadman Philippon Research Institute

Clinical translation of regenerative medicine

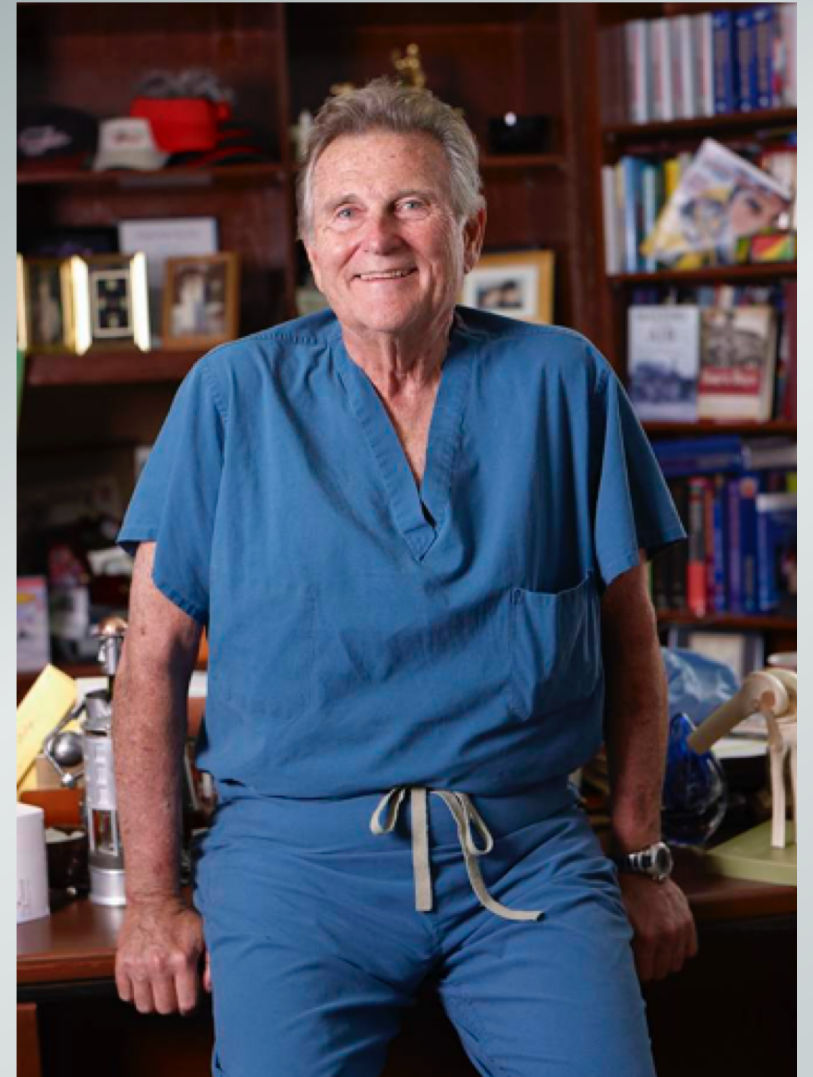


Dr. Richard Steadman: A Pioneer in Evidence-Based Orthopaedic Care

Dr. Steadman began collecting outcomes data on his patients when he moved to Vail and founded The Steadman Clinic in 1990

SPRI has grown this practice into a database containing records on over 155,000 clinic patients

Our elite surgeons routinely publish outcomes of their procedures in prestigious orthopaedic journals with follow-up of 5, 10 and even 20 years, establishing “gold standard” treatments for surgeons around the world



Building on Dr. Steadman's legacy: How do we evaluate regenerative medicine therapies?

Focus on assessing *Structure & Function* of regenerated tissues

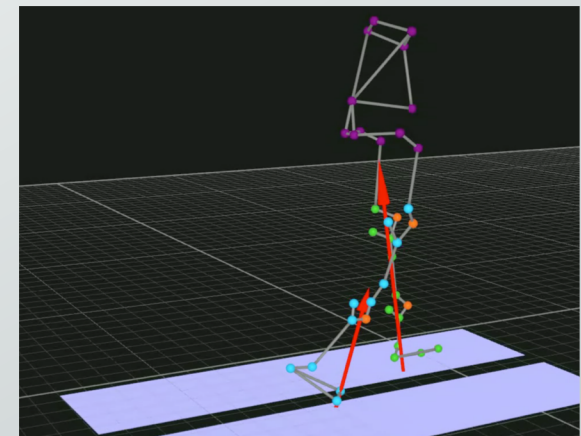
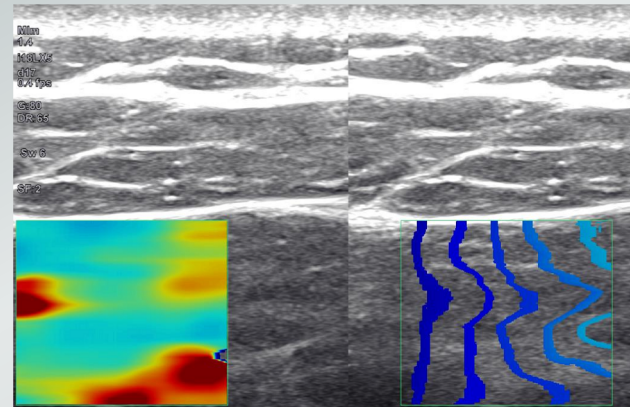
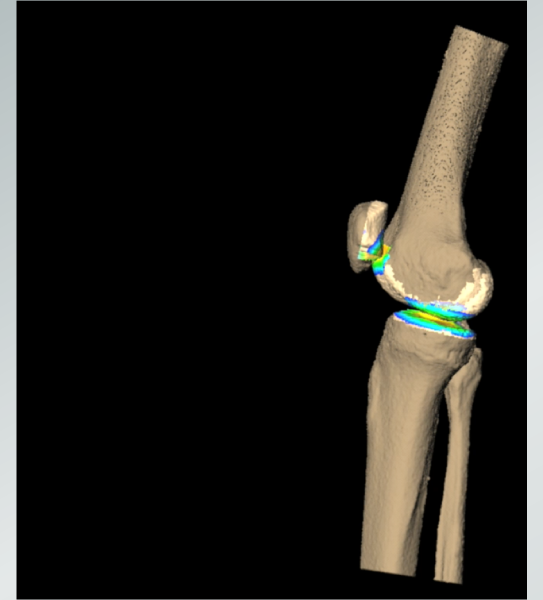
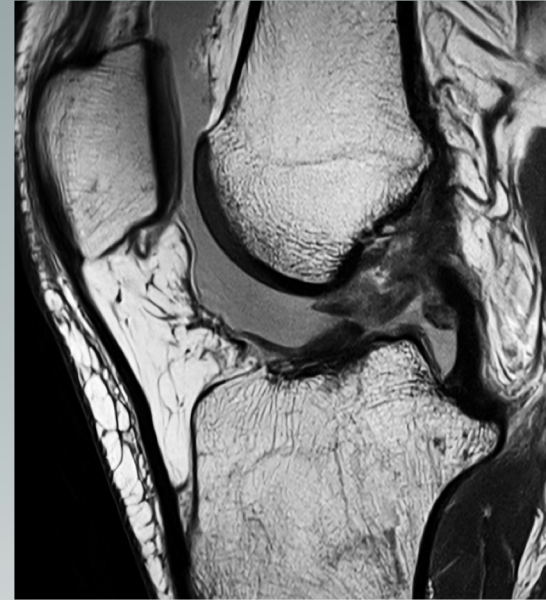
SPRI is an innovator for advanced musculoskeletal imaging:

MRI for tissue structure and quality

Ultrasound for local tissue properties

Dynamic imaging for tissue function

Whole-body Motion assessment



Imaging Resources: SPRI, TSC, Vail Health



Lauren Watkins, PhD



Charles Ho, MD

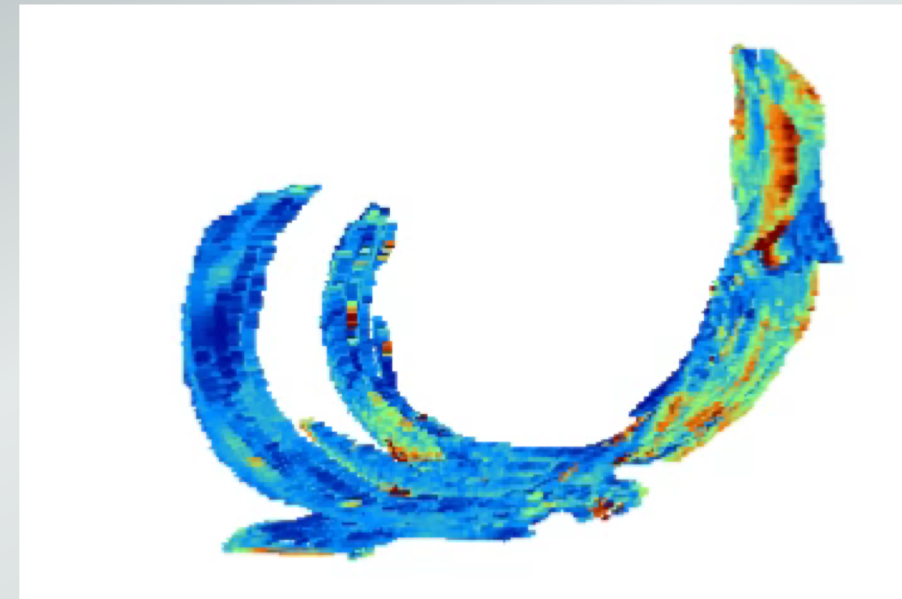
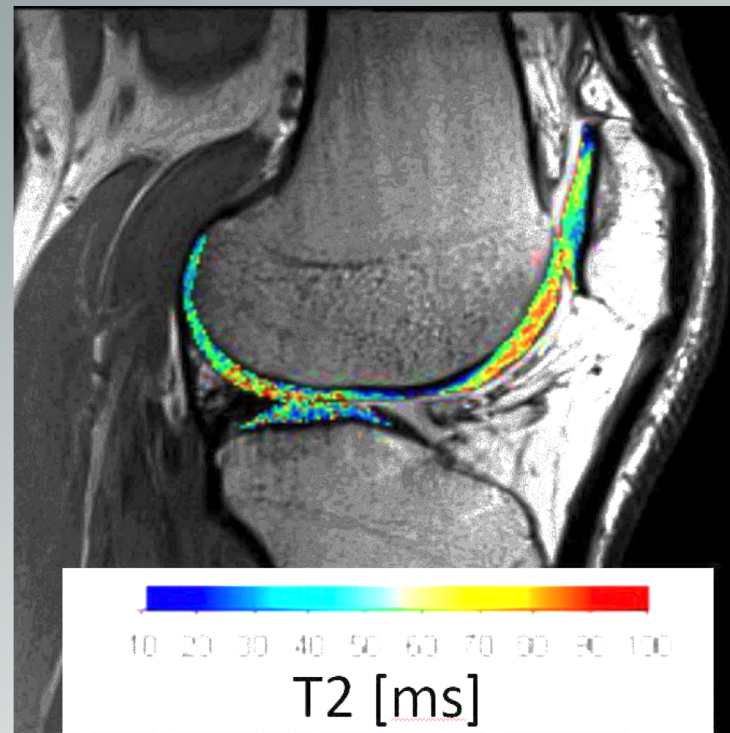
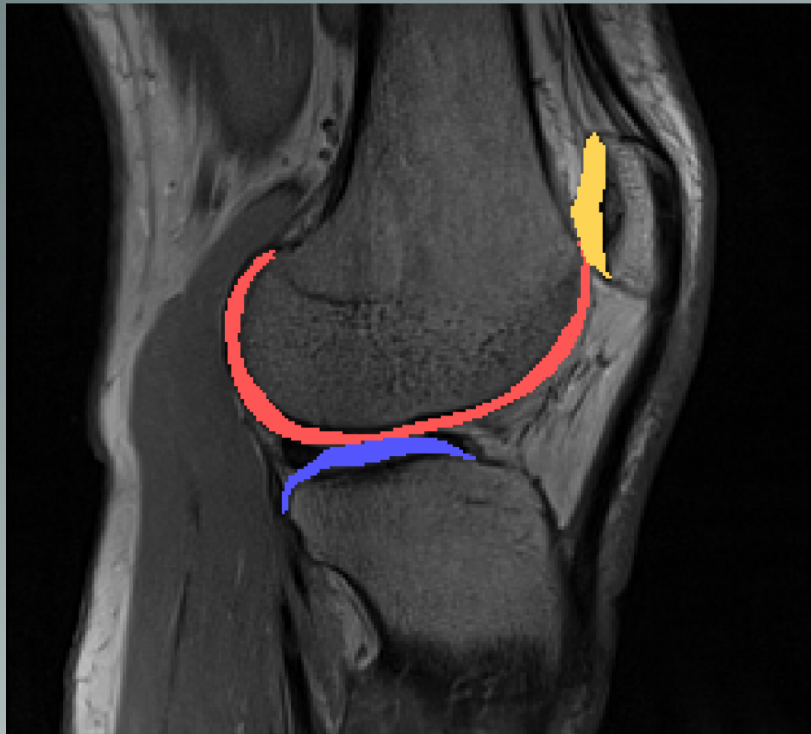
- Siemens Skyrafit 3T MRI (SPRI)
- Canon Vantage Galan 3T MRI
- Canon Aquilion ONE CT
- GE PET/CT



Canon/Toshiba
Aplio i800
Ultrasound

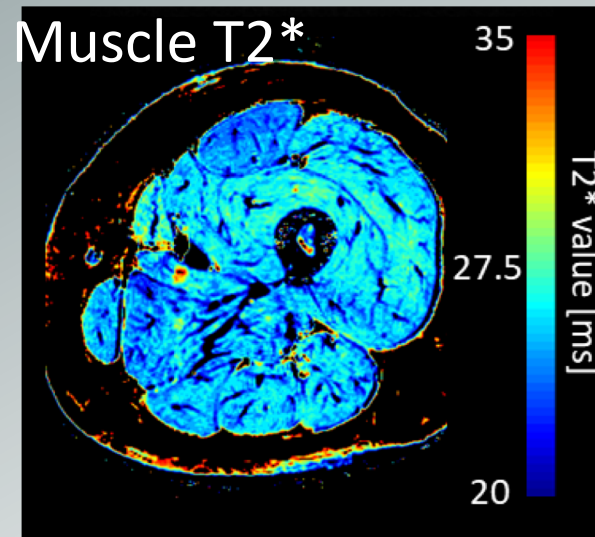
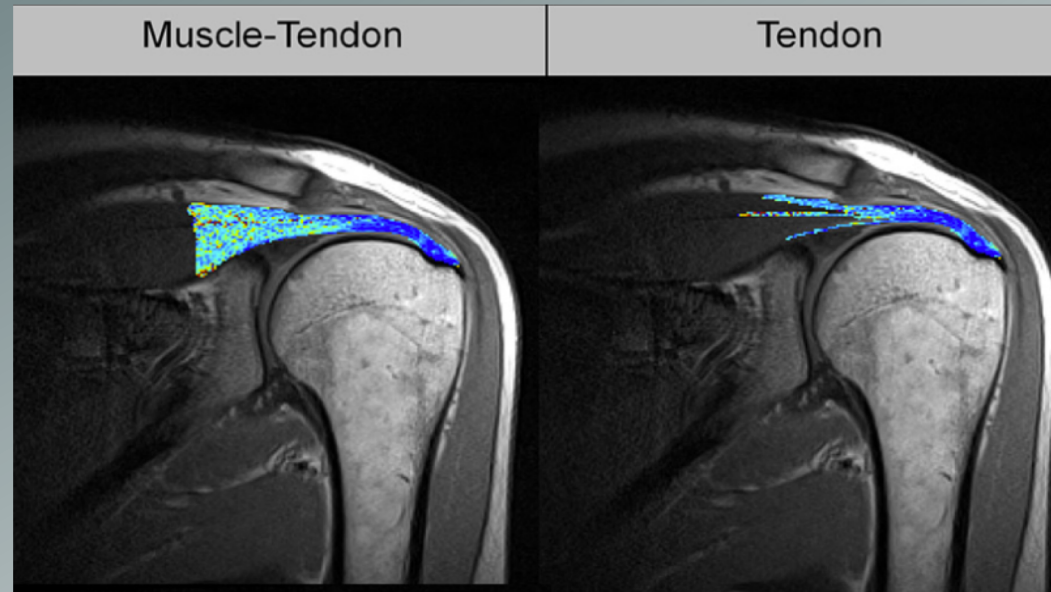
Imaging Cartilage

