Managing The Risk of Osteoarthritis Following ACL Injury

Brian Pietrosimone PHD ATC
Director, MOTION Science Institute
Associate Professor, Exercise and Sport Science

UNC | COLLEGE OF ARTS AND SCIENCES
Exercise and Sport Science

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Main Points for Today

- **Understand Risk** of Posttraumatic Osteoarthritis (PTOA) following ACL Injury

- **Detect Risk** of PTOA in patients with an ACL Injury

- **Manage Risk** of PTOA in patients with an ACL Injury

Understand – Detect – Manage

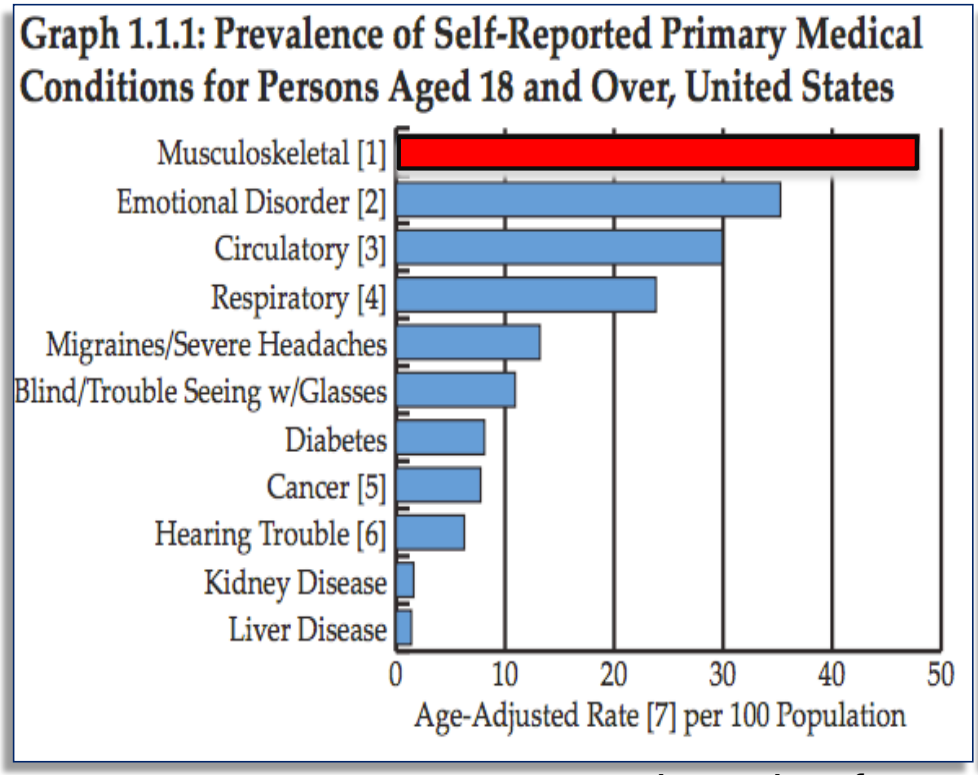
Understanding the Risk

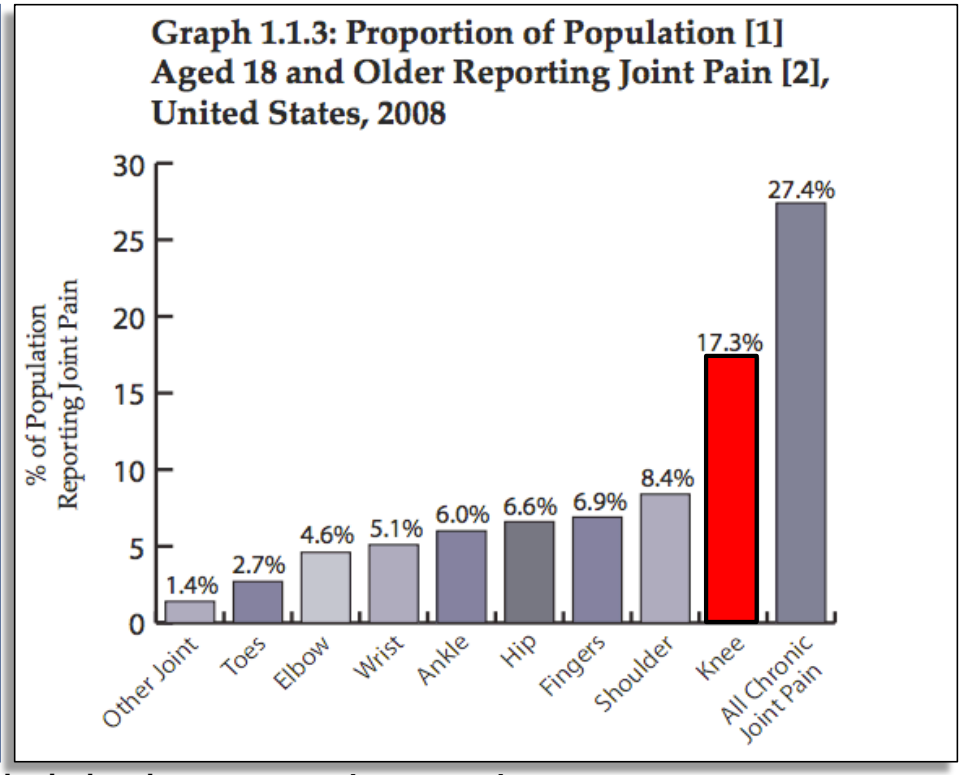
Question #1

Why Should Clinicians, who Treat ACL injuries, Care About Knee Osteoarthritis (OA)?

- OA is a Major Healthcare Concern
- OA is the Consequence of Traumatic Knee Injury
- You are likely Already Treating Early OA

The Burden of Musculoskeletal Disease





The Burden of Musculoskeletal Disease in the United States. Bone and Joint Initiative. 2008

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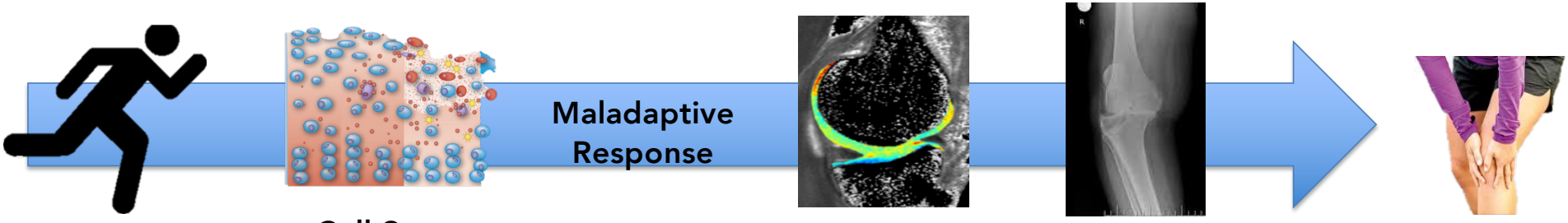
What is Arthritis

- Reactive Arthritis
- Septic Arthritis
- Psoriatic Arthritis
- Gout
- Rheumatoid Arthritis
- Osteoarthritis

Over 100 Different Types of Arthritis

Osteoarthritis



Moveable Joints

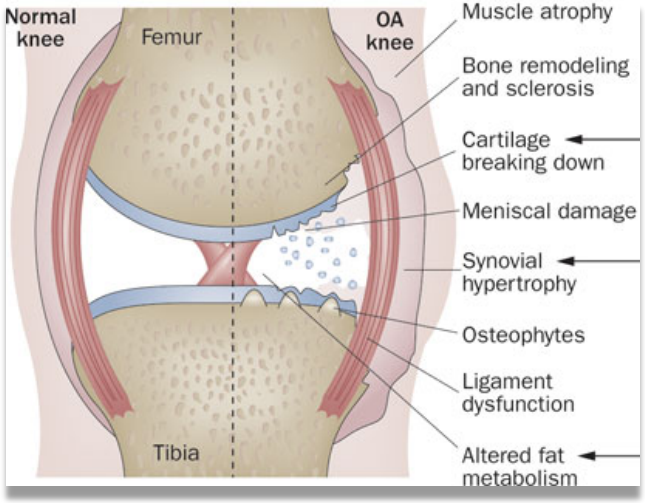
Cell Stress Caused Trauma

Abnormal Tissue Response

Anatomical Changes

Illness

Adapted from OARSI Definition



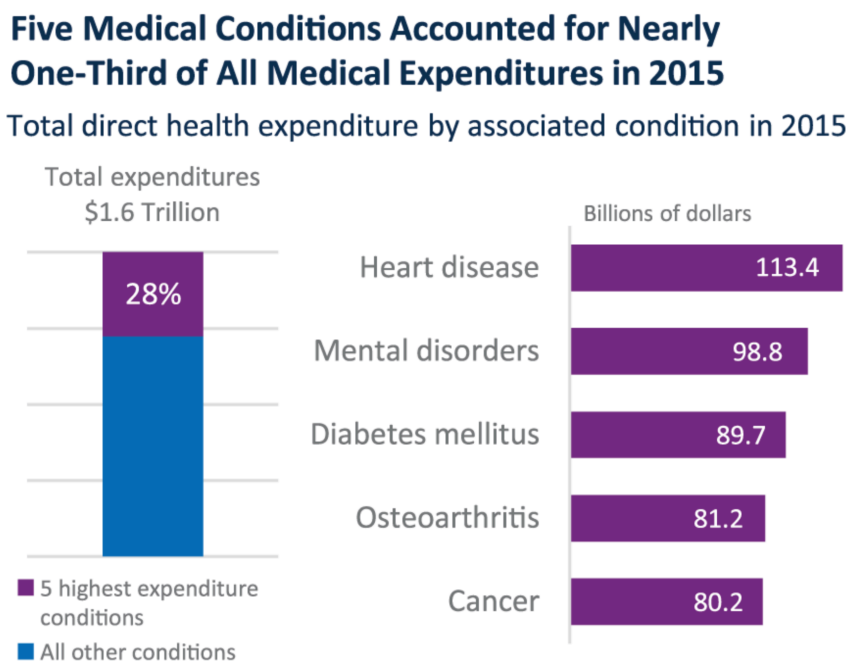
Hunter. *Nat. Rev. Rheumatol. 2010*

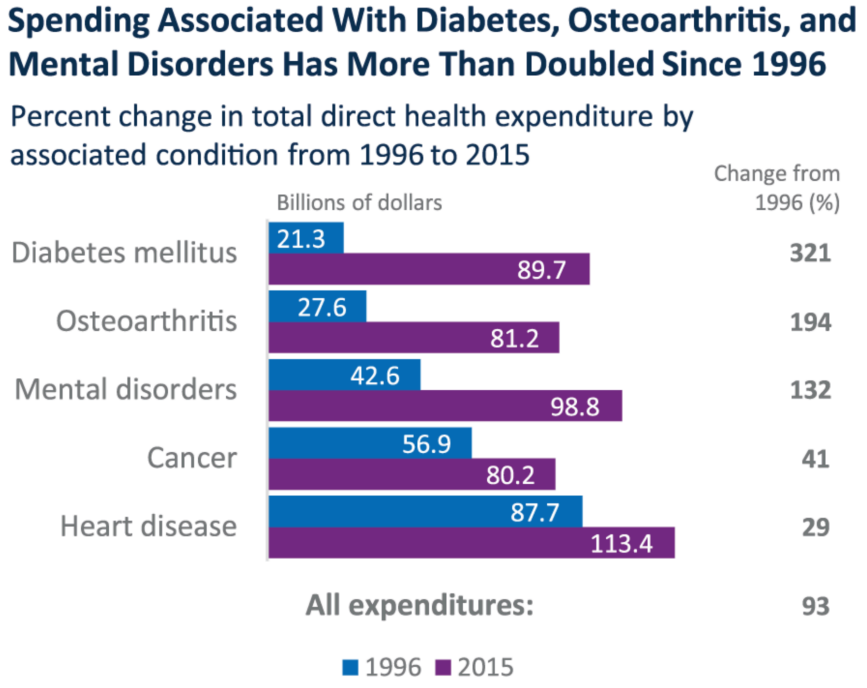
Multiple Tissues Involved

- Bone
- Cartilage
- Synovia
- Fat Pad
- Meniscus
- Ligaments

Many Unique Pathways to Onset & Progression

The Cost of Osteoarthritis





Biener et al. JAMA. 2019

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Knee Osteoarthritis by the Numbers