- Multiple techniques for assessing cartilage *quality* as well as loss
- Quantitative, 3D analysis of any joint surface

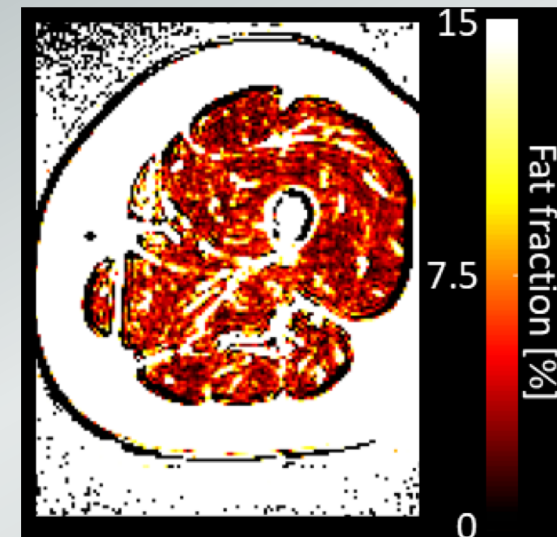


Imaging Muscle & Tendon

- T2/T2* & Ultra-short echo (UTE) imaging for evaluating muscle & tendon healing
- Diffusion-weighted imaging for fiber integrity and fibrosis
- Focus on shoulder & knee imaging

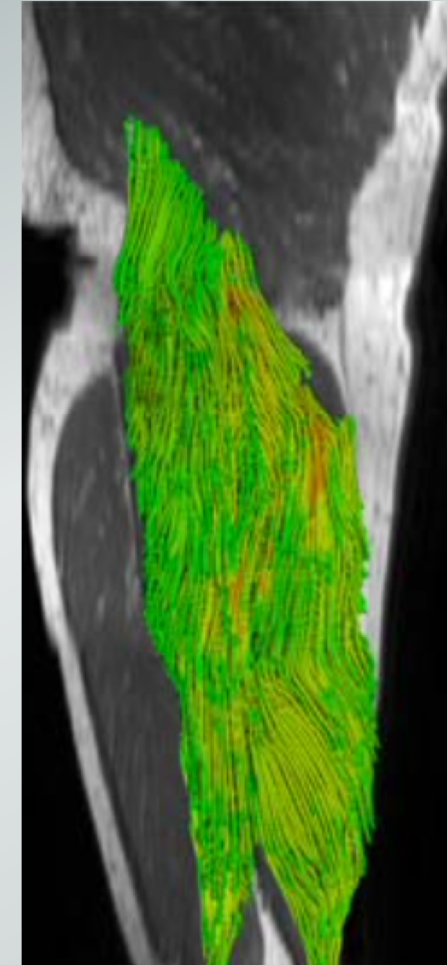


T2* - injury & fibrosis



Dixon - fat fraction

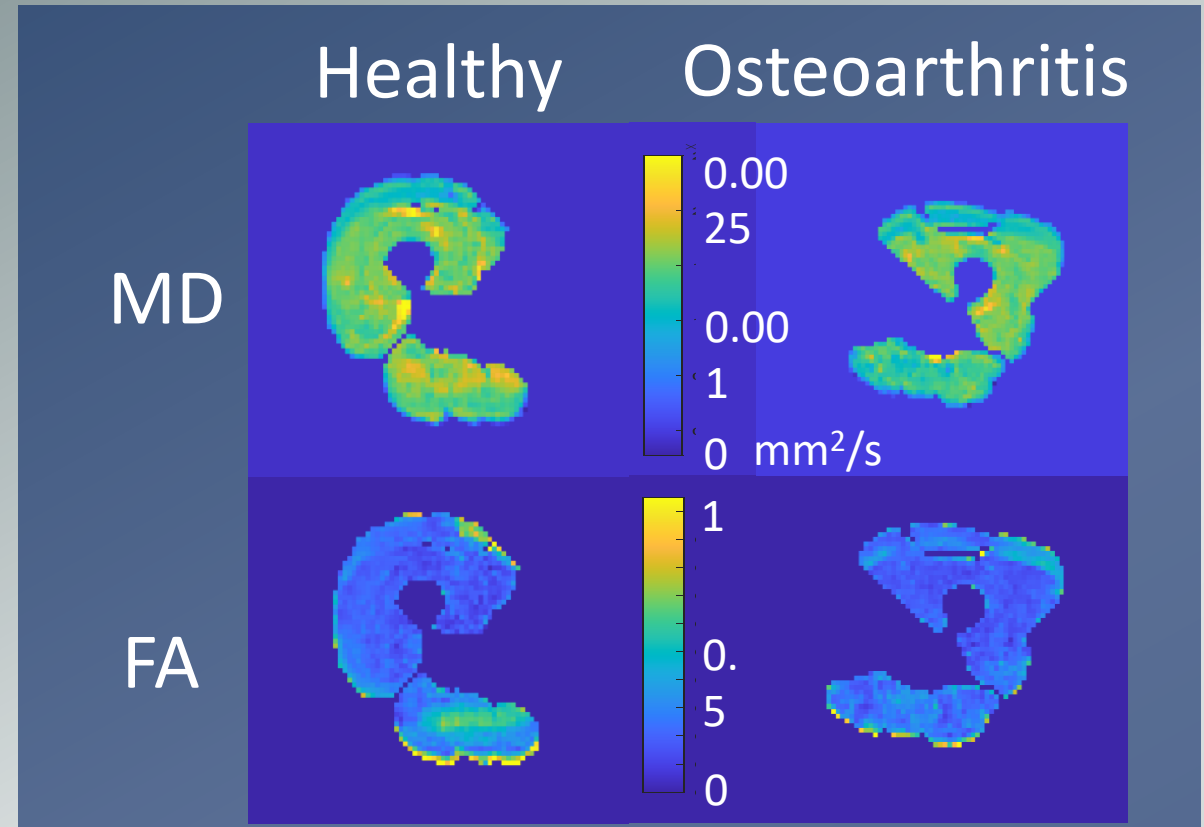
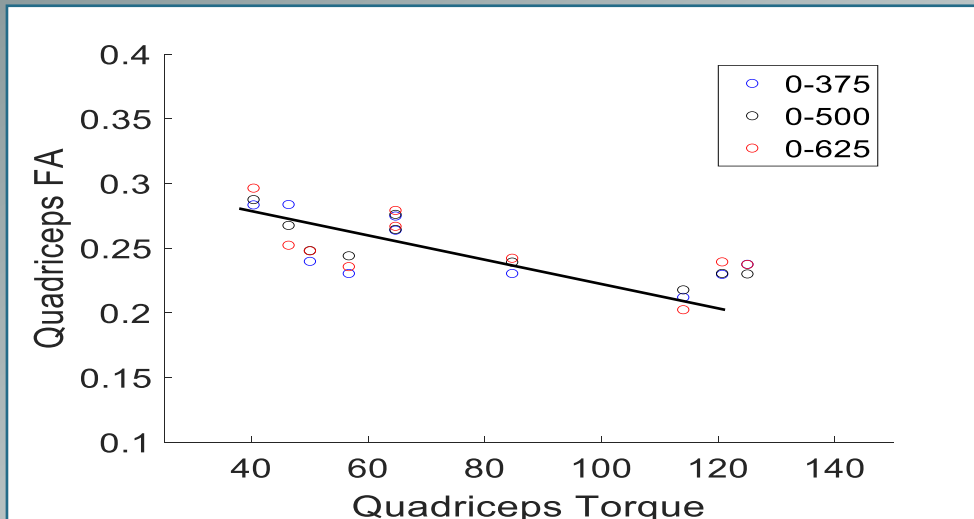
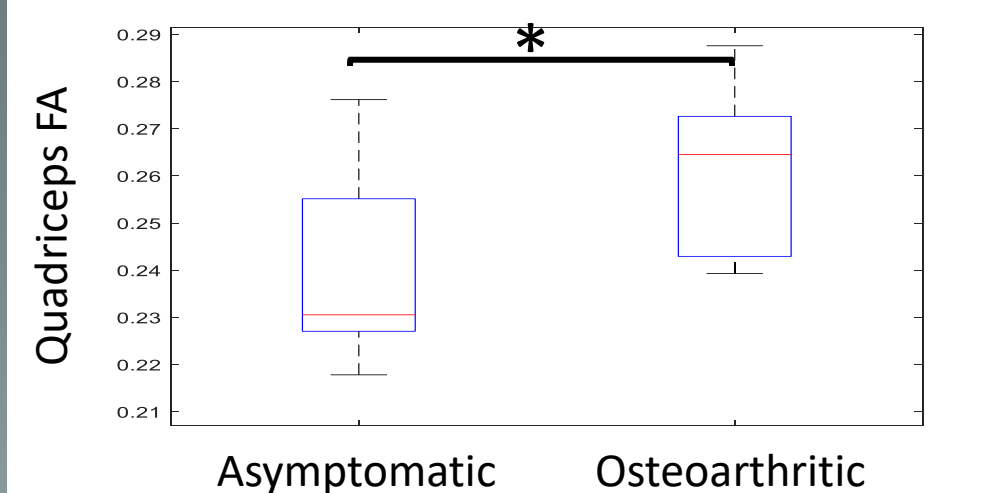
Muscle Diffusion



Thigh muscles in patients with osteoarthritis have pathologic changes



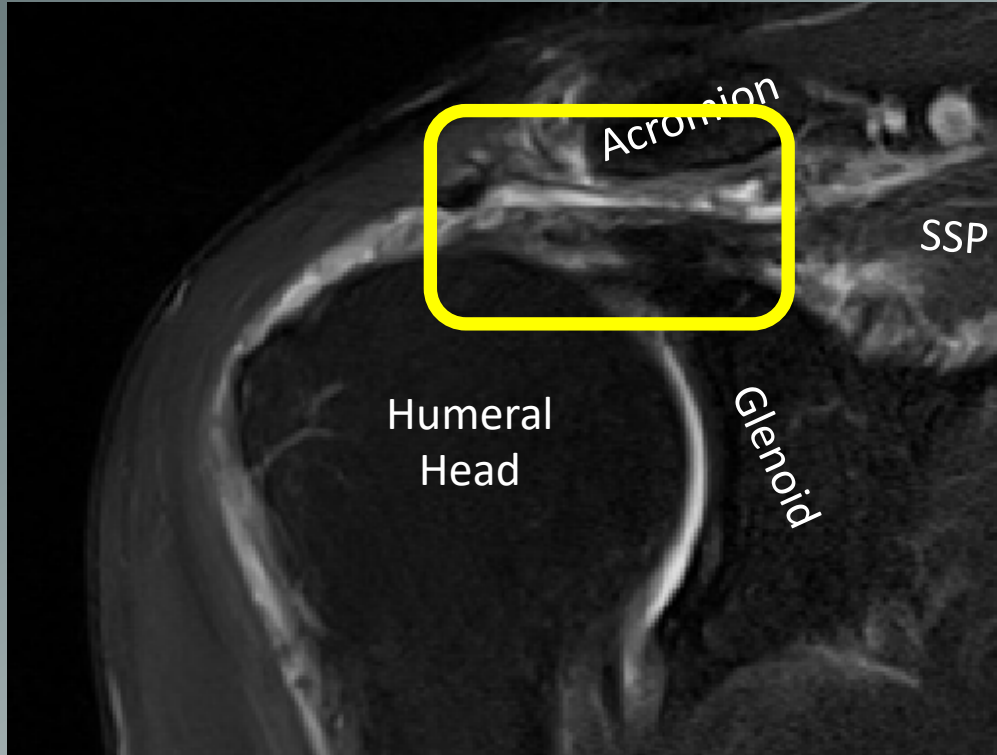
Dr. Ray
Kim



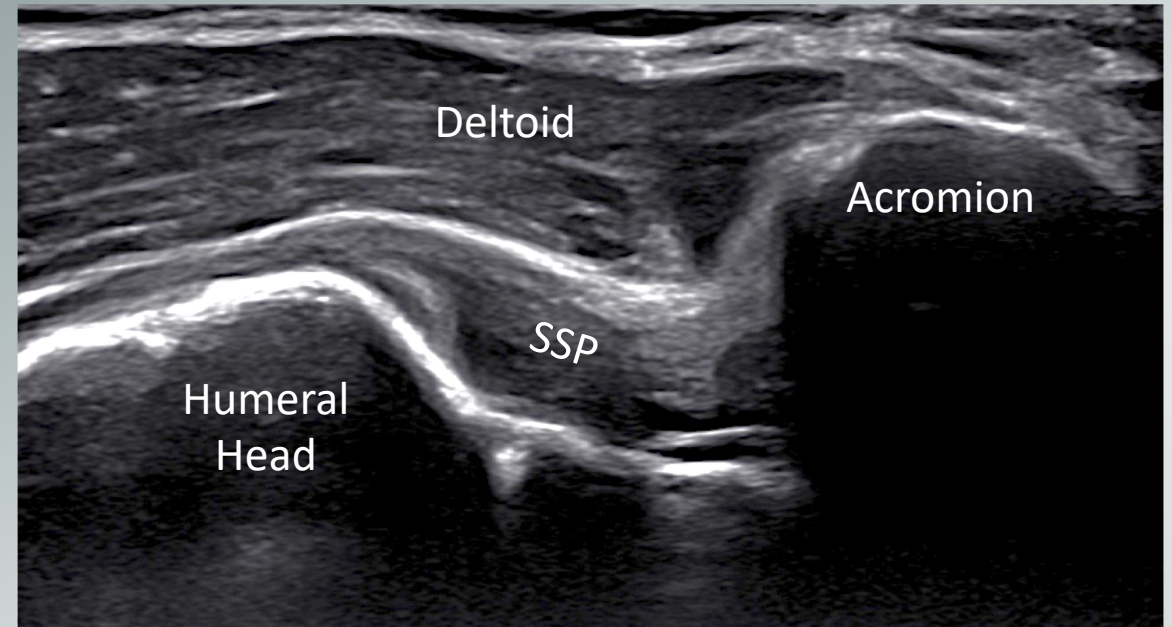
Improving muscle health after total knee replacement is a SPRI target for regenerative medicine therapies

Ultrasound: Expanding capabilities

MRI

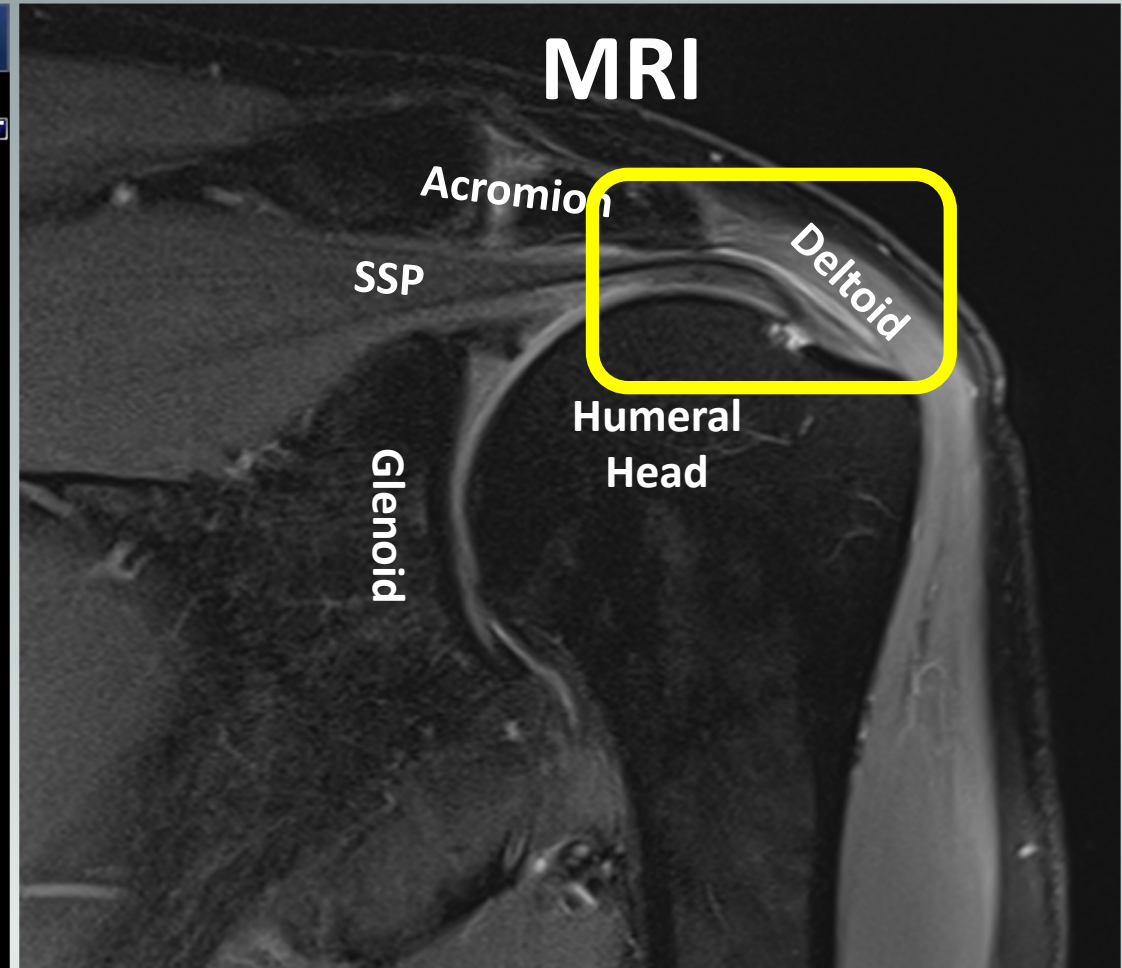
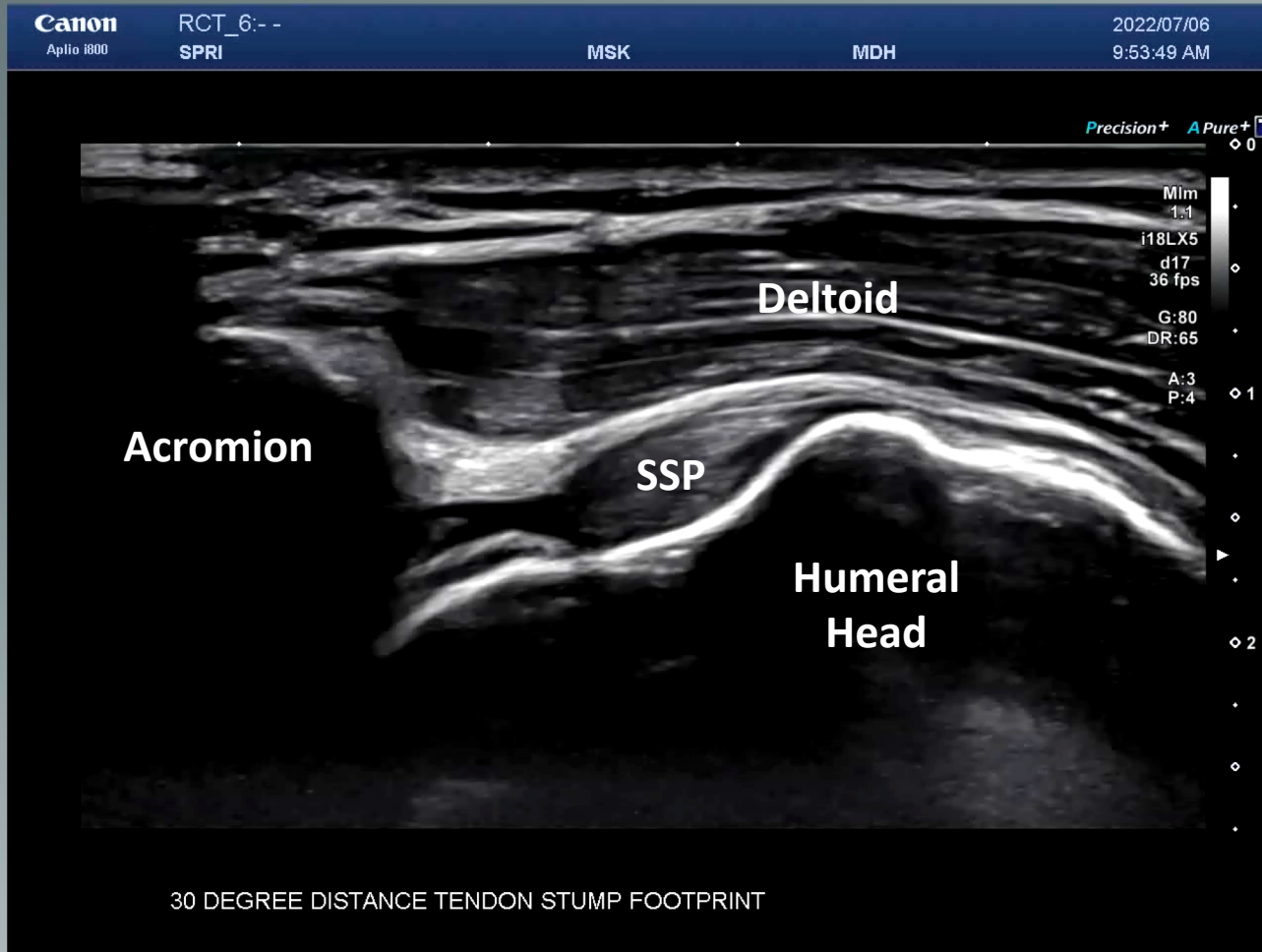


Ultrasound



- Rapid, in-office assessment
- High-resolution imaging

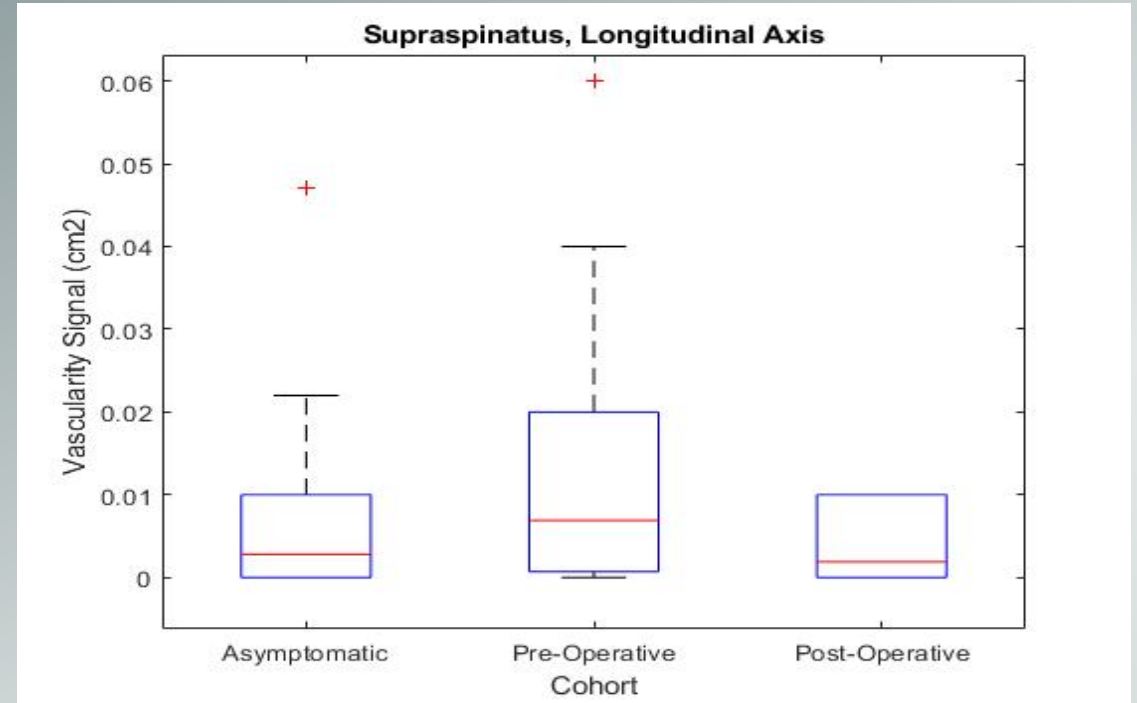
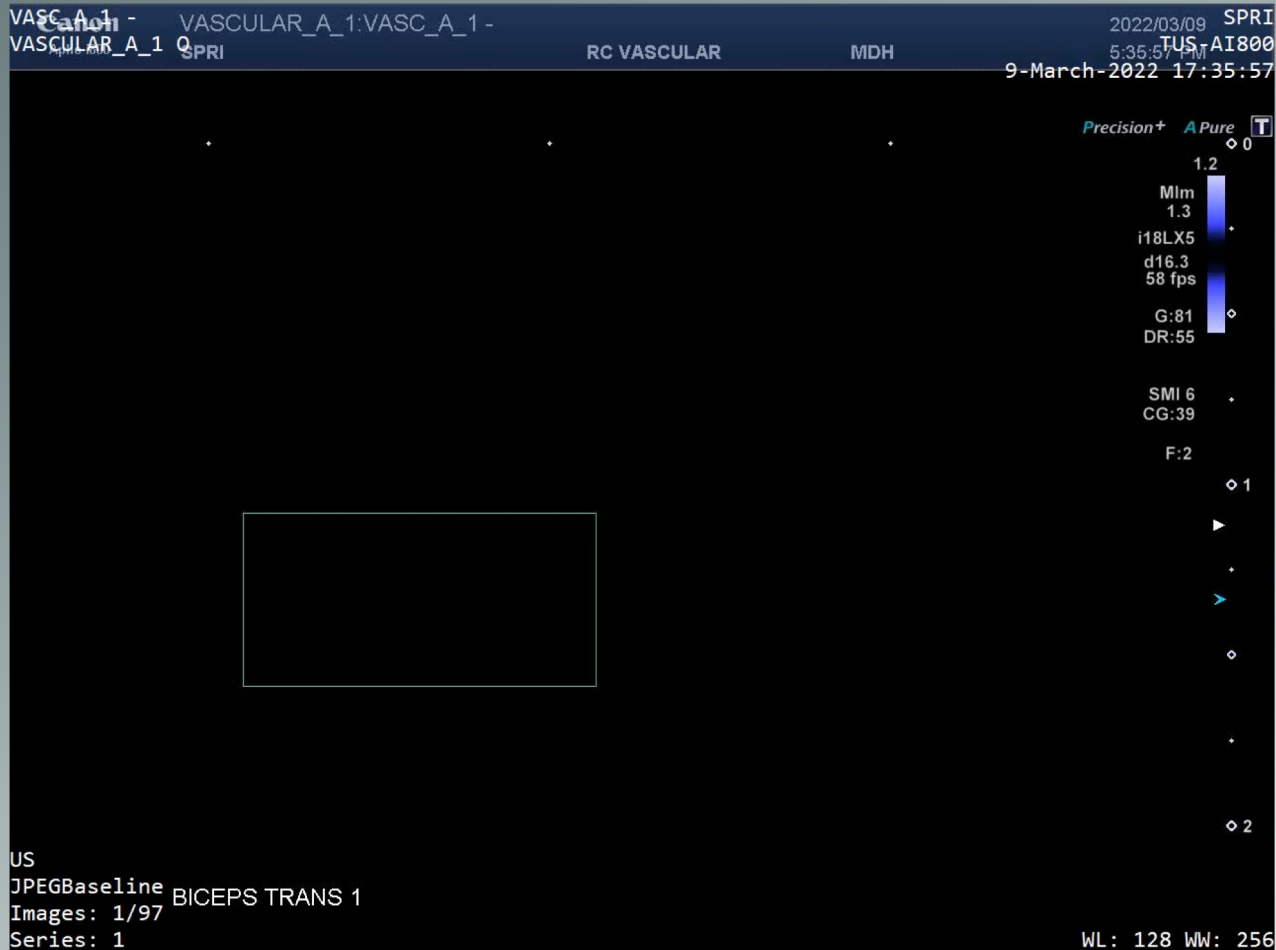
Dynamic Imaging with Ultrasound



Visualizing tendon movement for diagnosis & treatment planning

Advanced Ultrasound Techniques

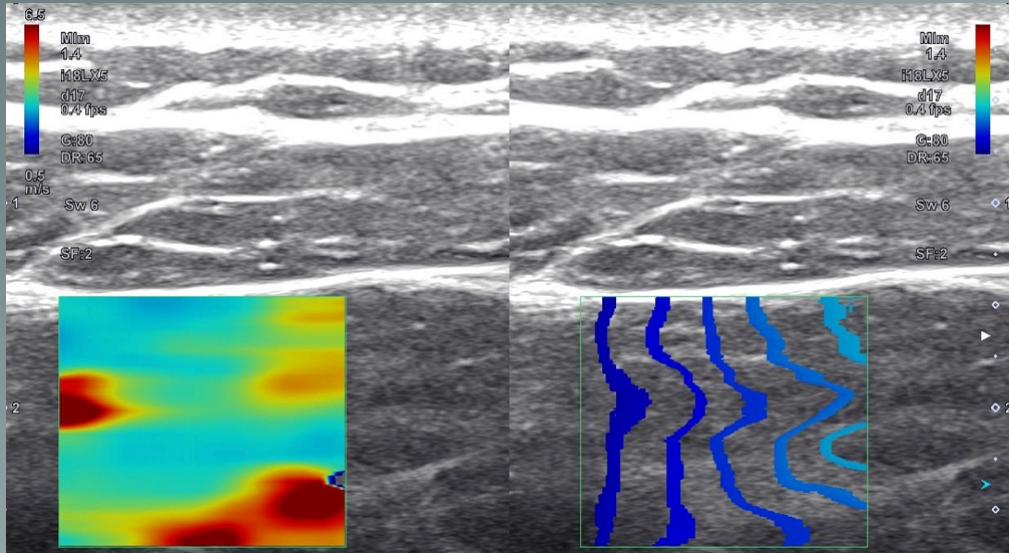
Microvascular imaging



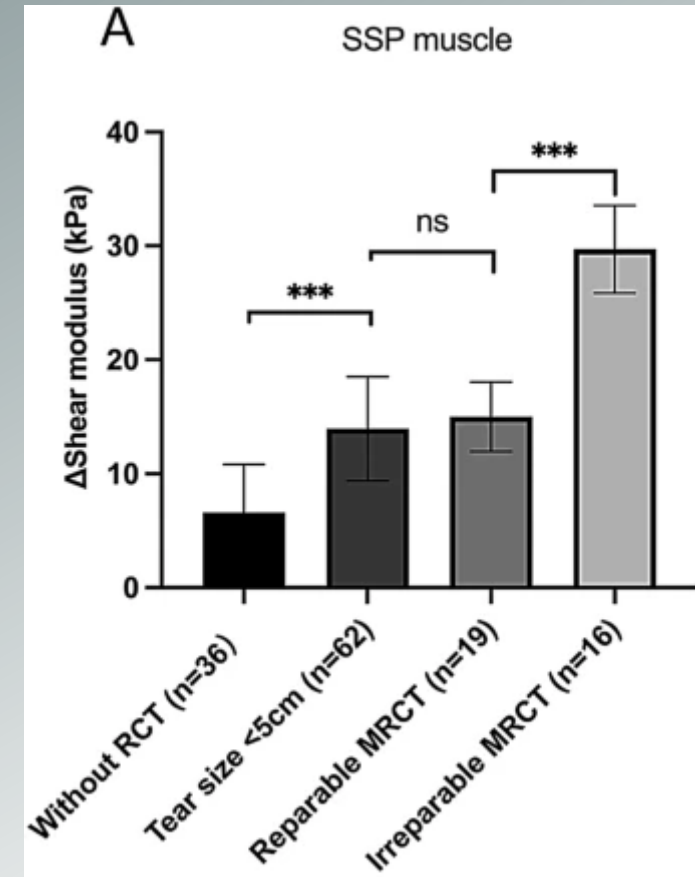
Rotator cuff tendon vascularity increases after injury to promote healing