11th Leading Cause of Disability Worldwide

Cross et al. Ann Rheum Dis. 2014

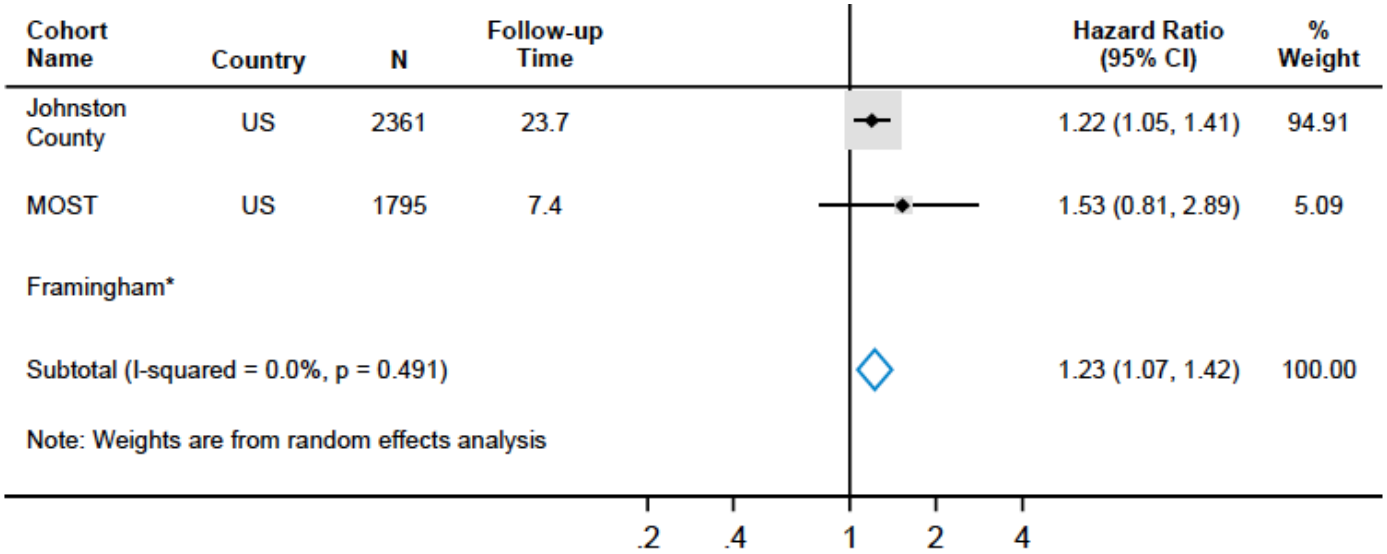
4.9% of US Population with Symptomatic Knee OA

Murphy and Helmick. Am J Nurs. 2012

55 Median Age of Knee OA

Losina et al. Arthritis Care Res. 2013

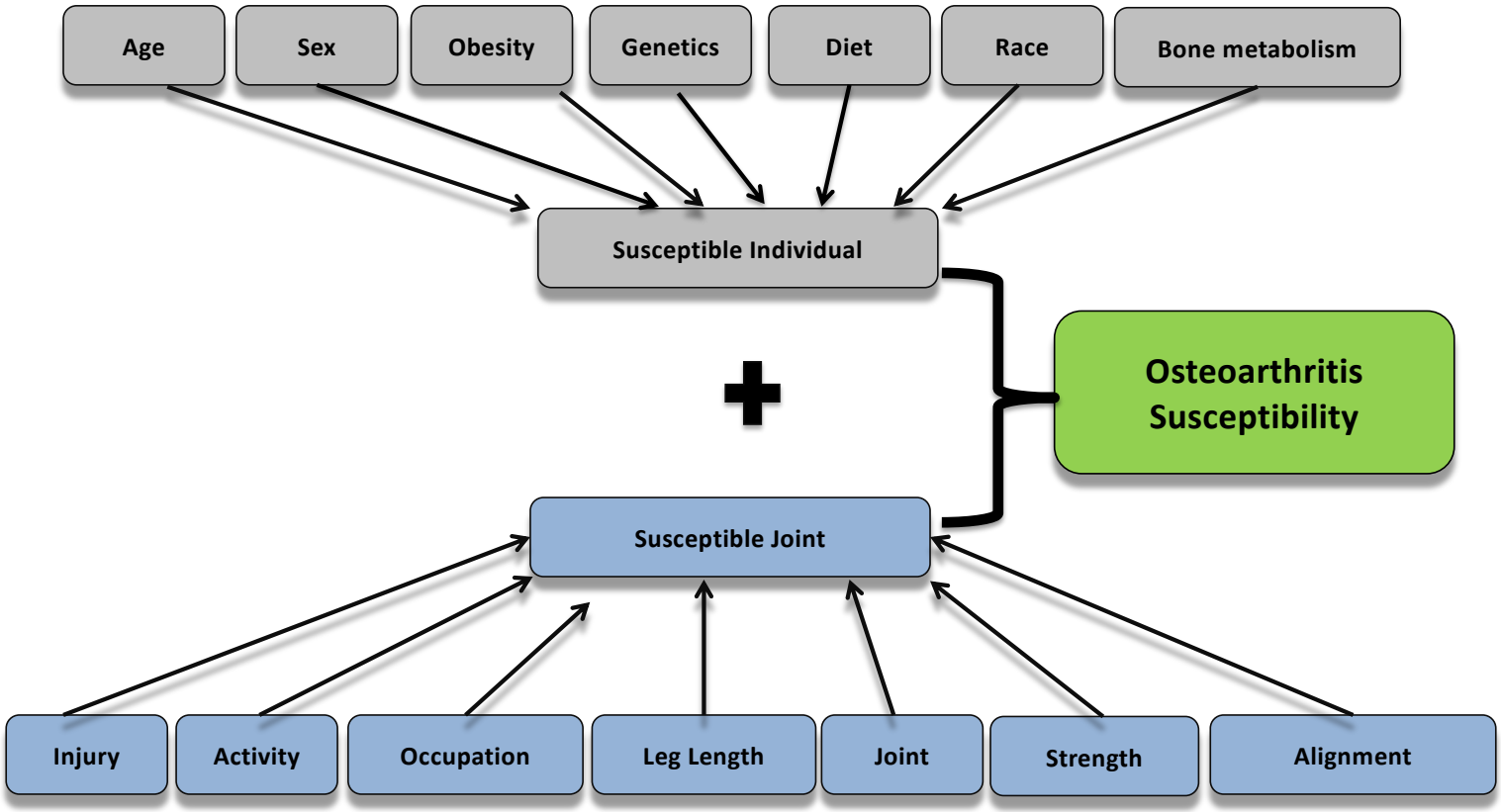
Knee Osteoarthritis & Mortality



- Symptomatic & Radiographic Knee OA compared to No Pain and Radiographic Knee OA
- After Adjusting for Age, Sex, Race
- 23% Increased Risk of Premature Death

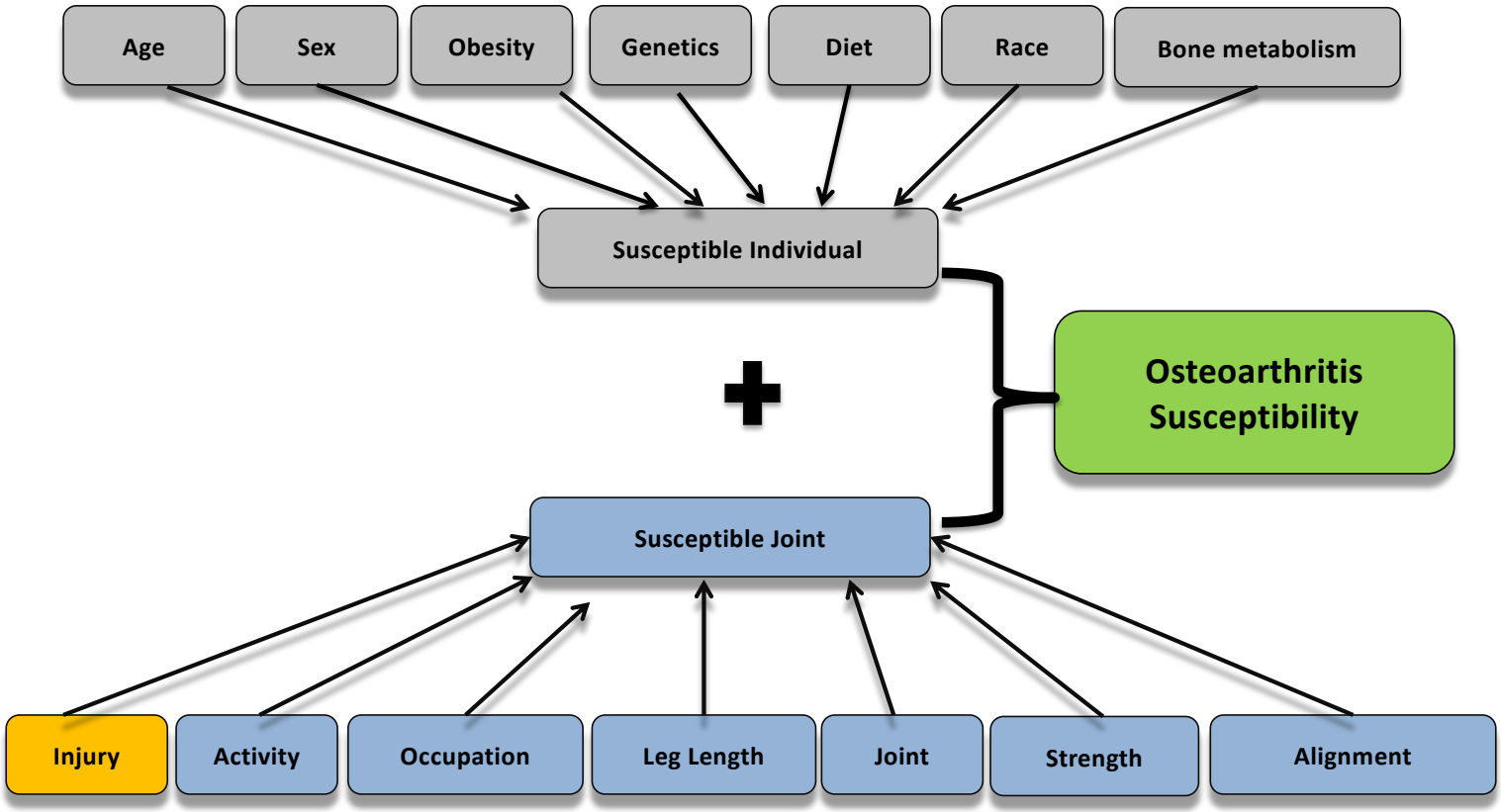
OARSI. Osteoarthritis: A Serious Disease. Submitted to US FDA 2016

Risk Factors



Neogi and Zhang. Epidemiology of Osteoarthritis. 2013

Risk Factors



Neogi and Zhang. Epidemiology of Osteoarthritis. 2013

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Posttraumatic Osteoarthritis

12 % of OA Cases Occur Following Injury

Brown et al. J Ortho Trauma. 2012

35 % of OA Cases in Military Population

Cameron et al. OARSI. 2017

Knee Injury Common Between Ages 16 – 24

Parkkari et al. BJSM. 2008

PTOA Causes More Disability

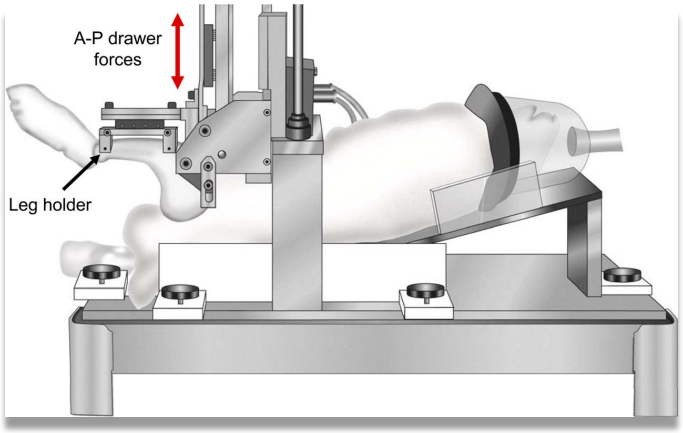
Ackerman et al. Osteoarthritis & Cartilage. 2015

Worse Outcomes Following Joint Replacement

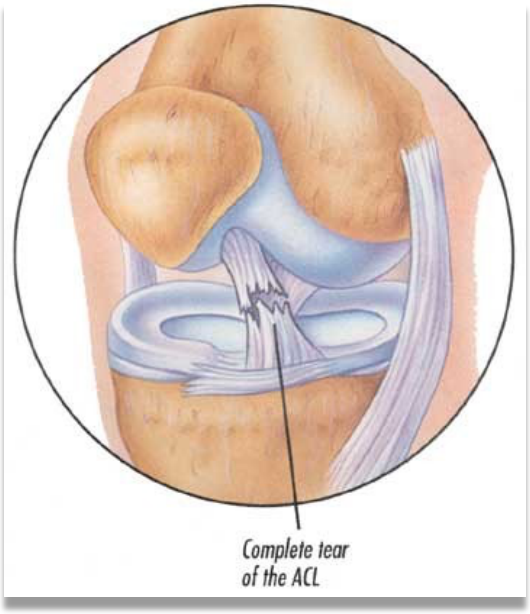
Lonner et al. J Arthroplasty. 1999

Weiss et al. J Arthroplasty. 2003

ACL Injury: A Model for PTOA



Tochigi et al. JB&JS. 2011



Incidence of ACL Injury

Annual Incidence

68.6 / 100,000 person-years

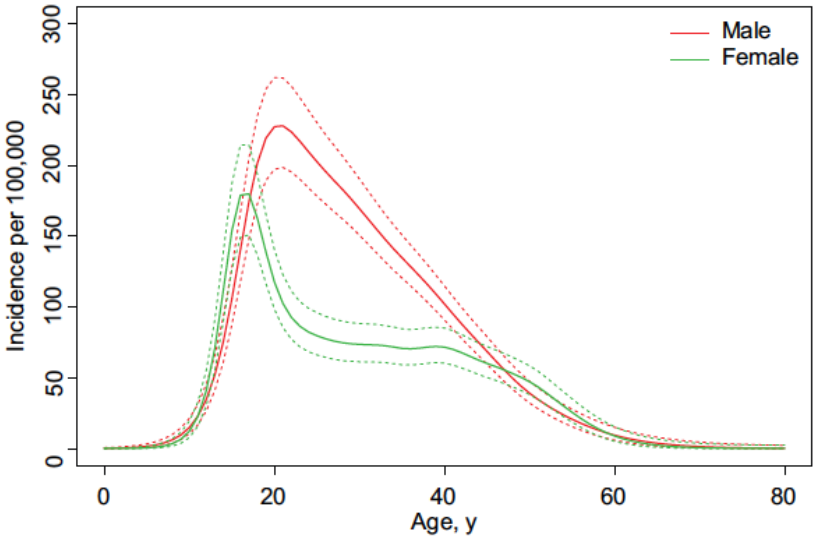
- Males 81.7
- Females 55.3

High Incidence in Youth

- Females 14-18 yo = 227.6
- Males 19-25 yo =241

ACL Reconstruction

- 75% Reconstructed 2005-2010
- 98.3% under the age of 18



Population Study - Olmsted Co , MN

144, 260 Individuals in 2010

January 1990 – December 2010

Sanders et al. AJSM. 2016

Goals of ACL Reconstruction

3-17 % sustain a re-rupture of the ACL Graft

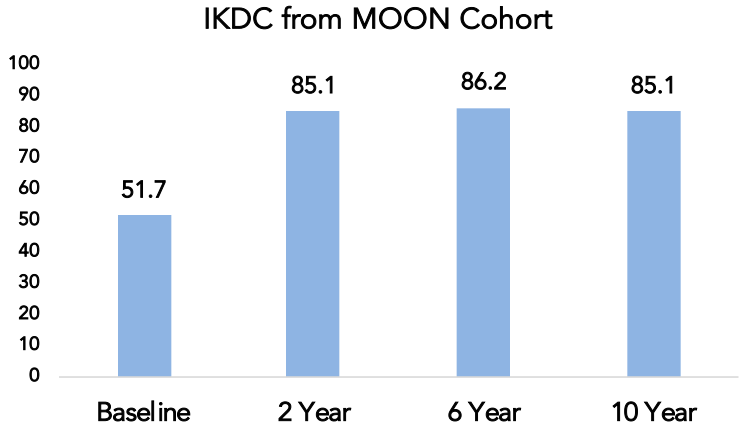
Wright RW. Am J Sports Med. 2011
Shelbourne et al. Am J Sports Med. 2009
Salmon et al. Arthroscopy. 2005

82% Return to Physical Activity
63% Return to Pre- Injury Status

Ardern et al. Br J Sports Med. 2011

Long-Term Consequence of ACL Injury

Persistent Symptoms

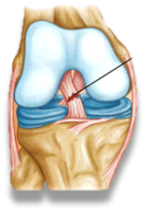


Spindler et al. Am J Sports Med. 2018

Posttraumatic Osteoarthritis

ACL Reconstructed
n= 2500

Decade 1 36% **Decade 2** 48%



ACL Deficient
n= 337

Decade 1 34%

Luc & Pietrosimone et al. J Athl Train. 2014

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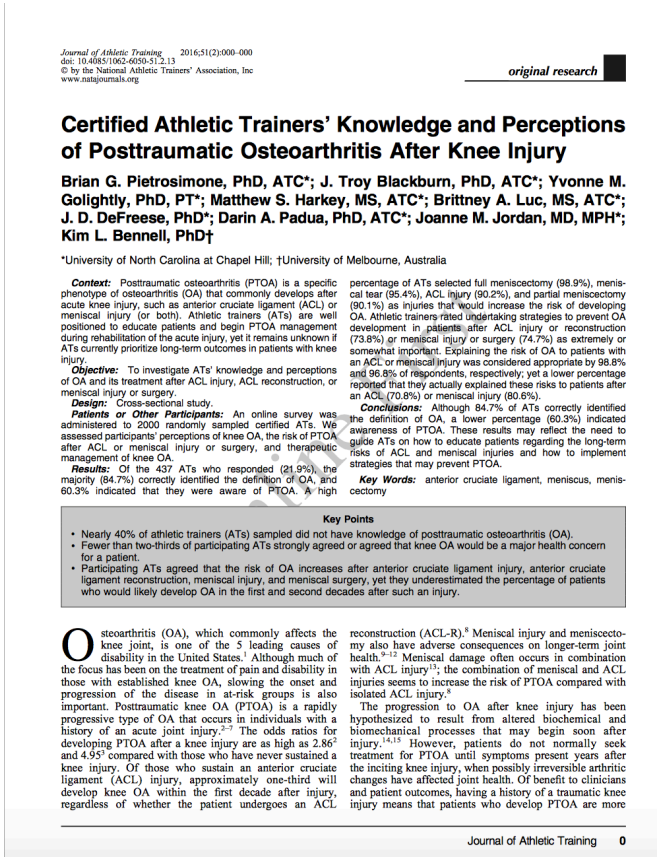
Perception of Posttraumatic OA



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www.natajournals.org

original research

Certified Athletic Trainers' Knowledge and Perceptions of Posttraumatic Osteoarthritis After Knee Injury

Brian G. Pietrosimone, PhD, ATC*; J. Troy Blackburn, PhD, ATC*; Yvonne M. Golightly, PhD, PT*; Matthew S. Harkey, MS, ATC*; Brittney A. Luc, MS, ATC*; J. D. DeFreese, PhD*; Darin A. Padua, PhD, ATC*; Joanne M. Jordan, MD, MPH*; Kim L. Bennell, PhD†

*University of North Carolina at Chapel Hill; †University of Melbourne, Australia

Context: Posttraumatic osteoarthritis (PTOA) is a specific phenotype of osteoarthritis (OA) that commonly develops after acute knee injury, such as anterior cruciate ligament (ACL) or meniscal injury (or both). Athletic trainers (ATs) are well positioned to educate patients and begin PTOA management during rehabilitation of the acute injury, yet it remains unknown if ATs currently prioritize long-term outcomes in patients with knee injury.

Objective: To investigate ATs' knowledge and perceptions of OA and its treatment after ACL injury, ACL reconstruction, or meniscal injury or surgery.

Design: Cross-sectional study.

Patients or Other Participants: An online survey was administered to 2000 randomly sampled certified ATs. We assessed participants' perceptions of knee OA, the risk of PTOA after ACL or meniscal injury or surgery, and therapeutic management of knee OA.

Results: Of the 437 ATs who responded (21.9%), the majority (84.7%) correctly identified the definition of OA, and 60.3% indicated that they were aware of PTOA. A high percentage of ATs selected full meniscectomy (98.9%), meniscal tear (95.4%), ACL injury (90.2%), and partial meniscectomy (90.1%) as injuries that would increase the risk of developing OA. Athletic trainers rated undertaking strategies to prevent OA development in patients after ACL injury or reconstruction (73.8%) or meniscal injury or surgery (74.7%) as extremely or somewhat important. Explaining the risk of OA to patients with an ACL or meniscal injury was considered appropriate by 98.8% and 96.8% of respondents, respectively; yet a lower percentage reported that they actually explained these risks to patients after an ACL (70.8%) or meniscal injury (80.6%).