Advanced Ultrasound Techniques

Shear Wave Elastography



Measures mechanical properties of tendons, ligaments & muscles



Injured rotator cuff tendons become stiff, making repair more difficult

Muscle strength testing

Isokinetic Dynamometer:
comprehensive assessment
of strength & power



Handheld, portable
testing



Clinical Interventions in Aging

Dovepress

open access to scientific and medical research

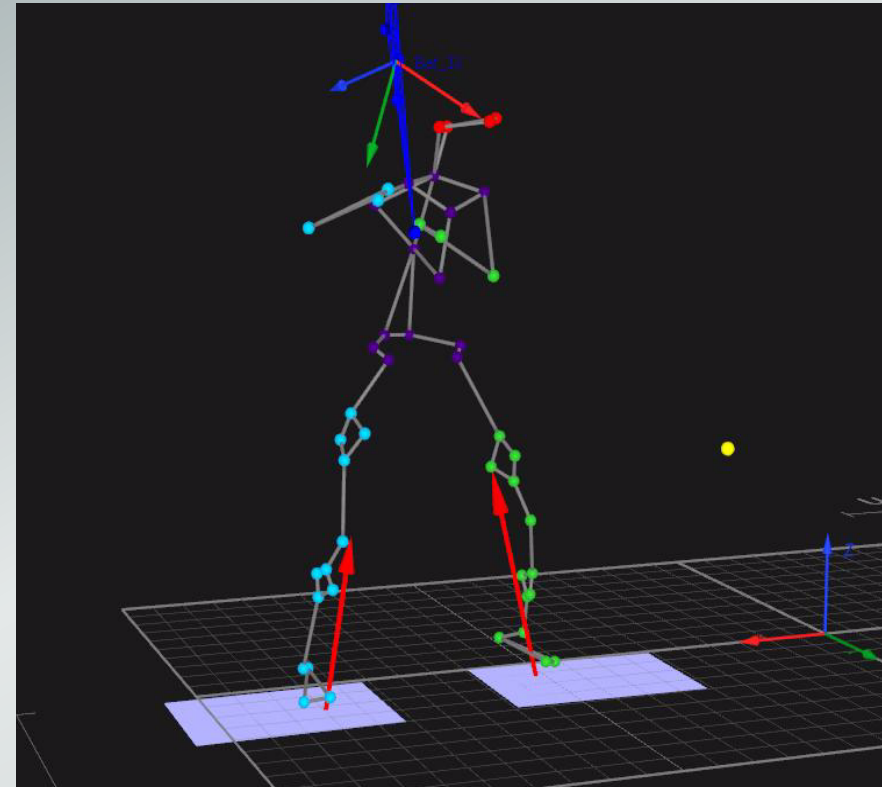
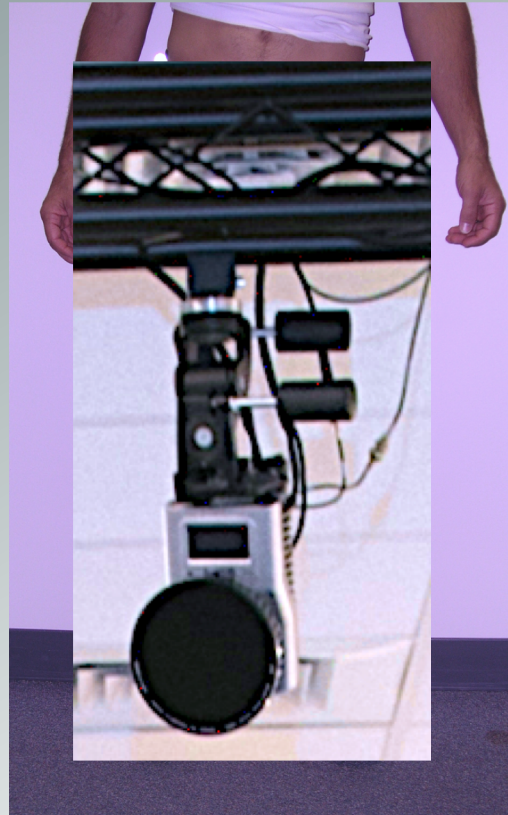
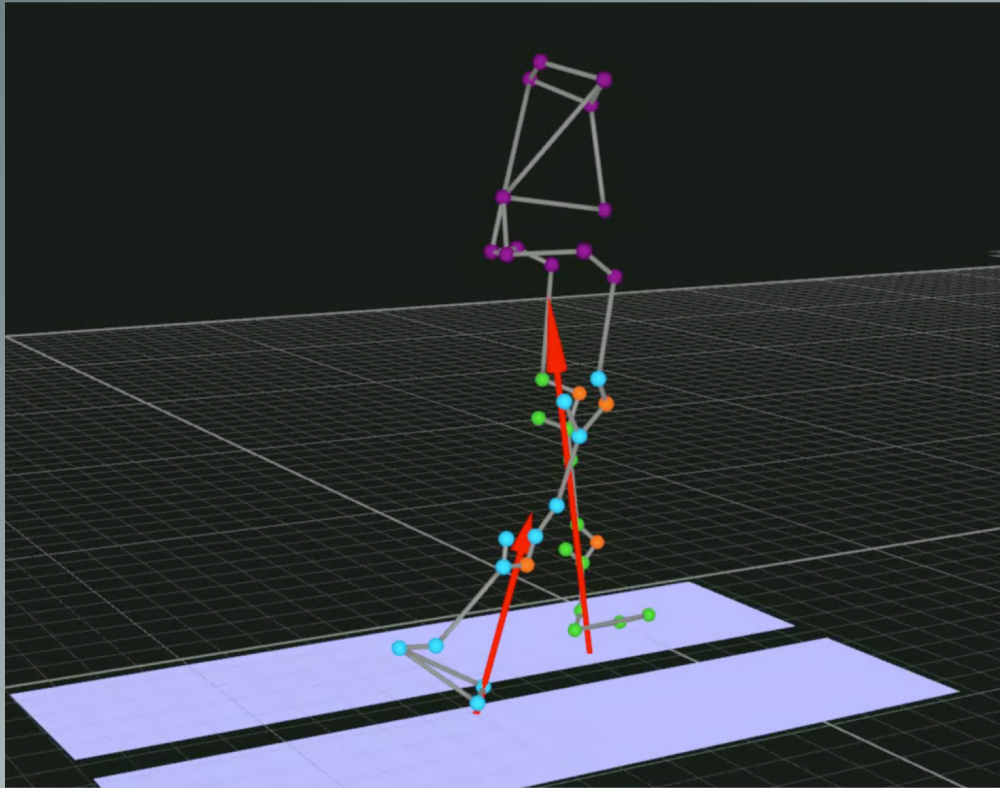
Open Access Full Text Article

REVIEW

Grip Strength: An Indispensable Biomarker For
Older Adults

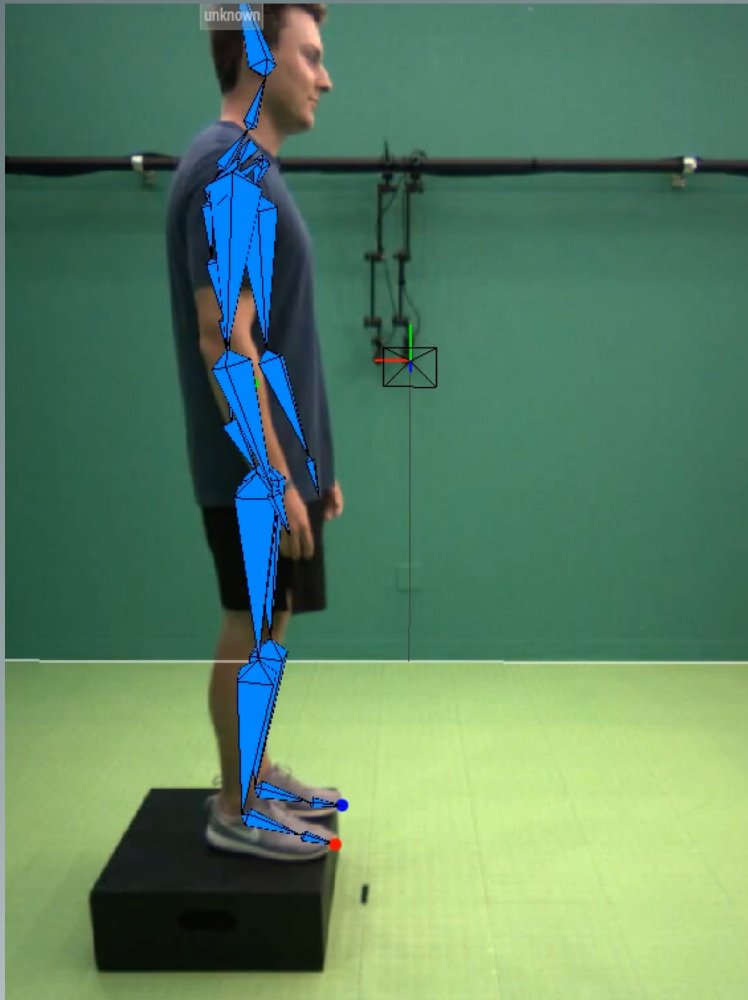
Whole-body movement: Video-motion analysis

Hi-precision measurement of musculoskeletal function



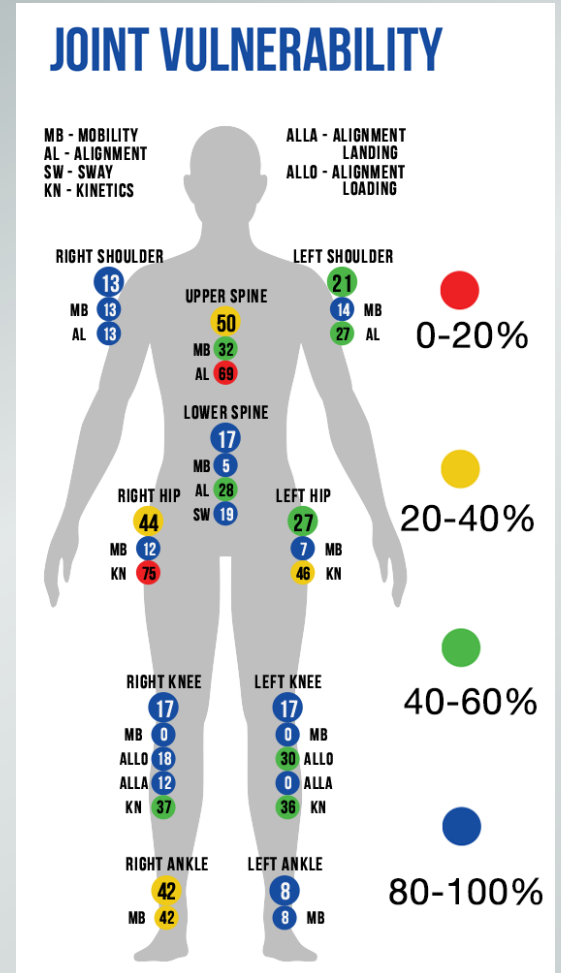
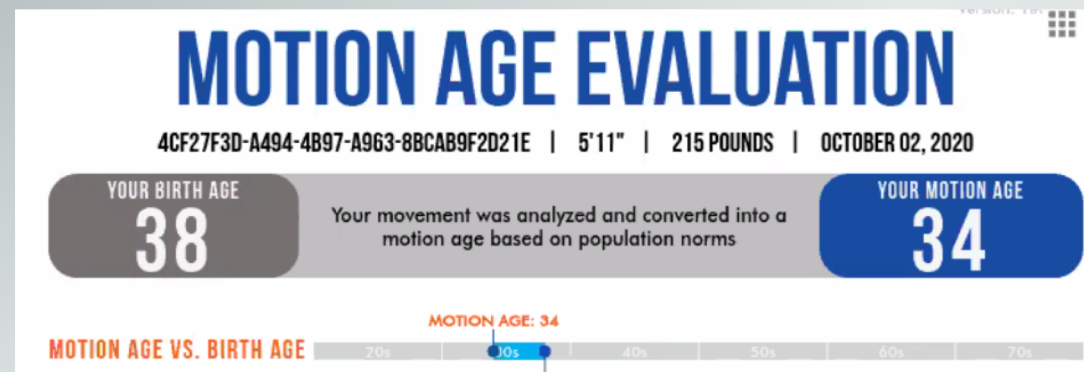
20 11-megapixel cameras, up to 500 frames/s

New Tech: Markerless motion analysis

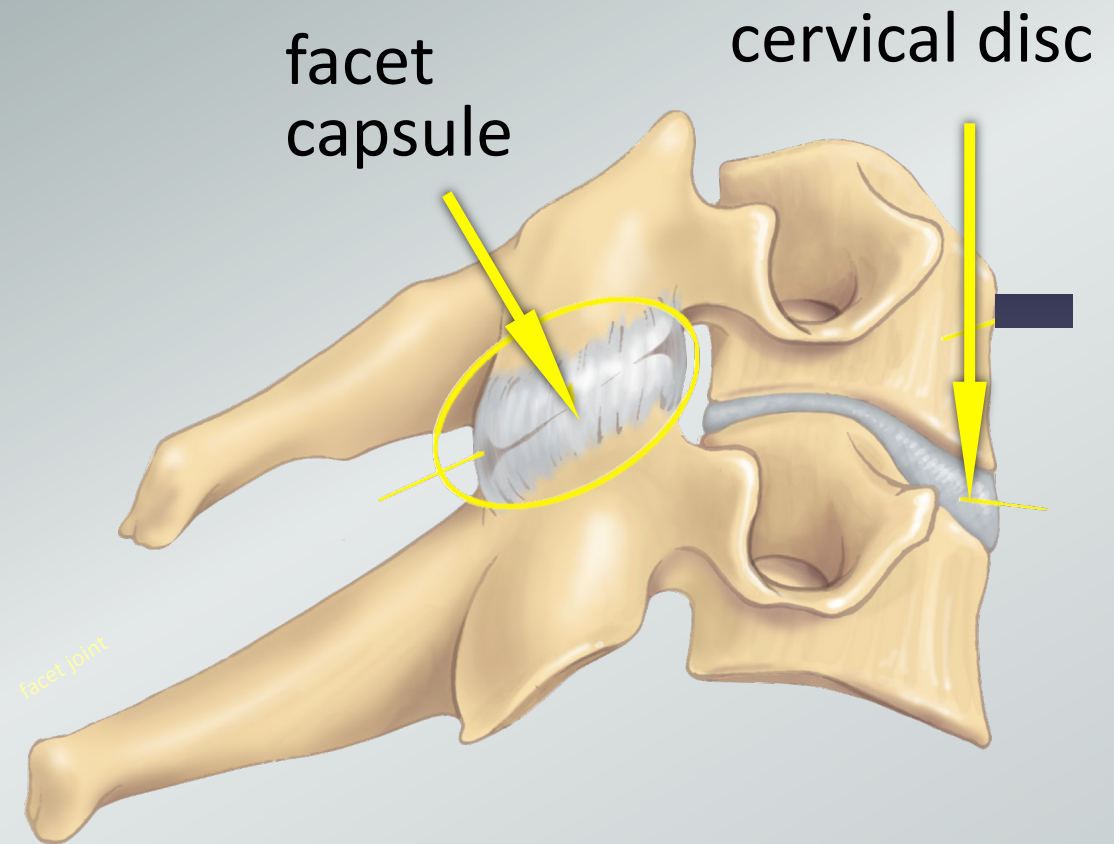
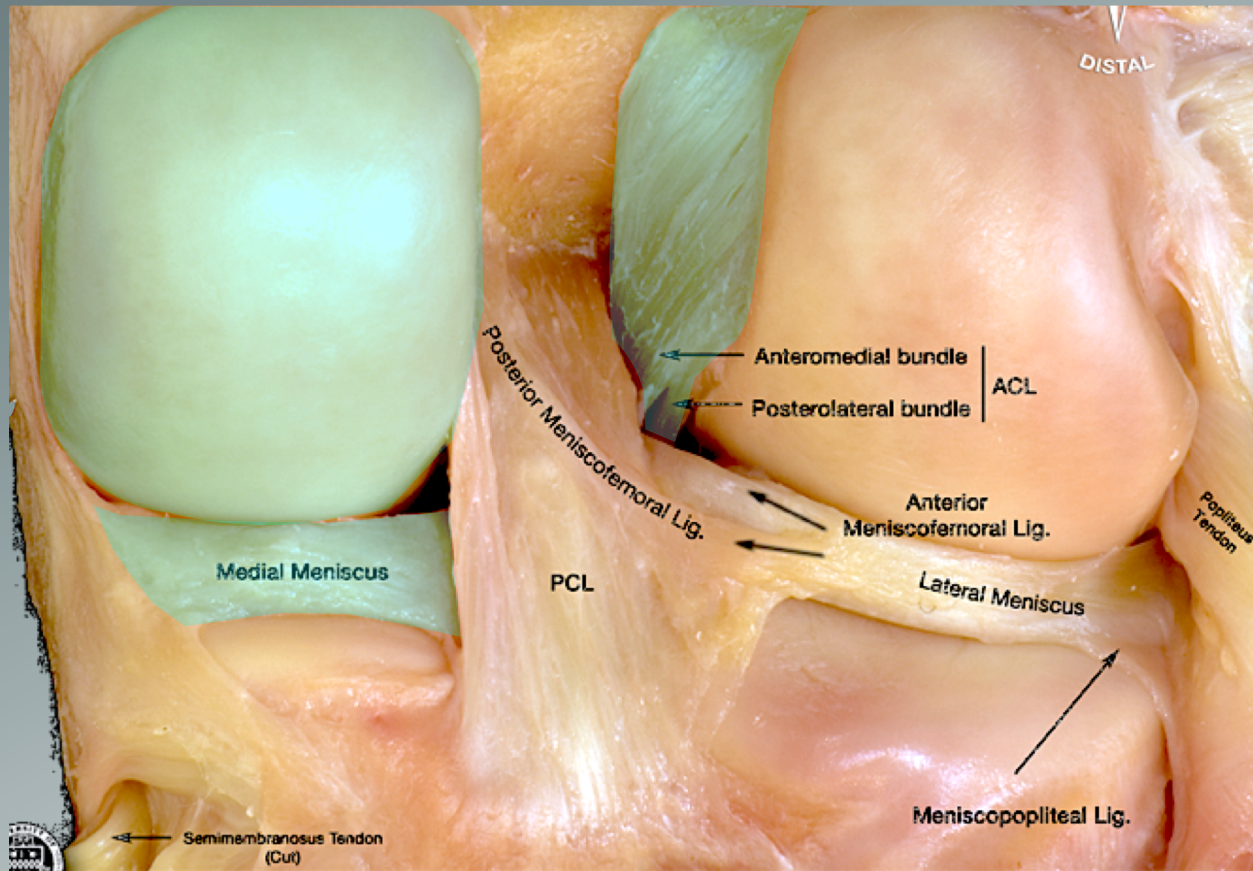


8 cameras collect
video for AI-based
motion tracking

< 15 minutes to
collect data and
generate a report



Challenge: Evaluating tissue mechanics

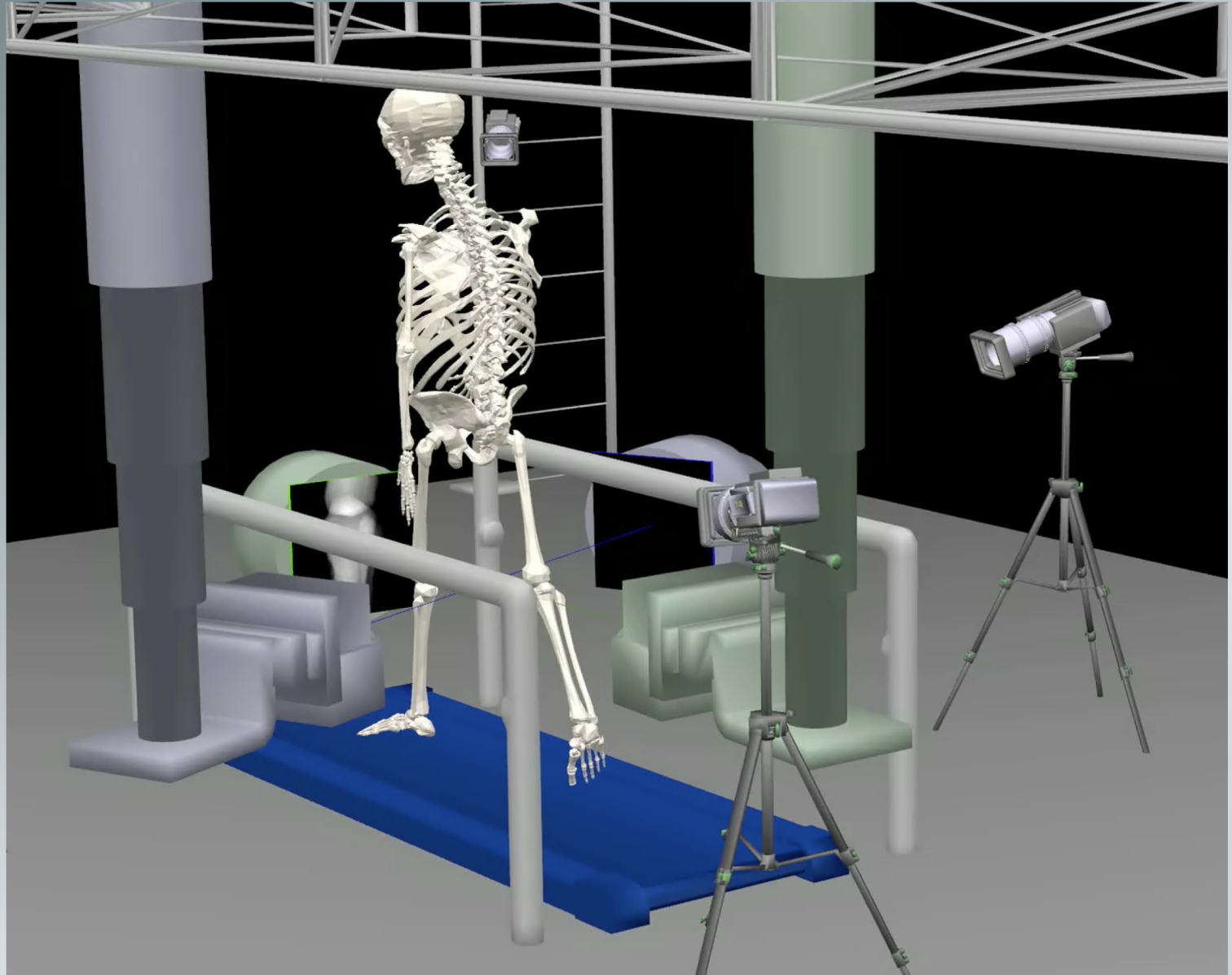


Dynamic Stereo X-ray (DSX)