Conclusions: Although 84.7% of ATs correctly identified the definition of OA, a lower percentage (60.3%) indicated awareness of PTOA. These results may reflect the need to guide ATs on how to educate patients regarding the long-term risks of ACL and meniscal injuries and how to implement strategies that may prevent PTOA.

Key Words: anterior cruciate ligament, meniscus, meniscectomy

Key Points

- Nearly 40% of athletic trainers (ATs) sampled did not have knowledge of posttraumatic osteoarthritis (OA).
- Fewer than two-thirds of participating ATs strongly agreed or agreed that knee OA would be a major health concern for a patient.
- Participating ATs agreed that the risk of OA increases after anterior cruciate ligament injury, anterior cruciate ligament reconstruction, meniscal injury, and meniscal surgery, yet they underestimated the percentage of patients who would likely develop OA in the first and second decades after such an injury.

Osteoarthritis (OA), which commonly affects the knee joint, is one of the 5 leading causes of disability in the United States.[1] Although much of the focus has been on the treatment of pain and disability in those with established knee OA, slowing the onset and progression of the disease in at-risk groups is also important. Posttraumatic knee OA (PTOA) is a rapidly progressive type of OA that occurs in individuals with a history of an acute joint injury.[2–7] The odds ratios for developing PTOA after a knee injury are as high as 2.86[2] and 4.95[3] compared with those who have never sustained a knee injury. Of those who sustain an anterior cruciate ligament (ACL) injury, approximately one-third will develop knee OA within the first decade after injury, regardless of whether the patient undergoes an ACL reconstruction (ACL-R).[8] Meniscal injury and meniscectomy also have adverse consequences on longer-term joint health.[9–12] Meniscal damage often occurs in combination with ACL injury[13]; the combination of meniscal and ACL injuries seems to increase the risk of PTOA compared with isolated ACL injury.[5]

The progression to OA after knee injury has been hypothesized to result from altered biochemical and biomechanical processes that may begin soon after injury.[14,15] However, patients do not normally seek treatment for PTOA until symptoms present years after the inciting knee injury, when possibly irreversible arthritic changes have affected joint health. Of benefit to clinicians and patient outcomes, having a history of a traumatic knee injury means that patients who develop PTOA are more

40% of ATs unaware of PTOA

37% OA not Major Health Concern

<u>Underestimated Prevalence</u>

of PTOA in 1st Decade Post ACLR

<u>Overestimated the Benefit</u>

of ACLR in Reducing PTOA

Pietrosimone et al. J Ath Train. 2017

Impact of Clinical Experience

Awareness of Post-Traumatic Osteoarthritis and Perceptions Change with Experience					
Years of ATC Experience	**1-5**	**6-10**	**11-15**	**16-20**	**21+**
Aware of PTOA	53%	54%	52%	69%	75%
Explain Risk of OA	60%	76%	73%	77%	80%
Provide Preventive Strategies to patients	58%	76%	71%	77%	81%

Standard of Care

What Factors Lead to Early PTOA?

How Can we Manage Early PTOA?

Day 1	Day 2- 9 Months	9 Months – 10 years	10 Years
			
ACL Injury	ACLR & Rehab	Physical Activity	Knee OA

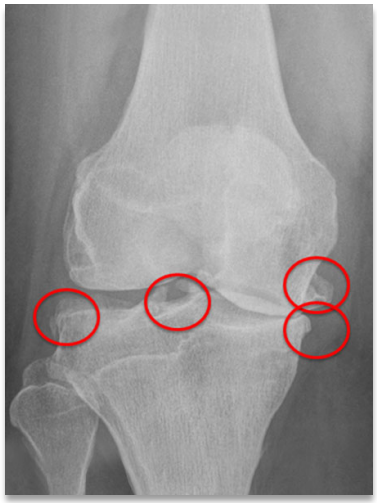
Detection of the Risk

Question #2

How can Clinicians begin to Identify Patients at Risk for PTOA?

- Traditional Methods are not Sensitive for Detecting PTOA
- Serial Assessments of Symptoms
- Use of Emerging Techniques

Detecting OA Too Little, Too Late



Osteopytes
Joint Space Narrowing

Kellgren and Lawrence. Ann Rheum Dis. 1957

Radiographic Changes Post-ACL

Radiographic Changes at 4 Years

N=39

Preoperative – Within 3 Weeks of Surgery

Follow up- 46 (SD 9) Months Post Surgery

Signs of Early PTOA?

31.6% ACLR demonstrated abnormal JSN

Inter-limb Differences

Lateral compartment = **5.4mm**

Controls Between Limb Difference **-0.01mm**

ACL Between Limb Difference - **0.32mm**

Tourville et al. AJSM. 2013

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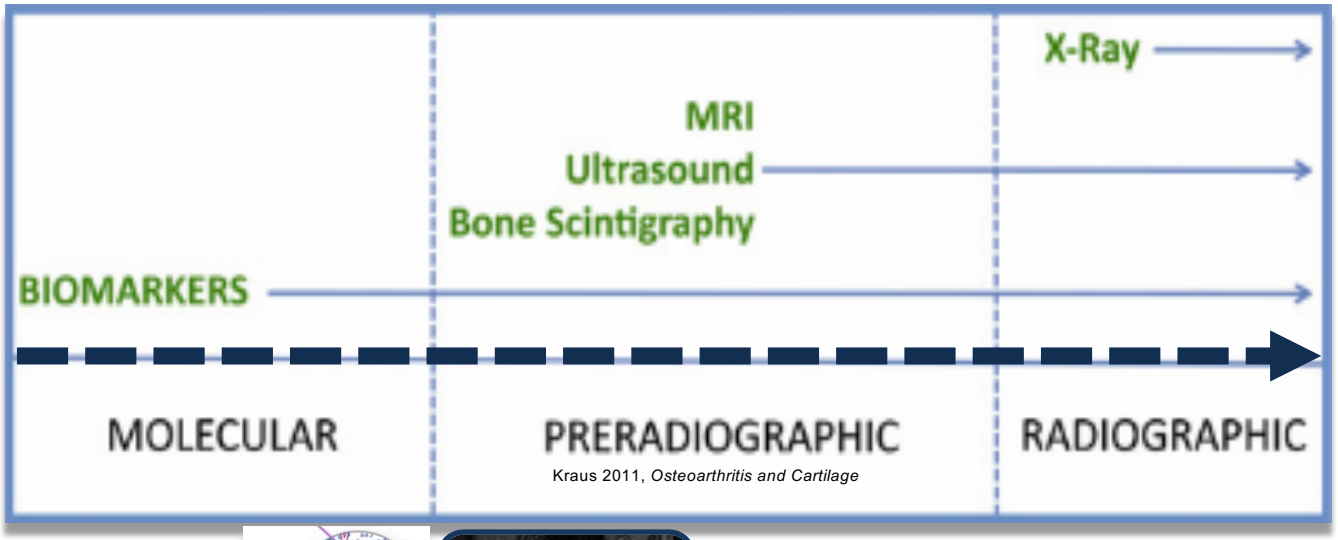
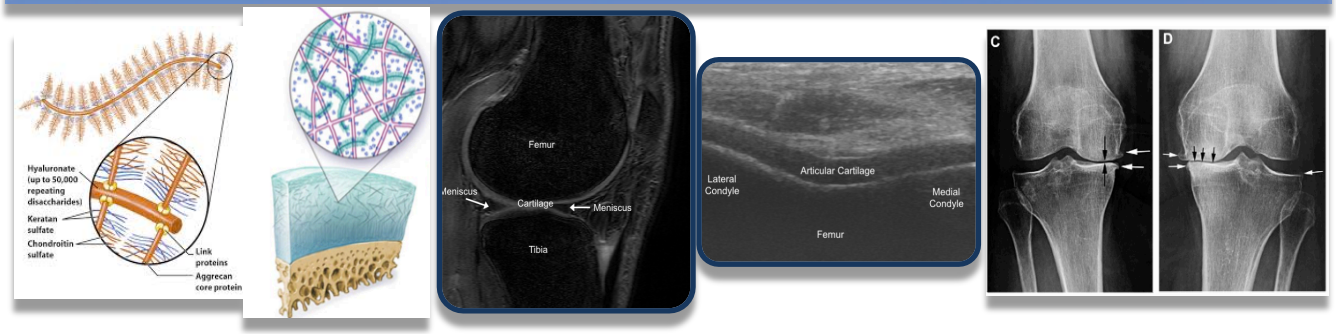
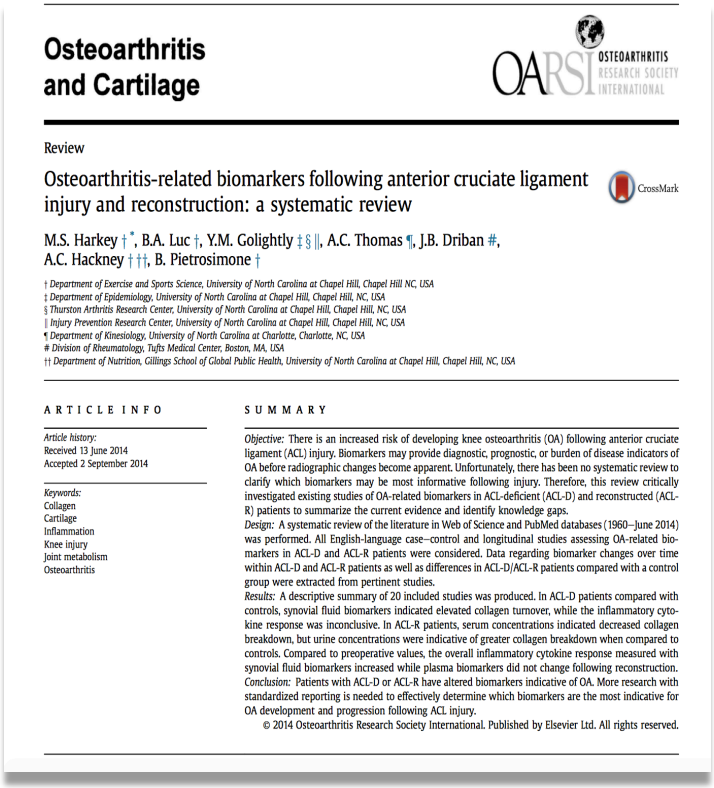
Detect Early Joint Changes



Kraus 2011, *Osteoarthritis and Cartilage*



Fluid Biomarkers & ACL Injury



Osteoarthritis and Cartilage

OARSI OSTEOARTHRITIS RESEARCH SOCIETY INTERNATIONAL

Review

Osteoarthritis-related biomarkers following anterior cruciate ligament injury and reconstruction: a systematic review

M.S. Harkey †,*, B.A. Luc †, Y.M. Golightly ‡,§,||, A.C. Thomas ¶, J.B. Driban #, A.C. Hackney †,††, B. Pietrosimone †

† *Department of Exercise and Sports Science, University of North Carolina at Chapel Hill, Chapel Hill NC, USA*
‡ *Department of Epidemiology, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA*
§ *Thurston Arthritis Research Center, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA*
|| *Injury Prevention Research Center, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA*
¶ *Department of Kinesiology, University of North Carolina at Charlotte, Charlotte, NC, USA*
# *Division of Rheumatology, Tufts Medical Center, Boston, MA, USA*
†† *Department of Nutrition, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA*