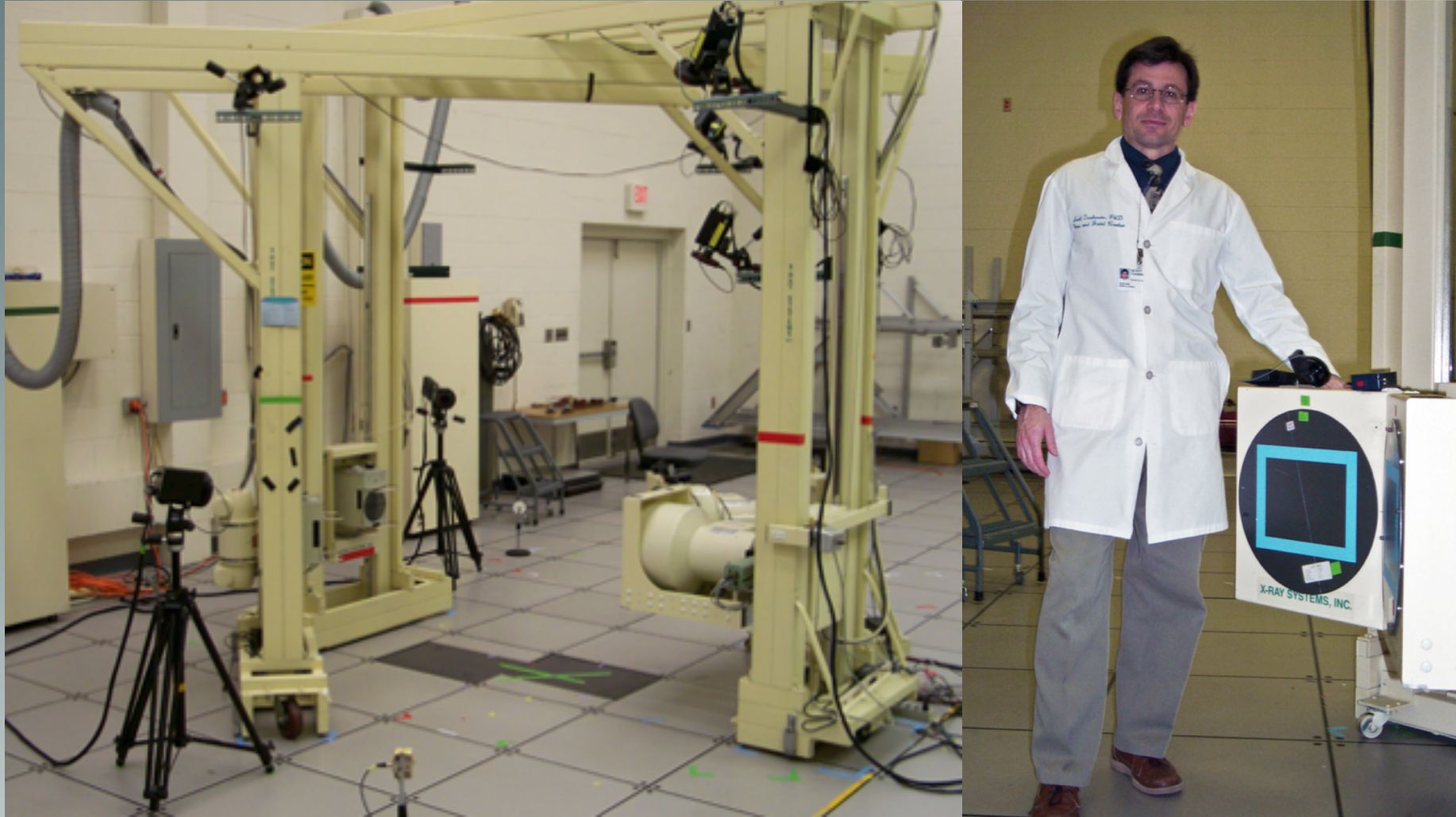
Direct imaging of
bone motion

High frame rates

Sub-mm 3D accuracy

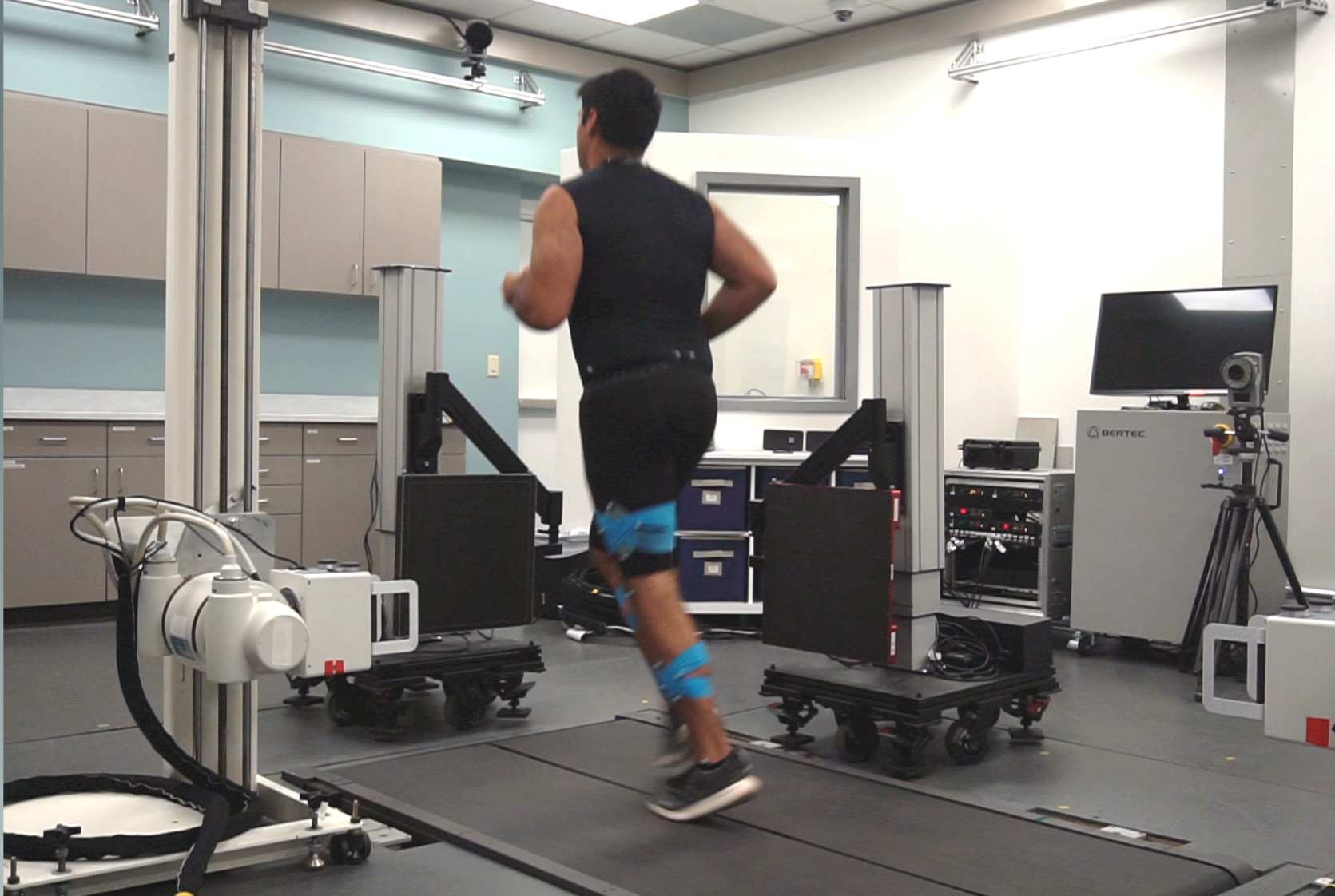


First Dynamic Stereo-Radiography (DSX) System: 1998



Henry Ford Hospital, Detroit, MI

SPRI DSX System: 2022

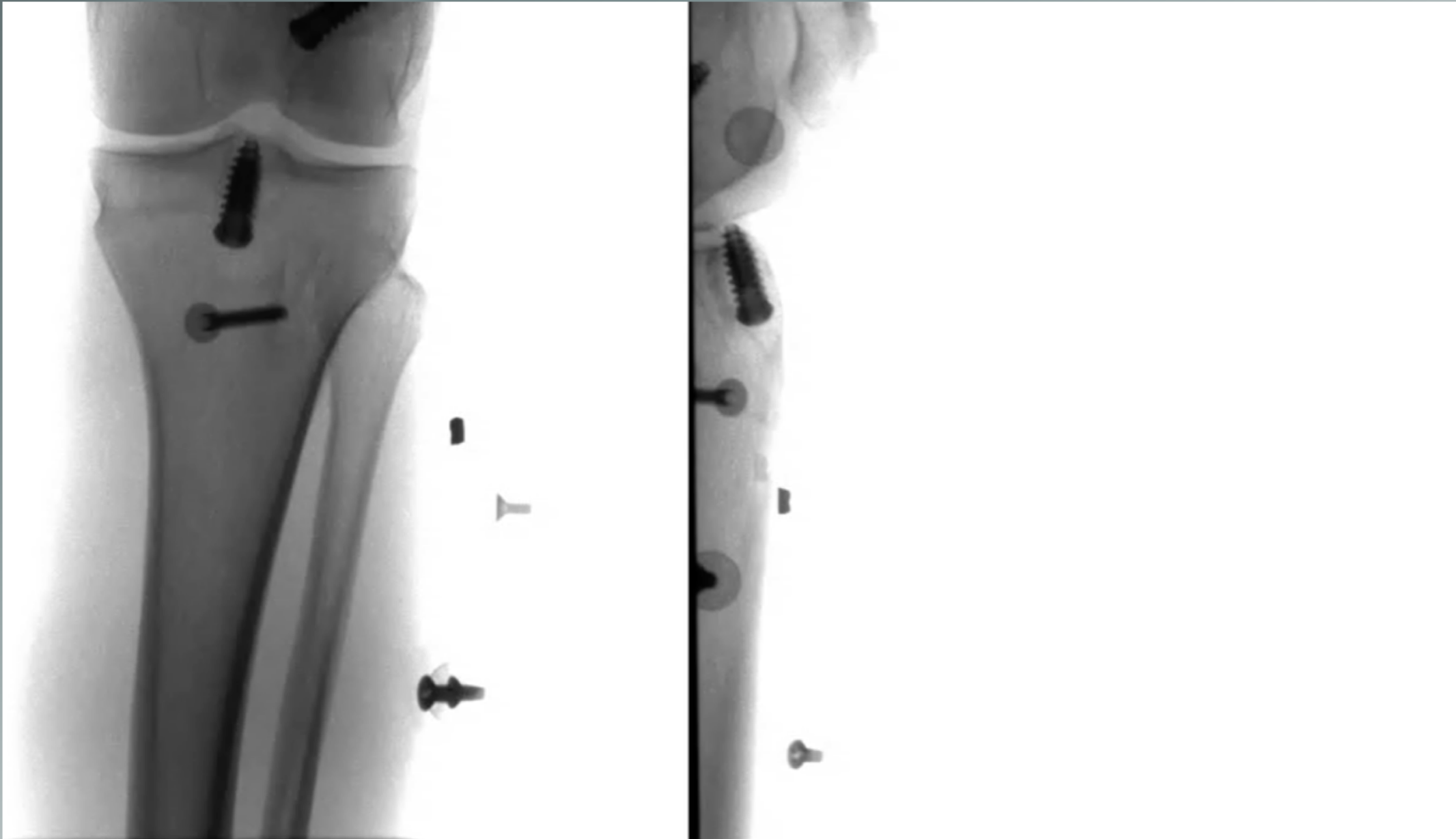


Advanced 9 Mpixel
flat-panel detectors

120 images/s

Low-dose 1ms
pulsed images

Cutting-edge X-ray imaging technology



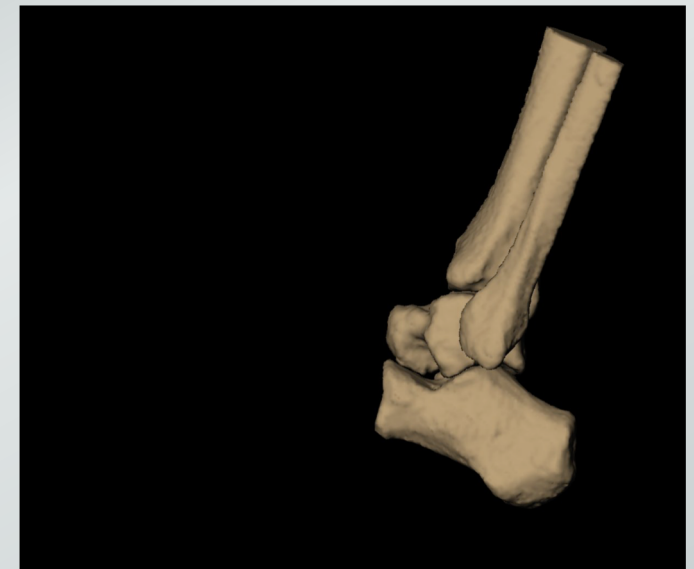
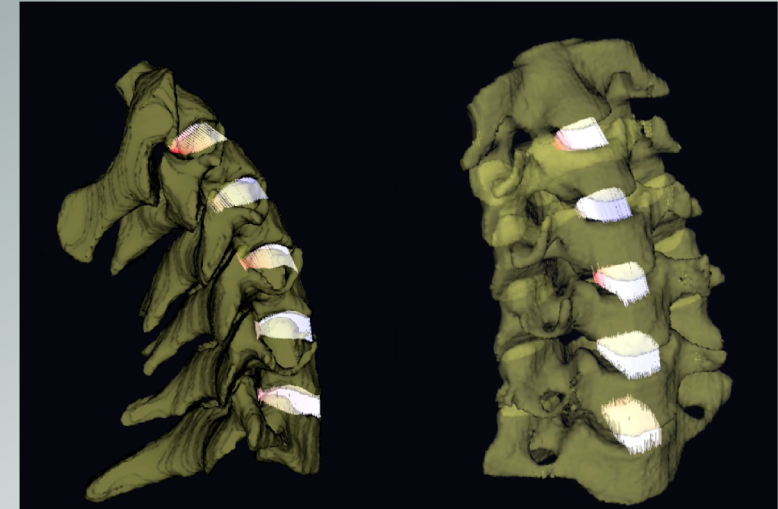
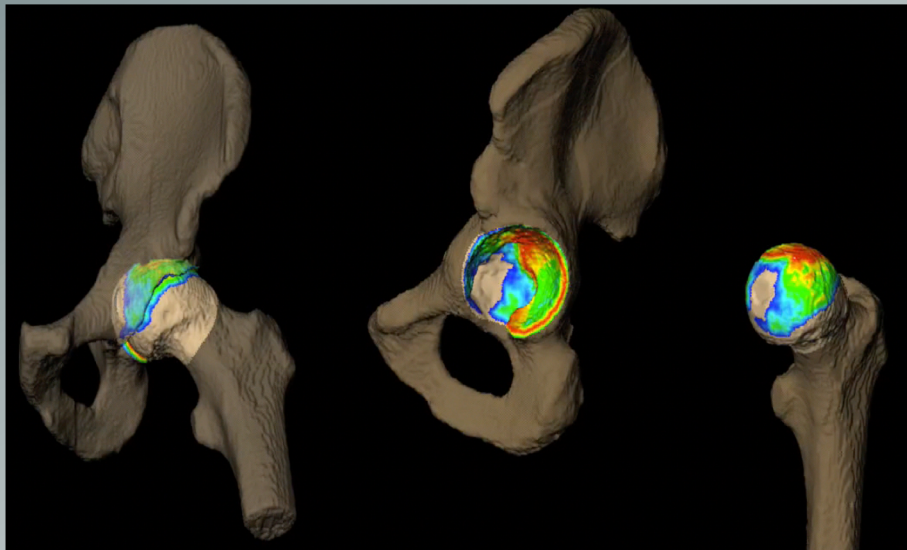
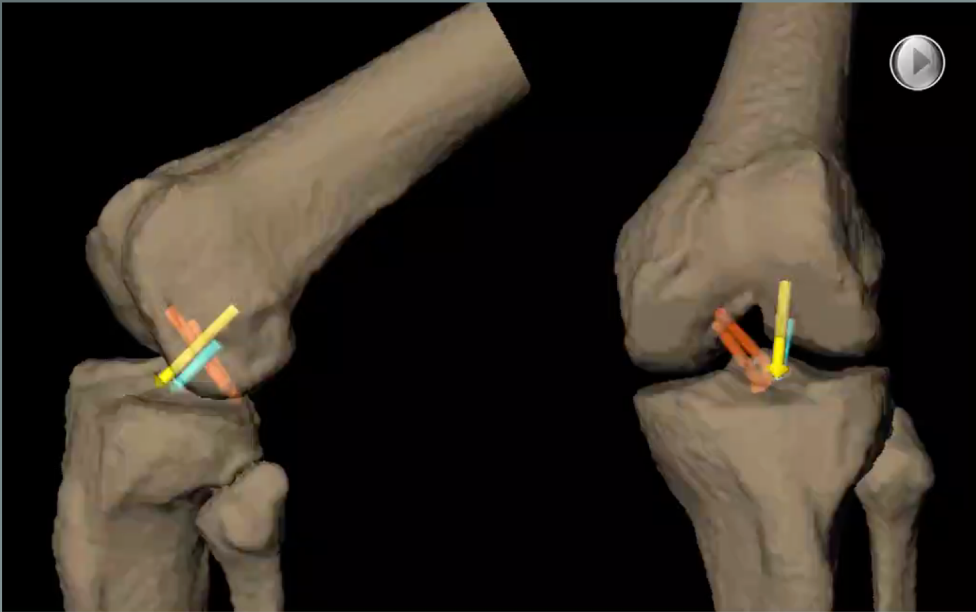
Jump Landing
120 images/s
1ms
exposures

Cutting-edge X-ray imaging technology

Jump Landing
120 images/s
1ms
exposures

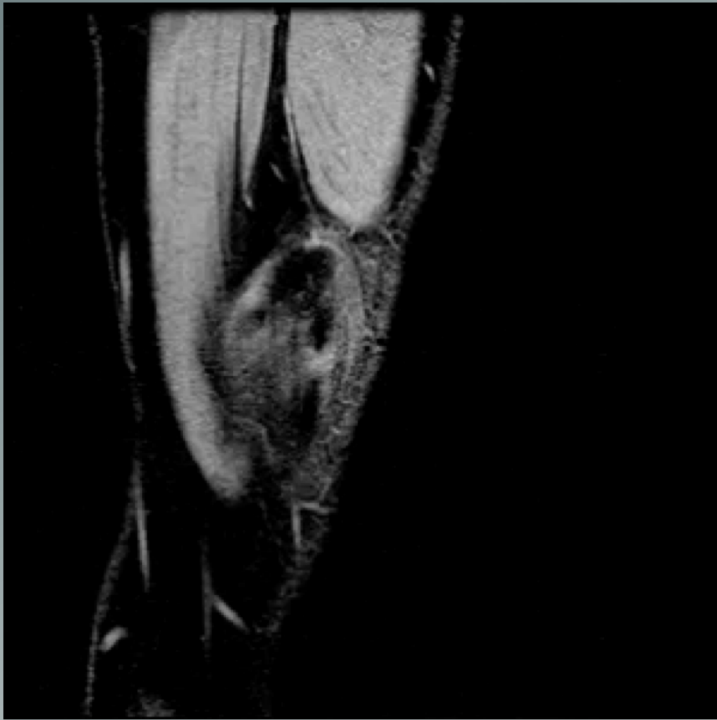


How do we use DSX in our research?