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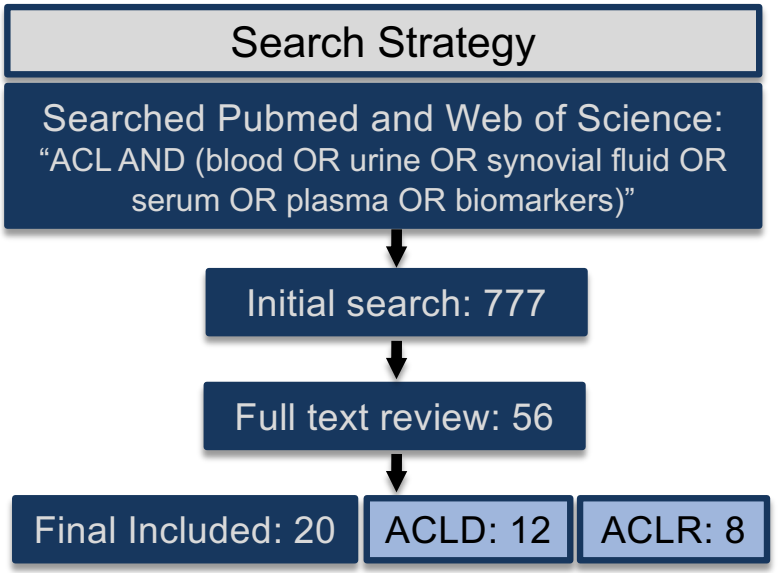
SUMMARY

Objective: There is an increased risk of developing knee osteoarthritis (OA) following anterior cruciate ligament (ACL) injury. Biomarkers may provide diagnostic, prognostic, or burden of disease indicators of OA before radiographic changes become apparent. Unfortunately, there has been no systematic review to clarify which biomarkers may be most informative following injury. Therefore, this review critically investigated existing studies of OA-related biomarkers in ACL-deficient (ACL-D) and reconstructed (ACL-R) patients to summarize the current evidence and identify knowledge gaps.

Design: A systematic review of the literature in Web of Science and PubMed databases (1960–June 2014) was performed. All English-language case–control and longitudinal studies assessing OA-related biomarkers in ACL-D and ACL-R patients were considered. Data regarding biomarker changes over time within ACL-D and ACL-R patients as well as differences in ACL-D/ACL-R patients compared with a control group were extracted from pertinent studies.

Results: A descriptive summary of 20 included studies was produced. In ACL-D patients compared with controls, synovial fluid biomarkers indicated elevated collagen turnover, while the inflammatory cytokine response was inconclusive. In ACL-R patients, serum concentrations indicated decreased collagen breakdown, but urine concentrations were indicative of greater collagen breakdown when compared to controls. Compared to preoperative values, the overall inflammatory cytokine response measured with synovial fluid biomarkers increased while plasma biomarkers did not change following reconstruction.

Conclusion: Patients with ACL-D or ACL-R have altered biomarkers indicative of OA. More research with standardized reporting is needed to effectively determine which biomarkers are the most indicative for OA development and progression following ACL injury.



Harkey & Pietrosimone et al. *Osteoarthritis and Cartilage*. 2015

Changes in Cartilage Composition

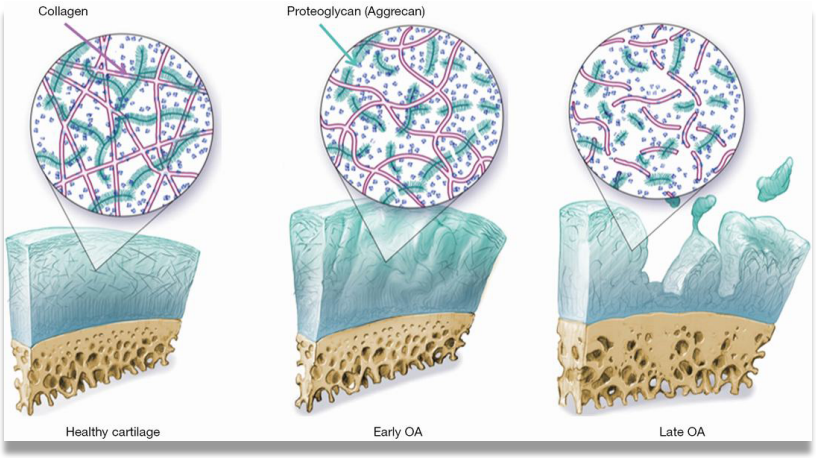


Image from Li et al. J Magn Reson Imaging 2013

Takeaway: 1) Type II collagen and proteoglycan alterations observed.

2) Inflammatory cytokine response inconclusive.

No Clear Early Soluble Biomarker of PTOA Following ACLR

Harkey & Pietrosimone et al. Osteoarthritis and Cartilage. 2015

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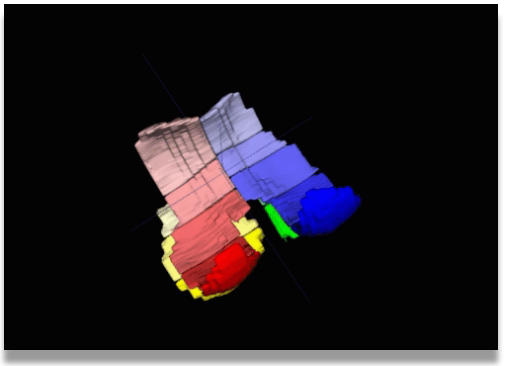
MRI



There is No CURRENT Accepted MRI Definition of Pre-OA

MRI Findings Can Provide Clues Of Abnormal Changes

Initial MRI Findings

Within Year 1

Femoral Bone Marrow Lesions

- 63% have BML on the lateral condyle following ACL injury

  Yoon. J Bone Joint Surg Am. 2011

Femoral BMLs Decrease Over Time

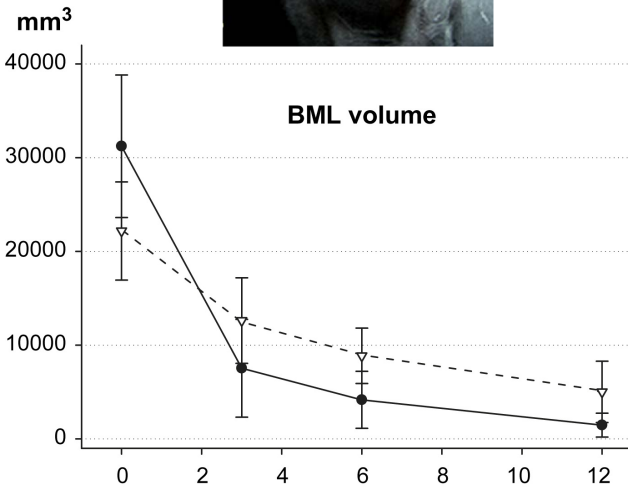
- Traumatic BML resolved in 38% of knees
- Patients with a ACLR had larger BMLs at 6 months

  Frobell et al. Osteoarthritis Cartilage 2009

Traumatic vs Chronic Femoral BMLs

- Traumatic BML Resolved 37% in 3m
- New BMLs in 21/47 knees 2 years

Frobell RB. J Bone Joint Surg Am. 2011



Frobell et al. Osteoarthritis Cartilage 2009

Compositional Changes

Within Years 1 & 2

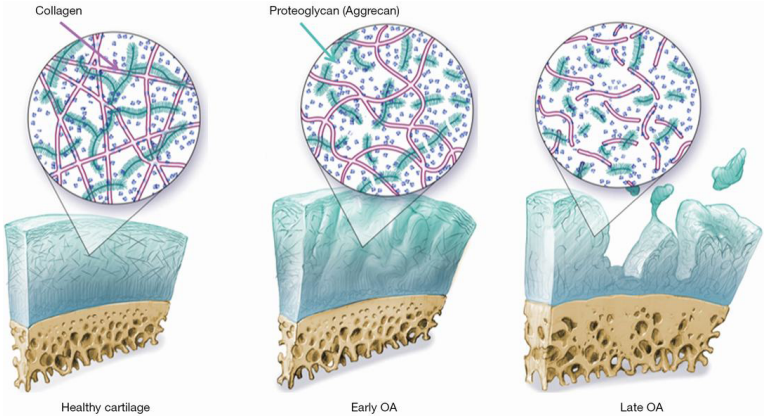
Decreased proteoglycan density is associated with OA progression and OA onset

Rautiainen et al. Mag Reson in Med. Epub

T1rho relaxation times are associated with proteoglycan density

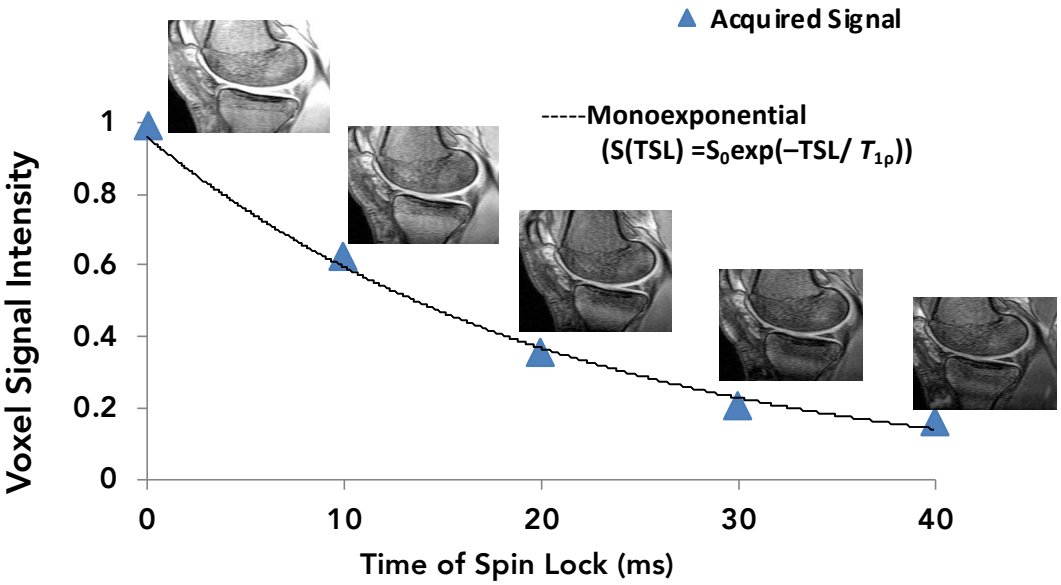
Regatte et al. Acad Radiol. 2002

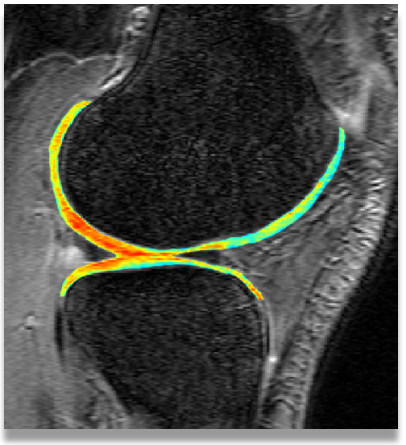
Wheaton et al. J Magn Reson Imaging. 2004

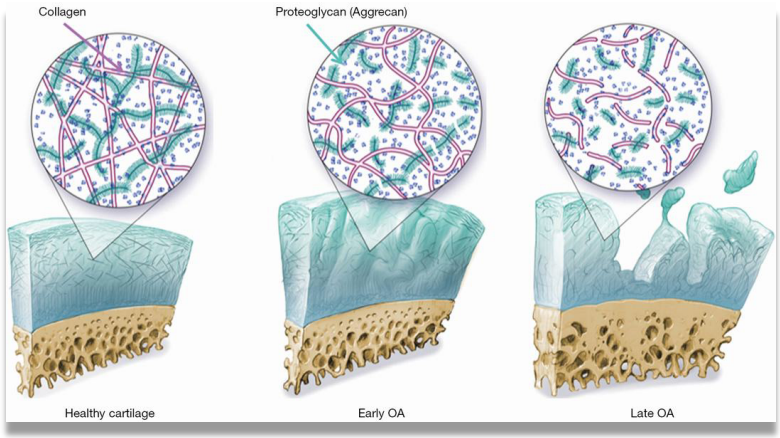


Li et al. J Magn Reson Imaging 2013

Measuring Cartilage Composition with T1ρ MRI



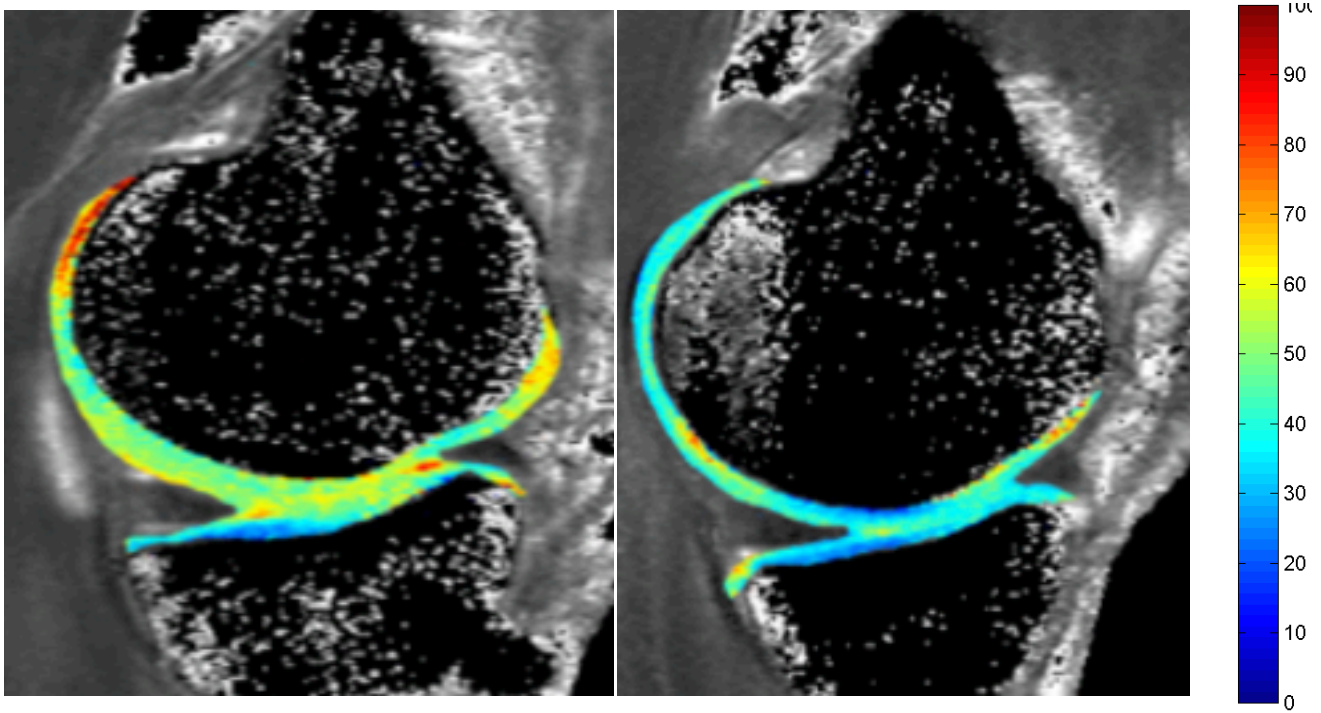




Li et al. J Magn Reson Imaging 2013

Cartilage Composition

Within Years 1 & 2



ACL Reconstructed Limb **Contralateral Limb**

12 months Post ACL Reconstruction

Pietrosimone et al. Knee. 2018; Pfeiffer & Pietrosimone et al. Arthr Care Res. 2017

T1ρ MRI & ACL Injury

Within Years 1 & 2

1 year post in posterior lateral tibial cartilage compared to controls

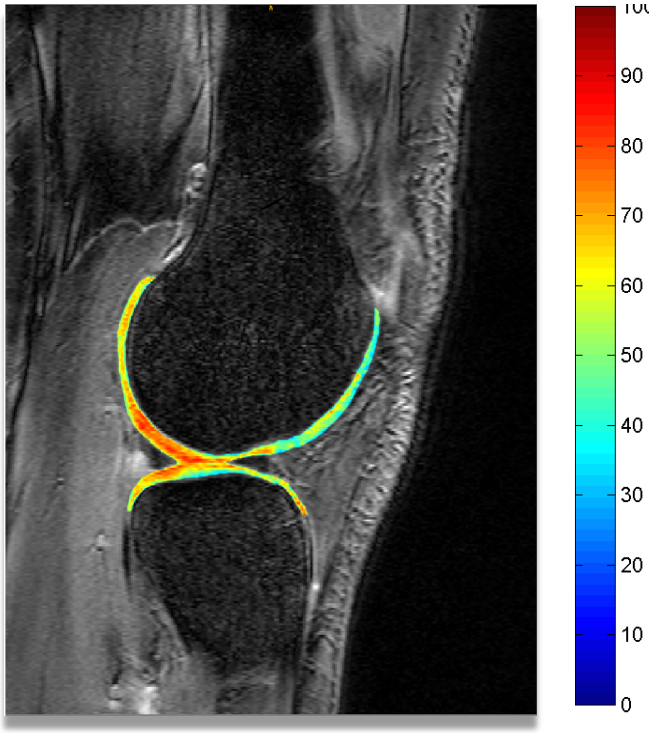
Li et al. Radiology. 2011

12-16 months post in medial tibia and femoral cartilage compared to contralateral

Theologis et al. KSSTA. 2014

2 years post in medial femoral cartilage compared to controls

Su et al. Osteoarthritis & Cartilage. 2013



Cartilage Thickness Post ACLR

Years 2- 6

Cartilage Thickening 2 years post-ACLR

- Medial Central Femoral Condyle

Frobell RB. J Bone Joint Surg Am. 2011

Cartilage Thinning 2 years post-ACLR

- Posterior Lateral & Medial Femur Condyle

Frobell RB. J Bone Joint Surg Am. 2011

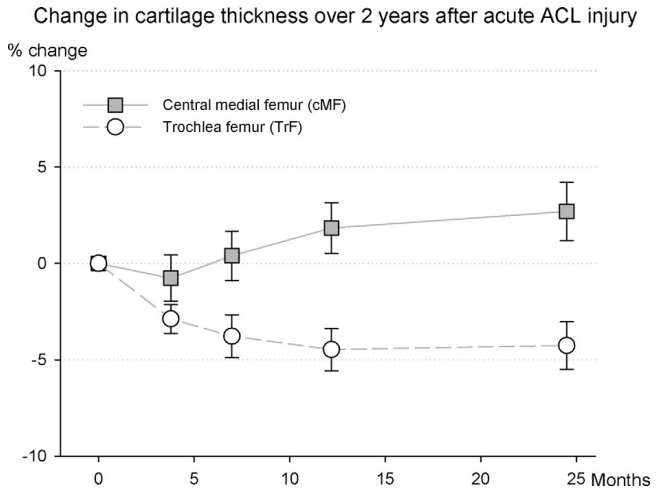
General Cartilage Thinning (Subjective)

- 3.7 years

Arnoldi et al. ROFO. 2011

- 6 years

Faber et al. AJSM. 1999



Frobell RB. J Bone Joint Surg Am. 2011

Curvature of Bone

Year 5

- N=111 ACL Injured Participants (Knee ACL, Nonsurgical vs Surgical Treatment [KANON] Study)
- Baseline and 5 year follow-up Assessed
- 62 – ACLR
- 59 – Rehabilitation only (30 received delayed ACLR with in 5 years)
- Increased body mass index, meniscal injury and ACLR are associated with increased flattening of the femur and increased depression of the tibial surface.

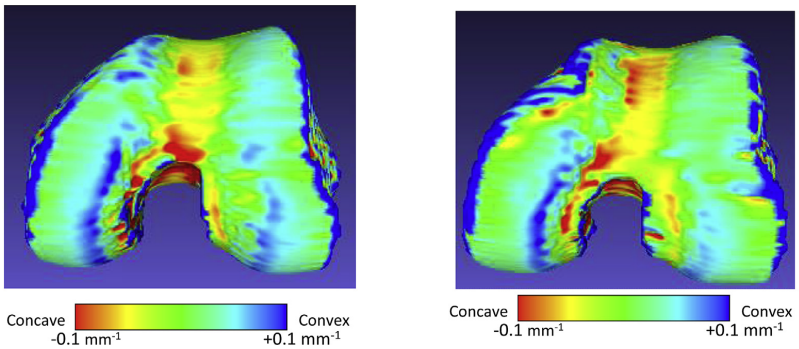


Image and Data from
Hunter et al. Osteoarthritis Cartilage. 2014

Change in bone curvature between baseline and five years for the whole cohort ($n = 111$)

	Change in curvature (mm^{-1})				
	Mean	SD	95% CI	*P* value	Standardized response mean
Femur	−0.0028	−0.0087	−0.003178 −0.002516	<0.001	−1.62
Medial femur	−0.0041	0.0029	−0.004604 −0.003516	<0.001	−1.40
Lateral femur	−0.0044	0.0031	−0.004989 −0.003816	<0.001	−1.41
Trochlea	−0.0020	0.0025	−0.002459 −0.001508	<0.001	−0.78
Tibia	−0.0035	0.0031	−0.004121 −0.002954	<0.001	−1.14
MT	−0.0020	0.0037	−0.002665 −0.001277	<0.001	−0.53
LT	−0.0036	0.0041	−0.00435 −0.002789	<0.001	−0.86

P-values reflect difference between baseline and 5 years.