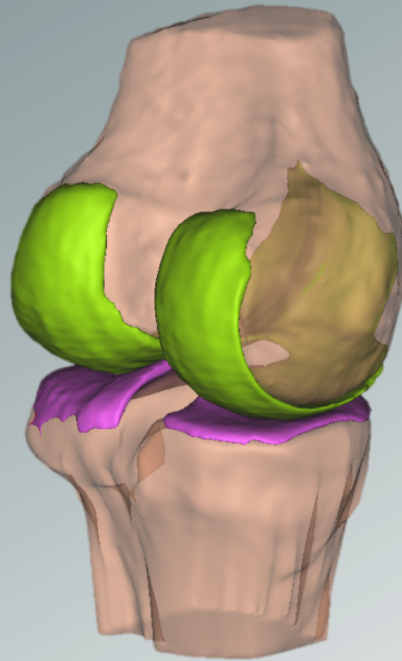


Advanced modeling of cartilage contact

Cartilage modeling

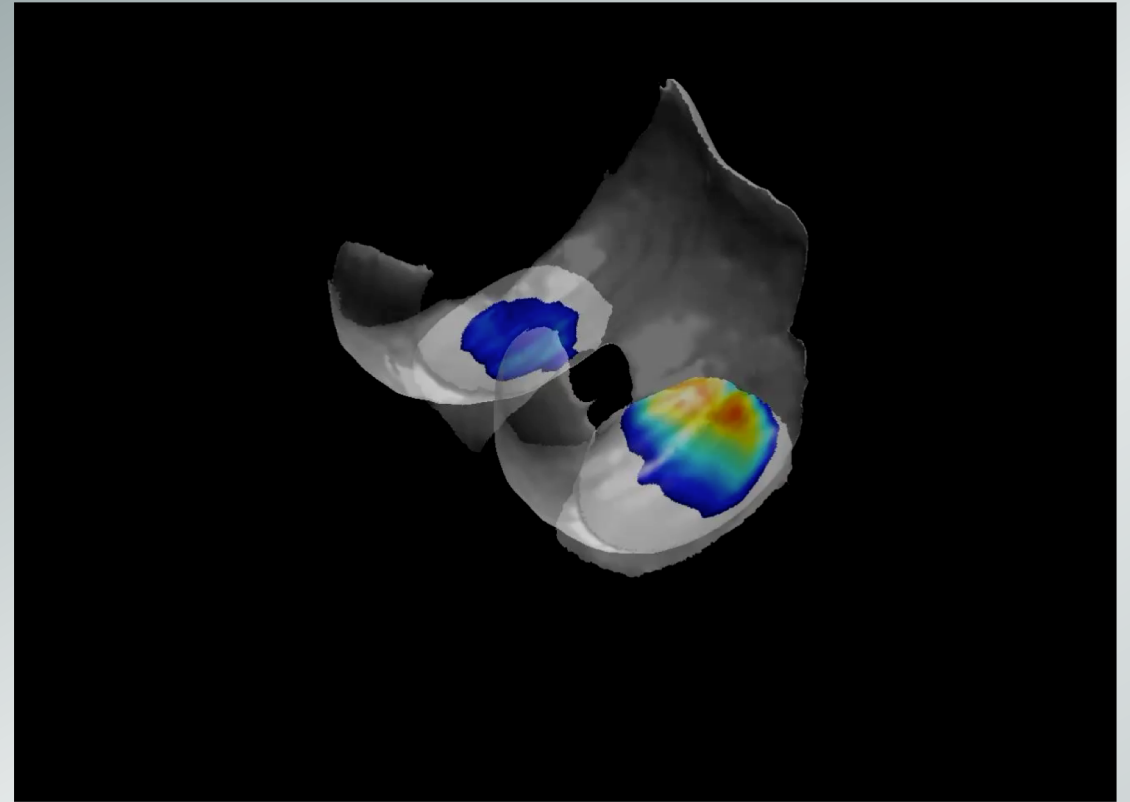


High resolution 3T MRI



Cartilage mapped
to CT bone models

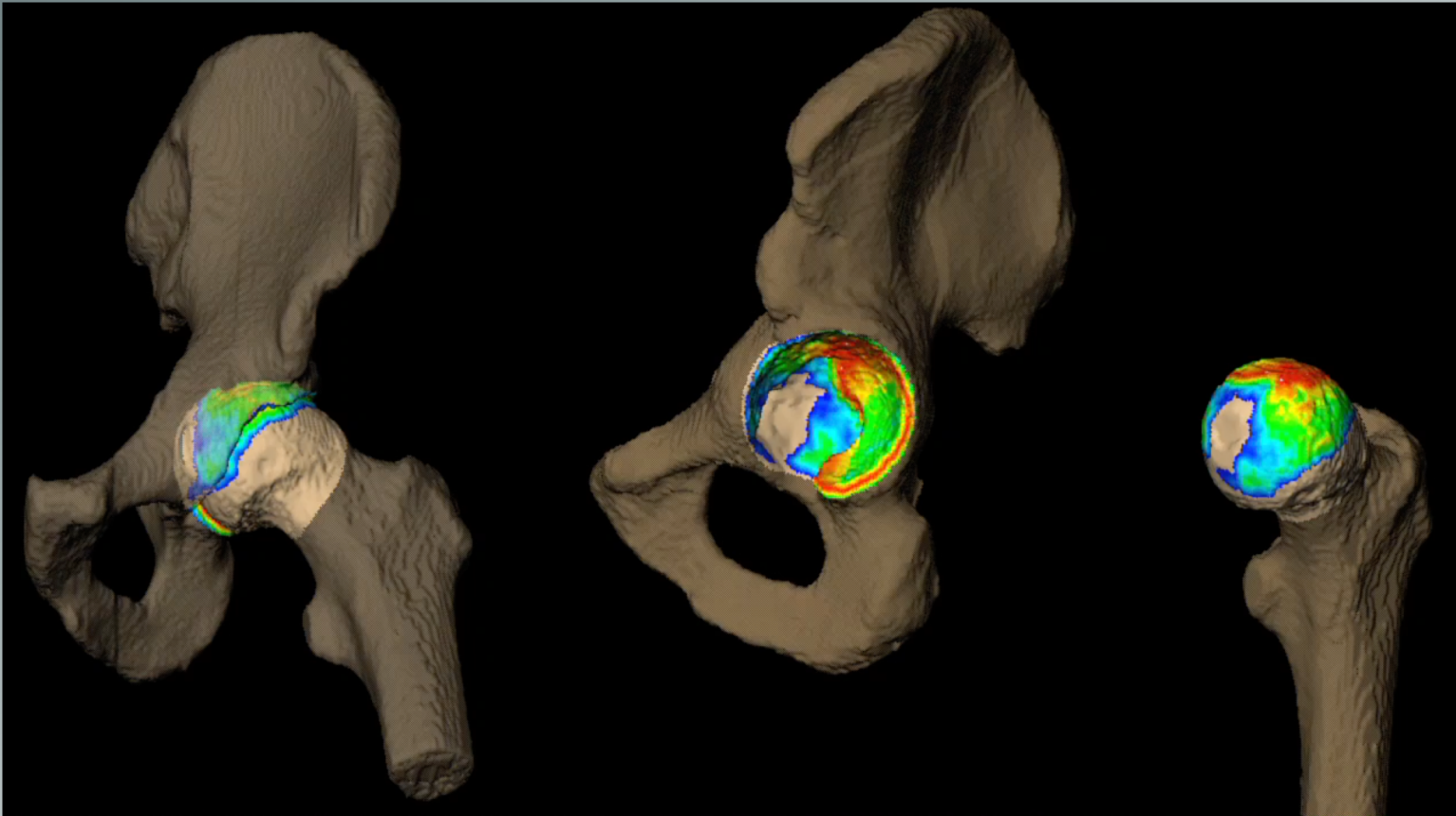
Contact algorithm



Cartilage deformation

Application: hip disorders

- Visualizing hip impingement
- Identifying patients at risk for hip problems



Dr. Marc
Philippon

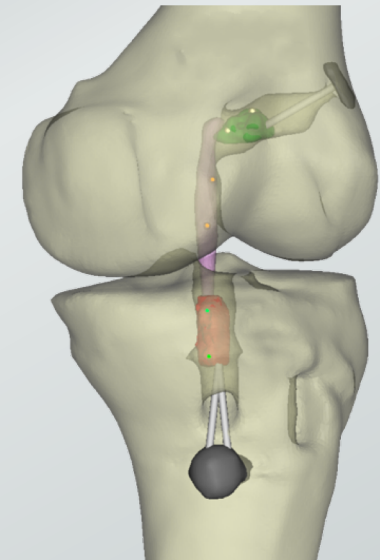
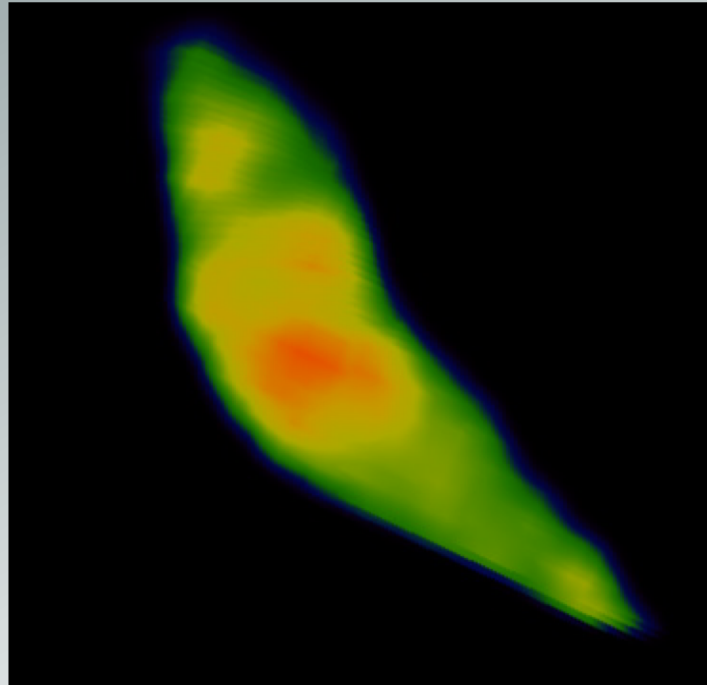
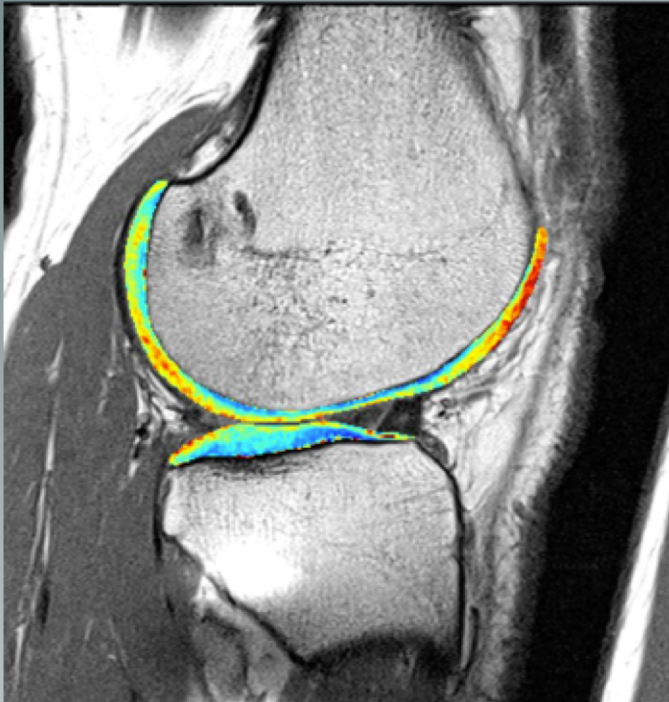


Application: knee ligament injury

- Latest-technology 3T MRI and CT
- T2 mapping for assessing cartilage health
- Ultra-short echo (UTE) imaging for evaluating tendon/ligament healing



Dr's Millett & Provencher

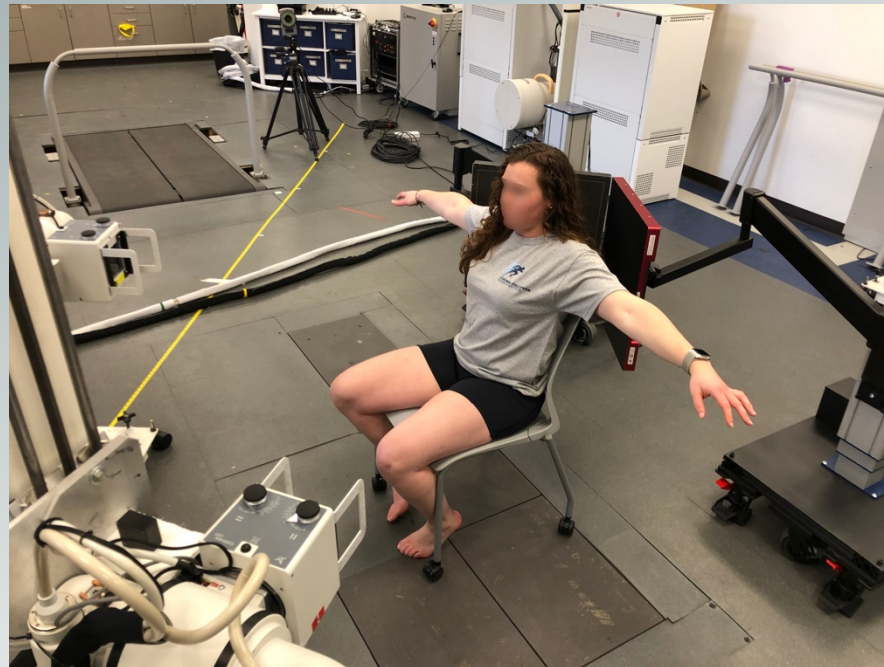
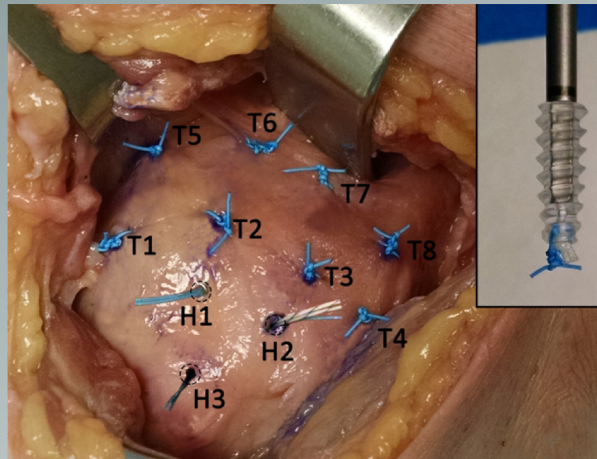
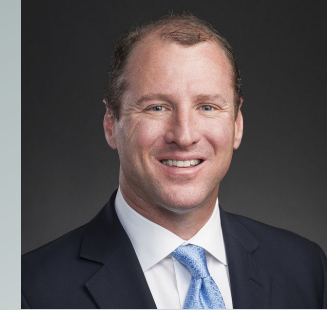
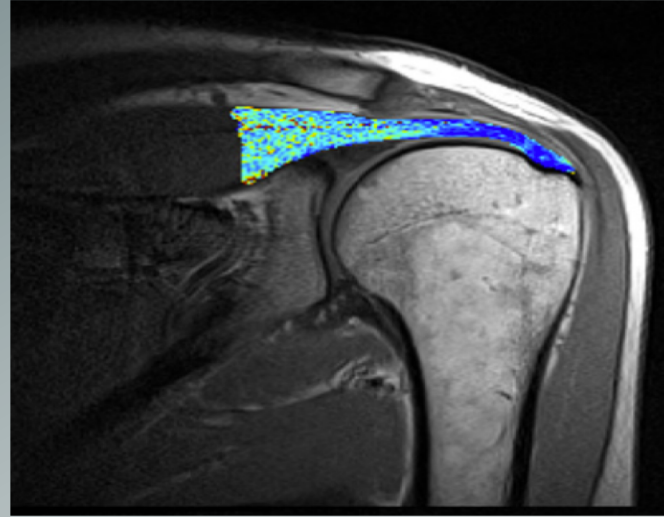


Application: Rotator cuff injury/repair

Advanced MRI: DWI, T2, UTE

Dynamic functional assessment
of glenohumeral motion

Tracking of soft tissue
displacement

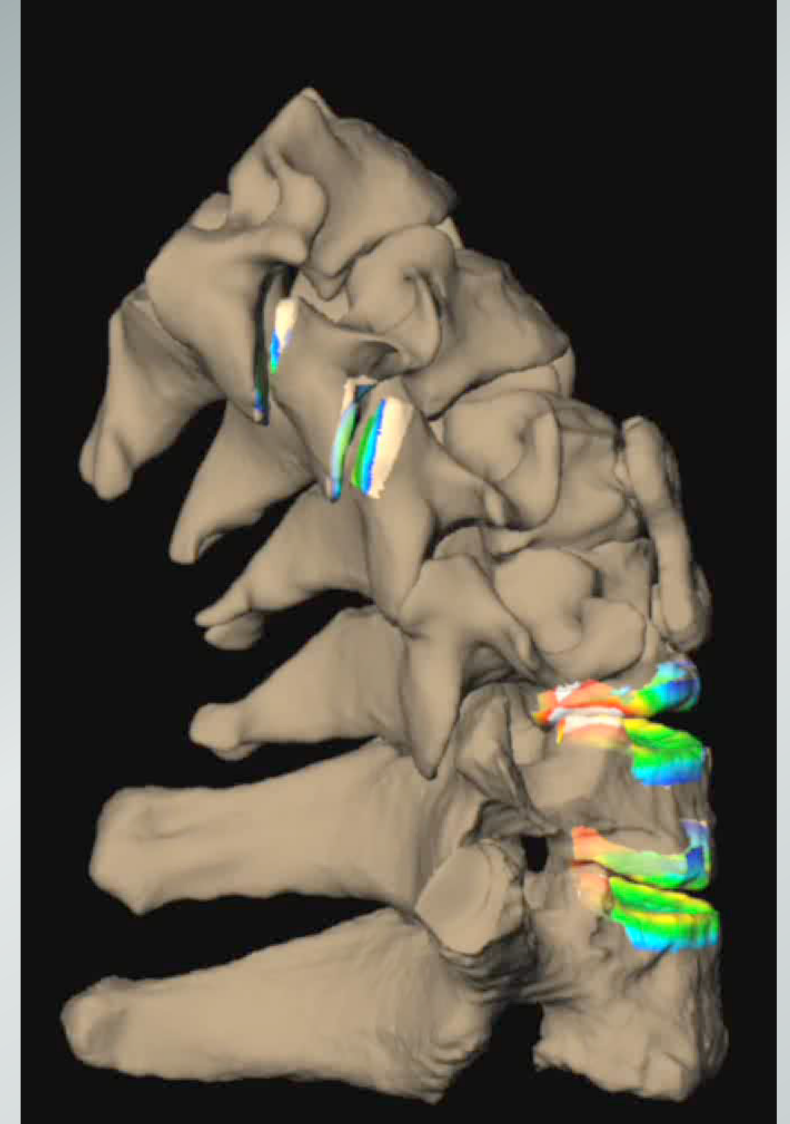
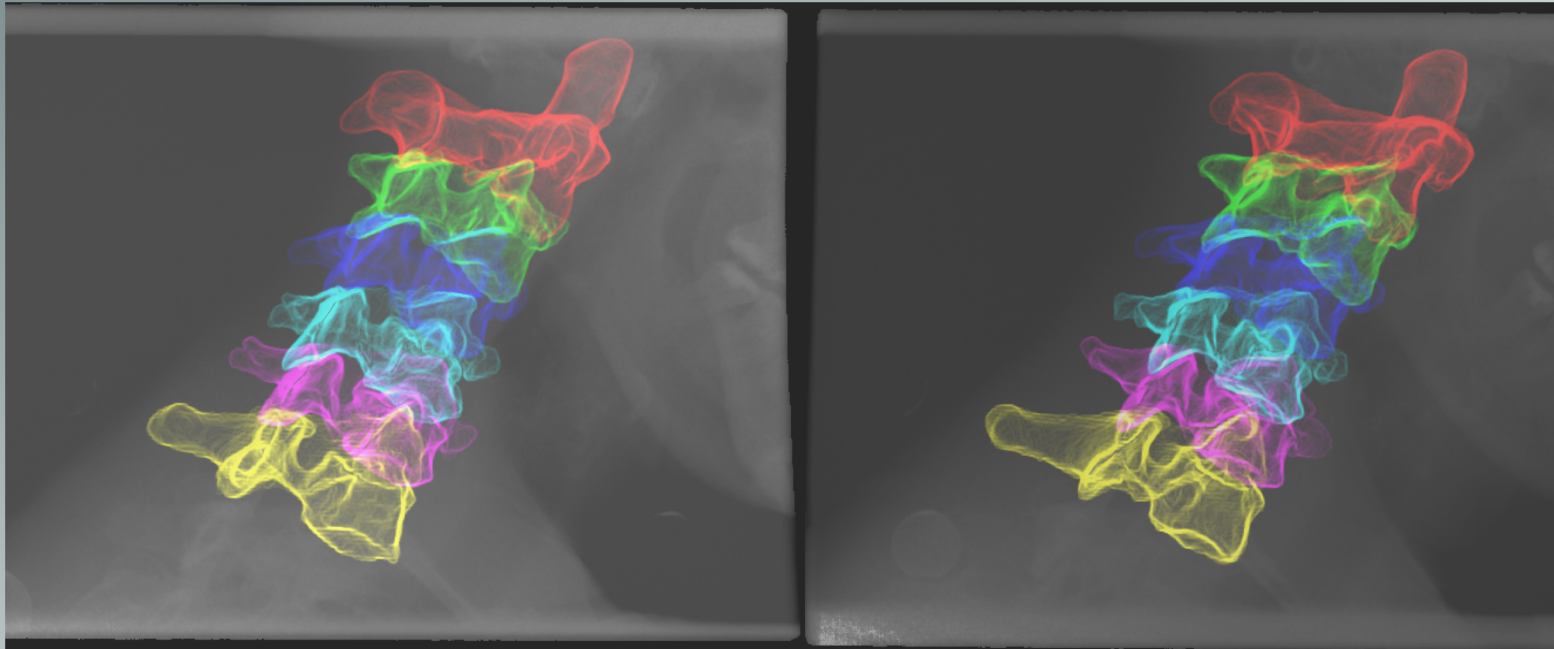