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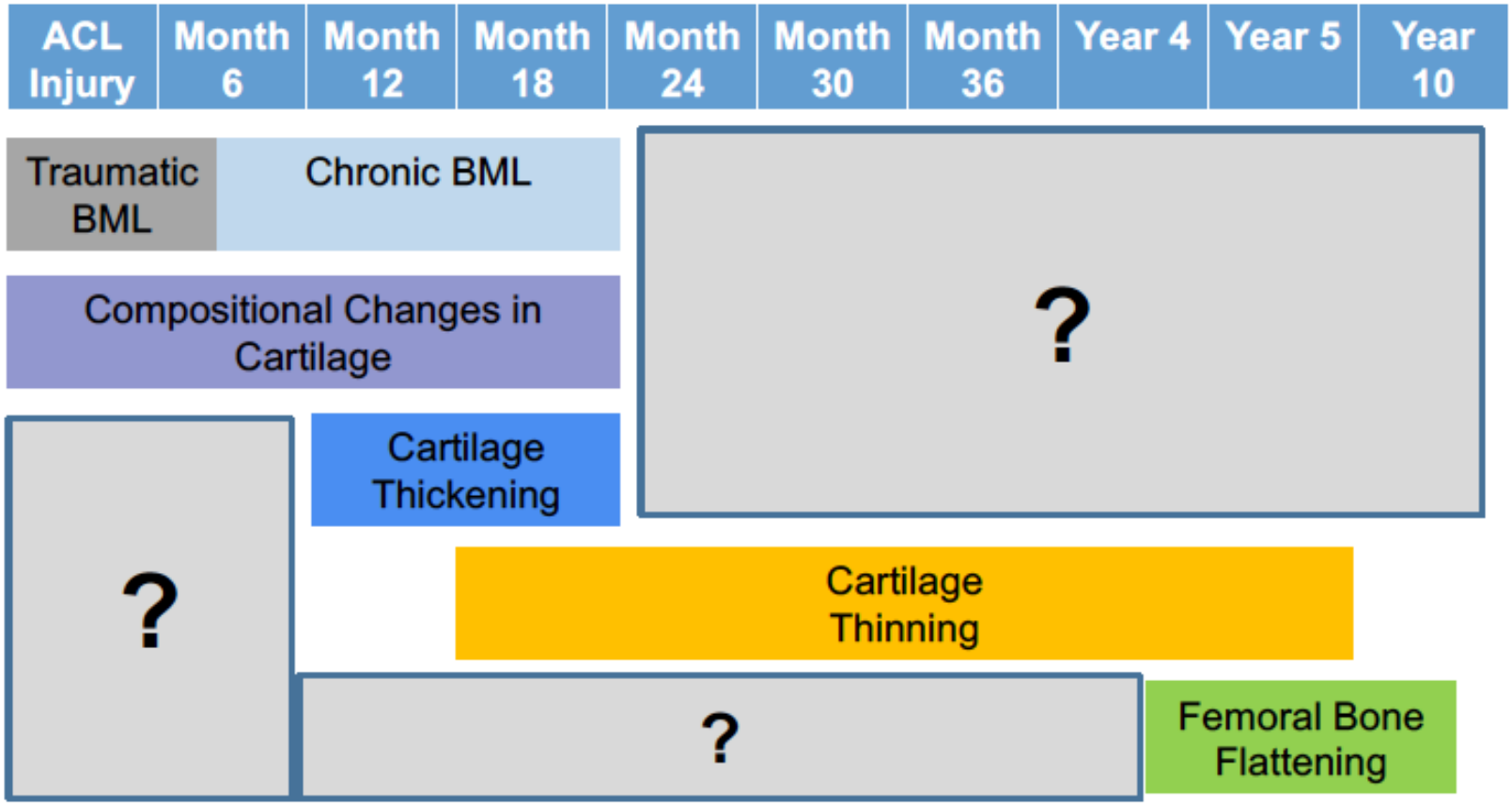
Timeline of MRI Findings



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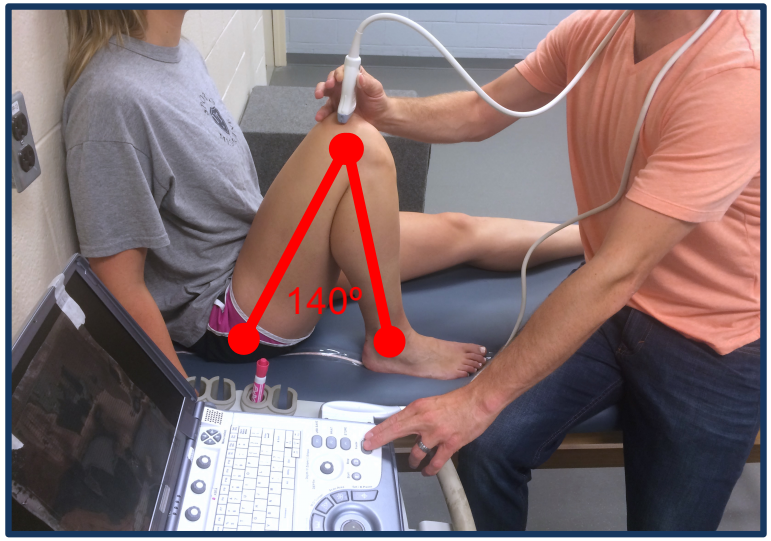
Assessing Cartilage with Ultrasound



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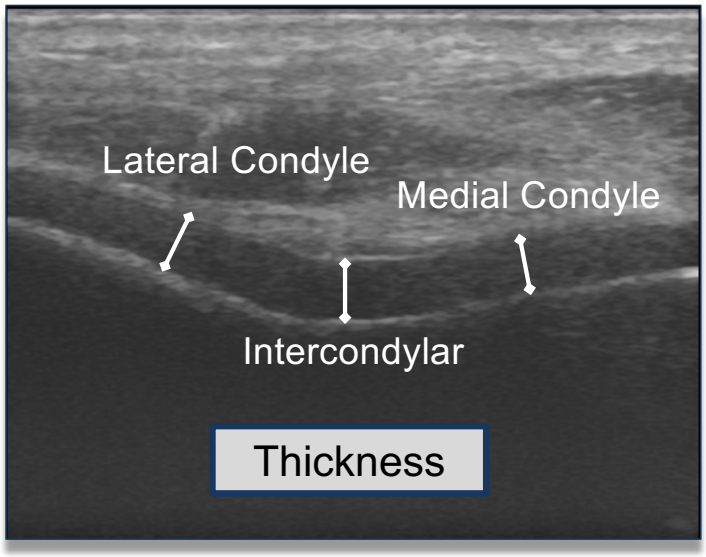
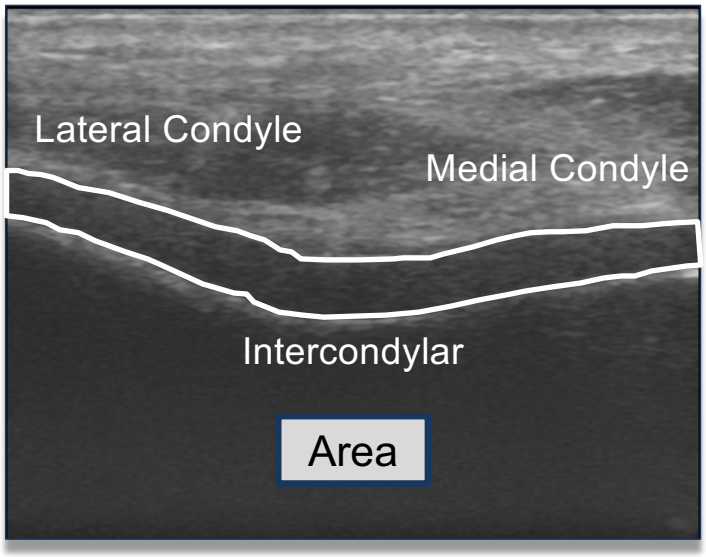
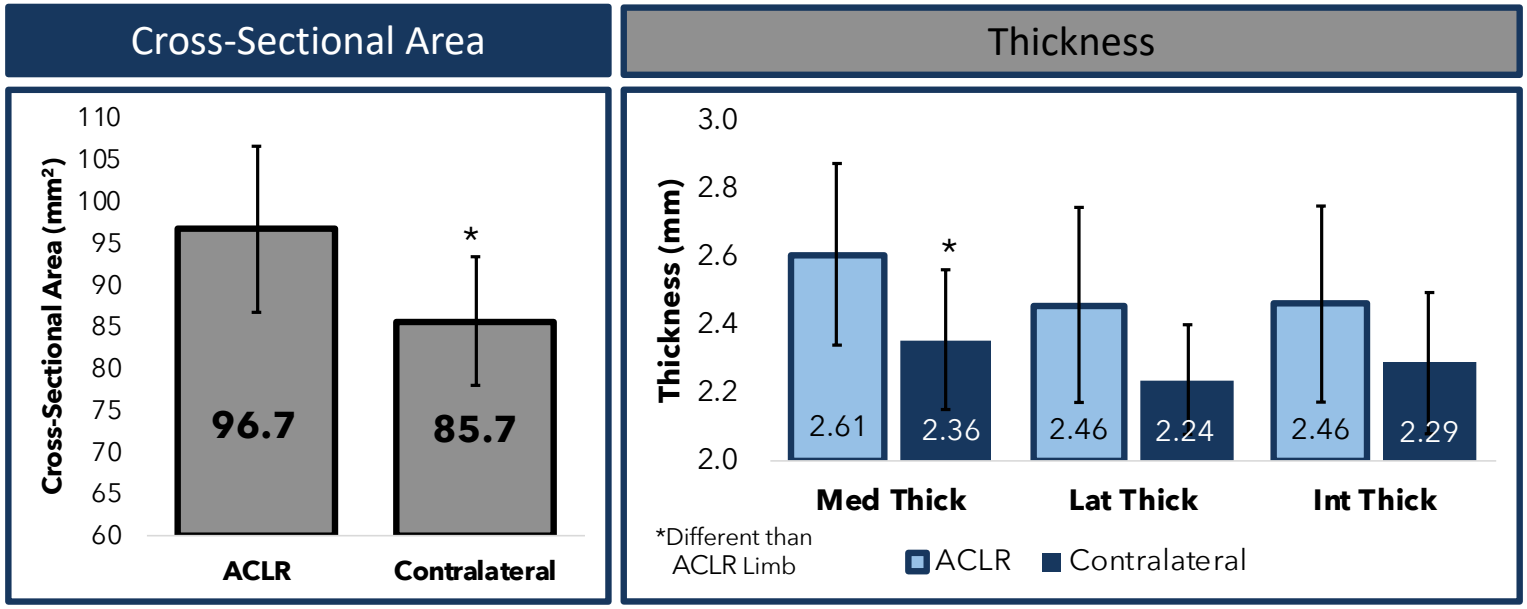
Structural Outcomes: Thickness & Area





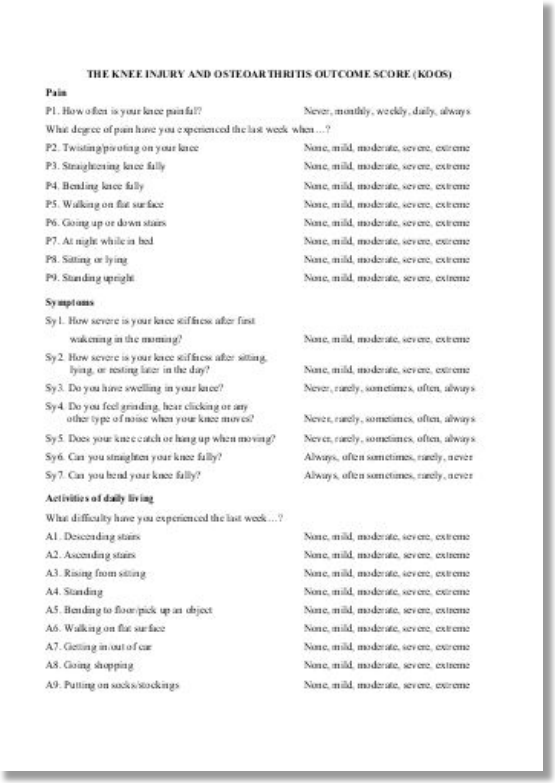
Thicker Cartilage Following ACLR



↑ femoral cartilage size in ACLR compared to contralateral limb at an average of ***3 years*** following surgery