Application: spine disorders



Dr. Sonny Gill

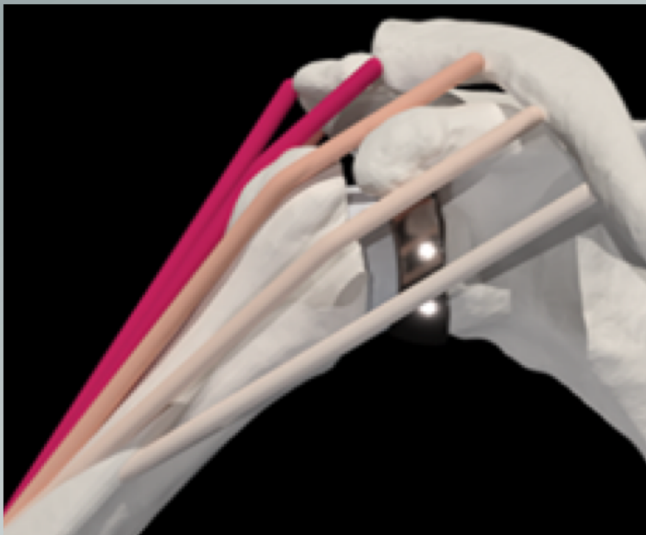
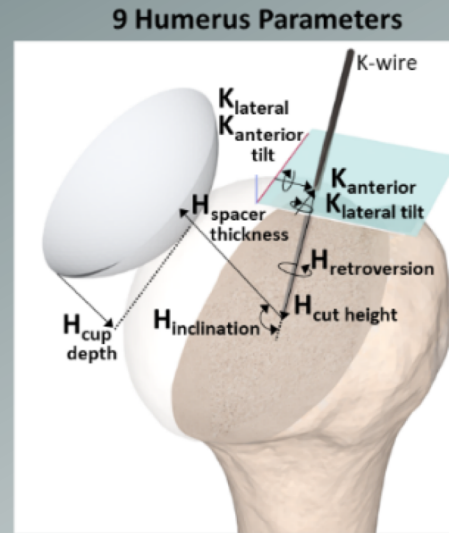
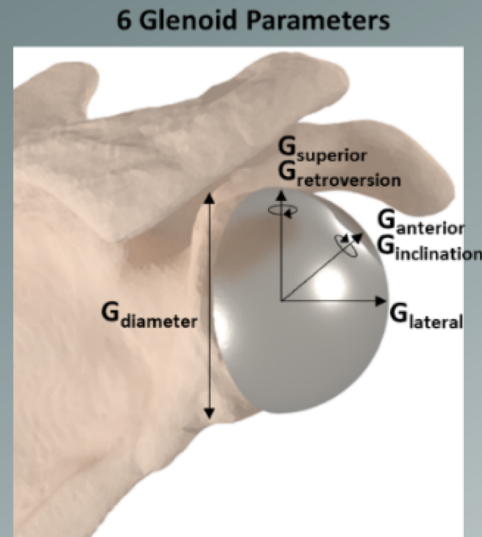
- Disc degeneration/fusion
- Low back pain



Computational Modeling

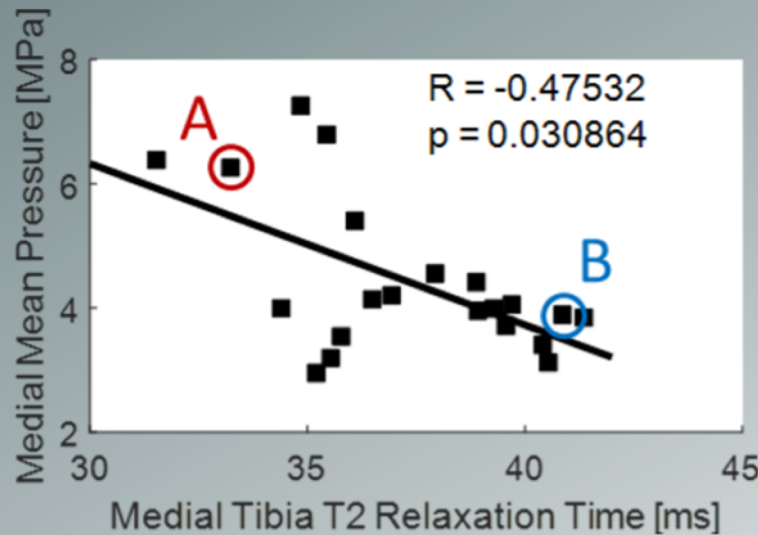
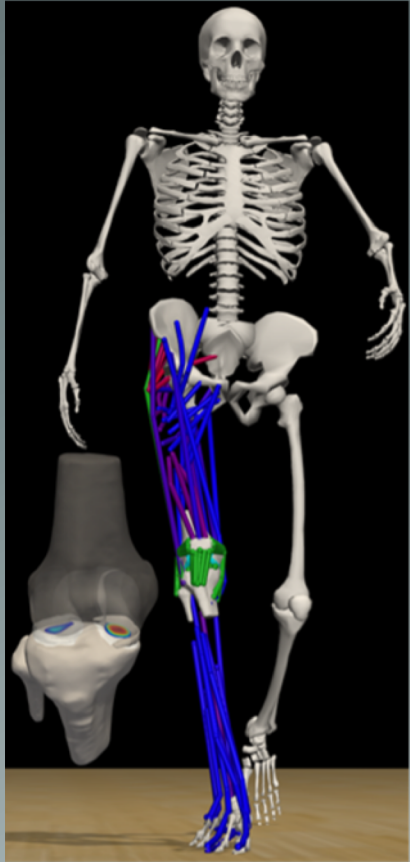


Colin Smith, PhD

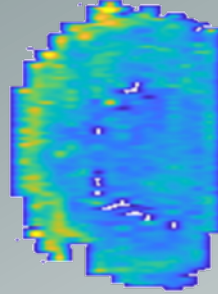


- Going beyond experimental data
- Simulation of treatment outcomes
- Optimized, personalized treatment planning

Modeling knee loading for osteoarthritis progression

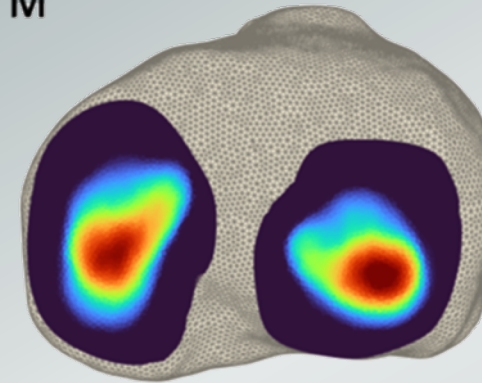


Example Subject A
Lower Medial T2

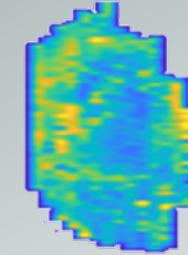


Higher Medial Pressure

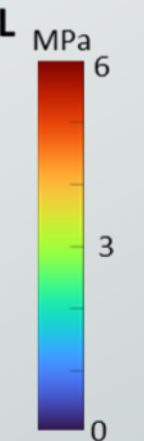
M



Example Subject B
Higher Medial T2



Lower Medial Pressure



Loading predictions correlated with MRI joint health

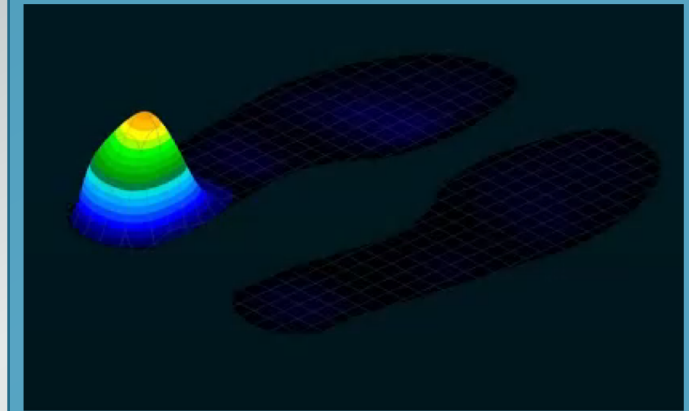
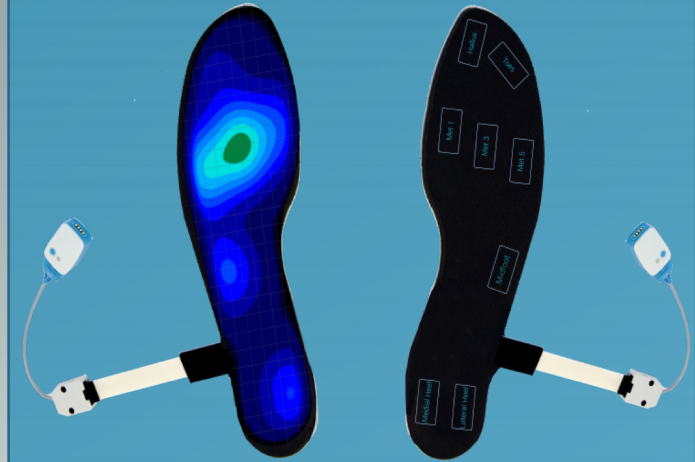
Wearable sensor technologies for studies in the field



EMG (muscle function)



IMU (motion)



Force/pressure

Ski injury reduction



Dr. Tom Hackett

SKI
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The confounding ACL Epidemic in Female Skiers

Women account for 60% of ACL injuries. The question is why?

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2017



PROGRAM GOALS:

- Optimizing equipment to improve skier balance and control
- Reduce falls & associated injuries



Golf Sports Medicine Program



Steve Atherton
PGA Master
Golf Pro

PROGRAM GOALS:

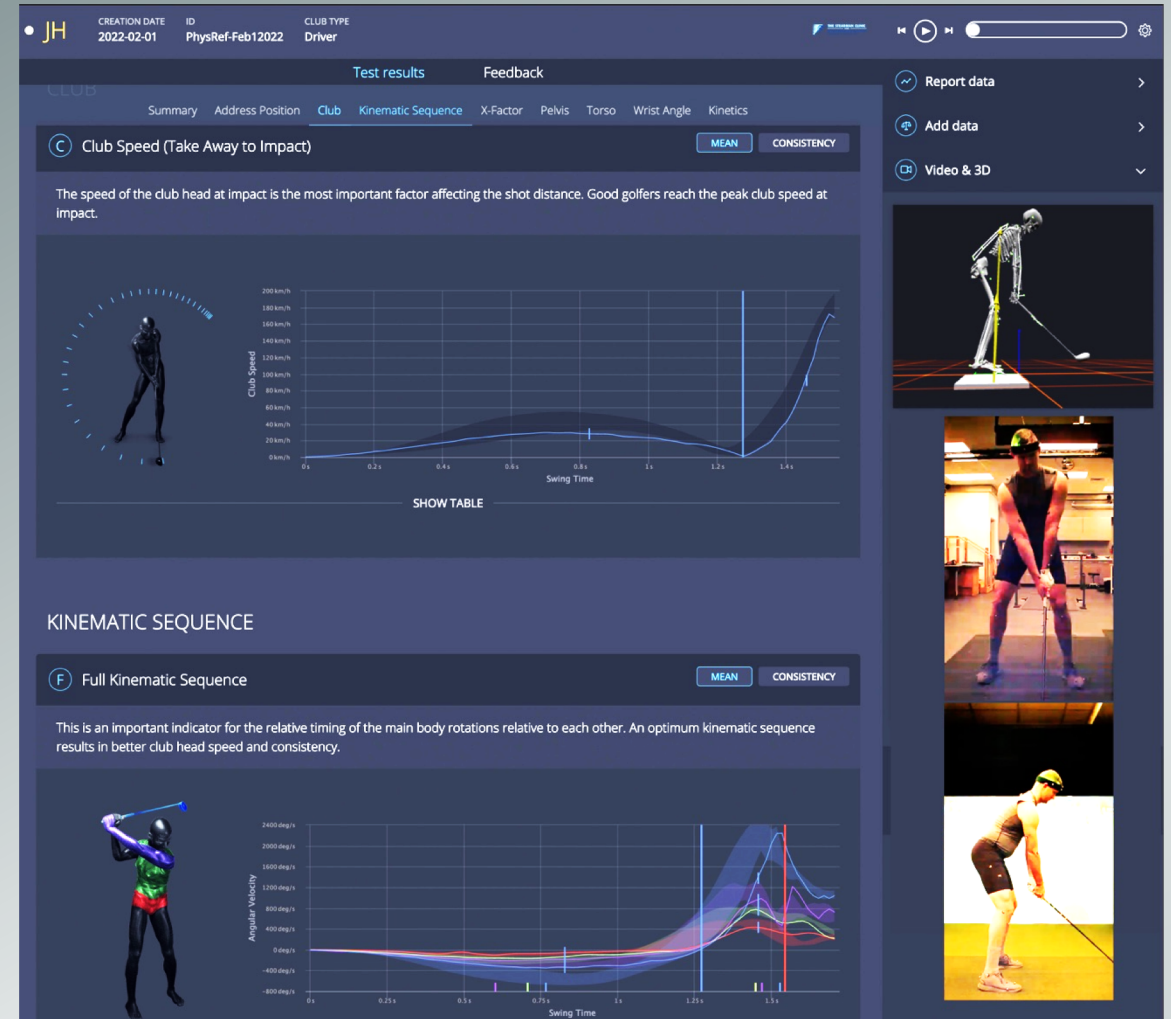
- Accelerate return-to-play after injury or surgery
- Optimize performance while minimizing injury or re-injury risk
- Help golfers at all skill levels improve their game



Unique combination of golf, biomechanics and orthopaedic expertise

Current Golf Studies: Shoulder surgery, hip arthroscopy, low back pain

Golf Analysis



Comprehensive, accurate 3D assessment and golf-specific reporting

Summary: SPRI Bioengineering

- One of the most well-equipped Biomotion labs in the world
- Cutting-edge medical imaging
- Extensive engineering expertise

These tools and techniques are ideal for comprehensive evaluation of orthopaedic and regenerative medicine treatments

SPRI's goal, working with TSC surgeons, is not only to develop the most advanced therapies but also to provide definitive evidence of their efficacy for improving musculoskeletal health





THE STEADMAN CLINIC
AND
STEADMAN PHILIPPON RESEARCH INSTITUTE



U.S. OLYMPIC
NATIONAL
MEDICAL CENTER