Harkey and Pietrosimone et al. Journal of Athletic Training. 2018

Patient- Reported Outcomes



THE KNEE INJURY AND OSTEOARTHRITIS OUTCOME SCORE (KOOS)

Pain

P1. How often is your knee painful?	Never, monthly, weekly, daily, always
What degree of pain have you experienced the last week when …?	
P2. Twisting/pivoting on your knee	None, mild, moderate, severe, extreme
P3. Straightening knee fully	None, mild, moderate, severe, extreme
P4. Bending knee fully	None, mild, moderate, severe, extreme
P5. Walking on flat surface	None, mild, moderate, severe, extreme
P6. Going up or down stairs	None, mild, moderate, severe, extreme
P7. At night while in bed	None, mild, moderate, severe, extreme
P8. Sitting or lying	None, mild, moderate, severe, extreme
P9. Standing upright	None, mild, moderate, severe, extreme

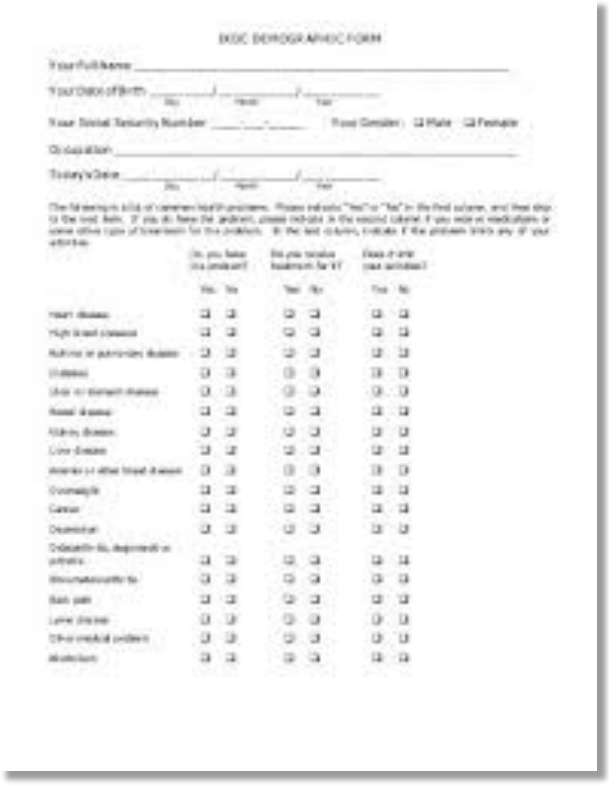
Symptoms

Sy1. How severe is your knee stiffness after first wakening in the morning?	None, mild, moderate, severe, extreme
Sy2. How severe is your knee stiffness after sitting, lying, or resting later in the day?	None, mild, moderate, severe, extreme
Sy3. Do you have swelling in your knee?	Never, rarely, sometimes, often, always
Sy4. Do you feel grinding, hear clicking or any other type of noise when your knee moves?	Never, rarely, sometimes, often, always
Sy5. Does your knee catch or hang up when moving?	Never, rarely, sometimes, often, always
Sy6. Can you straighten your knee fully?	Always, often sometimes, rarely, never
Sy7. Can you bend your knee fully?	Always, often sometimes, rarely, never

Activities of daily living

What difficulty have you experienced the last week …?	
A1. Descending stairs	None, mild, moderate, severe, extreme
A2. Ascending stairs	None, mild, moderate, severe, extreme
A3. Rising from sitting	None, mild, moderate, severe, extreme
A4. Standing	None, mild, moderate, severe, extreme
A5. Bending to floor/pick up an object	None, mild, moderate, severe, extreme
A6. Walking on flat surface	None, mild, moderate, severe, extreme
A7. Getting in/out of car	None, mild, moderate, severe, extreme
A8. Going shopping	None, mild, moderate, severe, extreme
A9. Putting on socks/stockings	None, mild, moderate, severe, extreme

Knee Injury and Osteoarthritis Outcomes Score



International Knee Documentation Committee Index

Screening with Patient-Reported Outcomes

Quality of Life	≤ 87.5 %
PAIN	**≤ 86 %**
Symptoms	**≤ 85 %**
Activities of Daily Living	**≤ 87 %**
Sports & Recreation	**≤ 85%**

Knee Injury and Osteoarthritis Outcomes Score (KOOS)

Quality of Life
+ 2 of the Following Subscales

Englund et al. Arthritis Rheum. 2003

Clinically Symptomatic

	Year 2 N=1530	Year 6 N=1506
Clinically Symptomatic	43%	39%

Multicenter Orthopaedic Outcomes Network (MOON)

Wasserstein et al. Osteoarthritis Cartilage. 2015

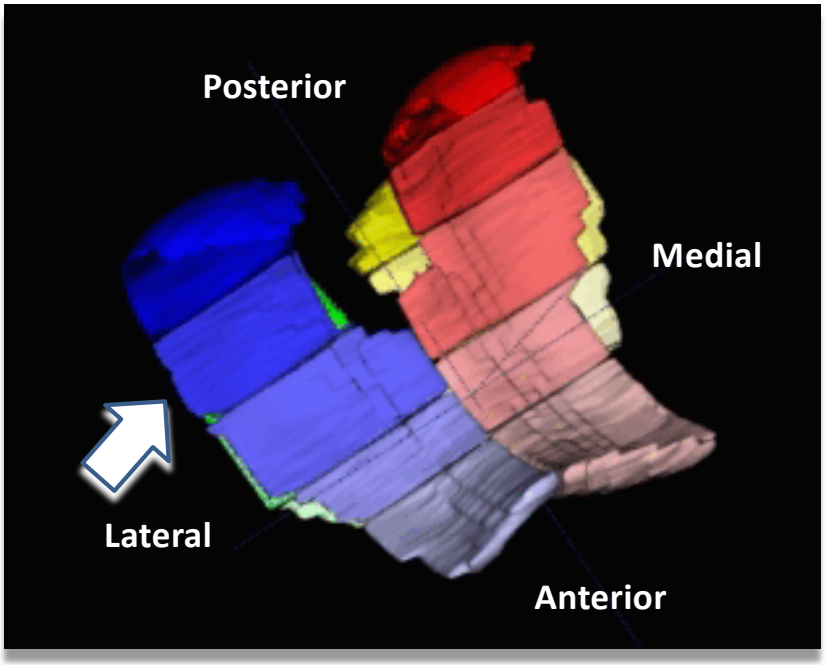
Radiographic PTOA Prevalence 1 Decade Post-ACLR

36%

KOOS & Cartilage Composition

KOOS Score	Correlation
Pain	-0.54
Activities of Daily Living	-0.56
Sports Function	-0.62
Quality of Life	-0.59

N= 18, Unilateral ACLR



Pietrosimone et al. Knee. 2018

Walking Speed: An Indicator of PTOA

Walking Speed – "The Sixth Vital Sign"

Fritz & Lusardi. J Geriatr Phys Ther

Walking Speed is Generally Stable Until Age 62

Himann et al. Med Sci Sports Exerc. 198

Habitual Walking Speed Predicts Idiopathic OA

White et al. Arthritis Care and Research. 2010
Purser et al. Arthritis Care and Research. 2012

0.1 m/s Decrease in 12-months in Risk of OA by 8%

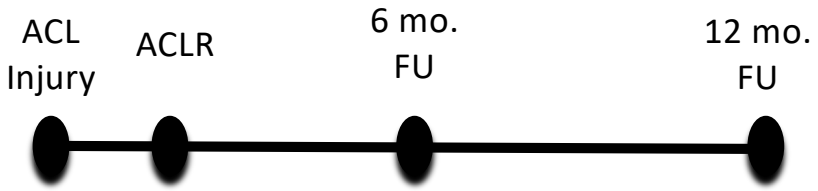
Herzog & Pietrosimone et al. J Rheumatology. 2017

Can Walking Speed Predict PTOA?

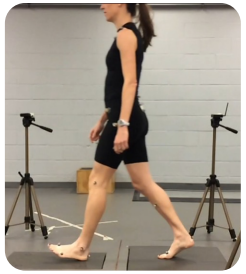
Slower Walkers and T1ρ

Participants	9 males, 11 females
Age	22.05 ± 3.93 years
Height	177.47 ± 12.58 cm
Weight	75 ± 13.91 kg
BMI	23.63 ± 2.39 kg/m^2
Days between ACL injury and ACLR	32.35 ± 14.17 days
6 month Following ACLR Walking Speed	1.30 ± 0.12 m/s

Study Design



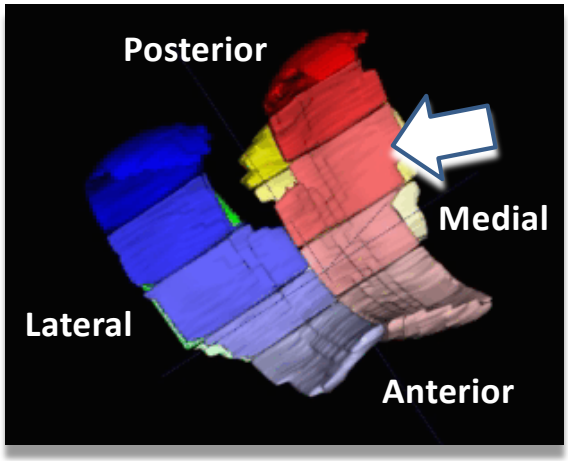
Walking Speed

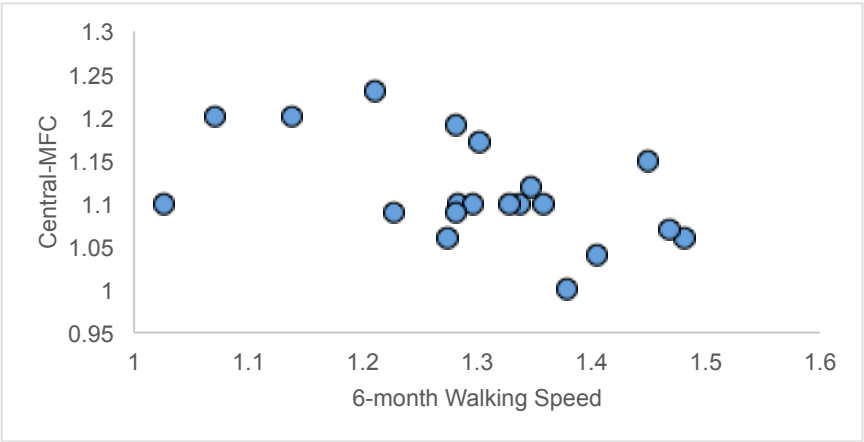


T1ρ MRI

Pfeiffer & Pietrosimone et al. Arth Care Res. 2017

Slower Walkers and T1ρ





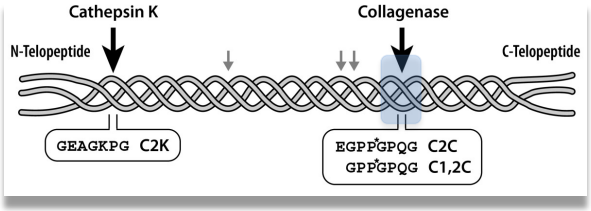
r=-0.495, P=0.013

Pfeiffer & Pietrosimone et al. Arth Care Res. 2017

Collagen Degradation & Walking Speed

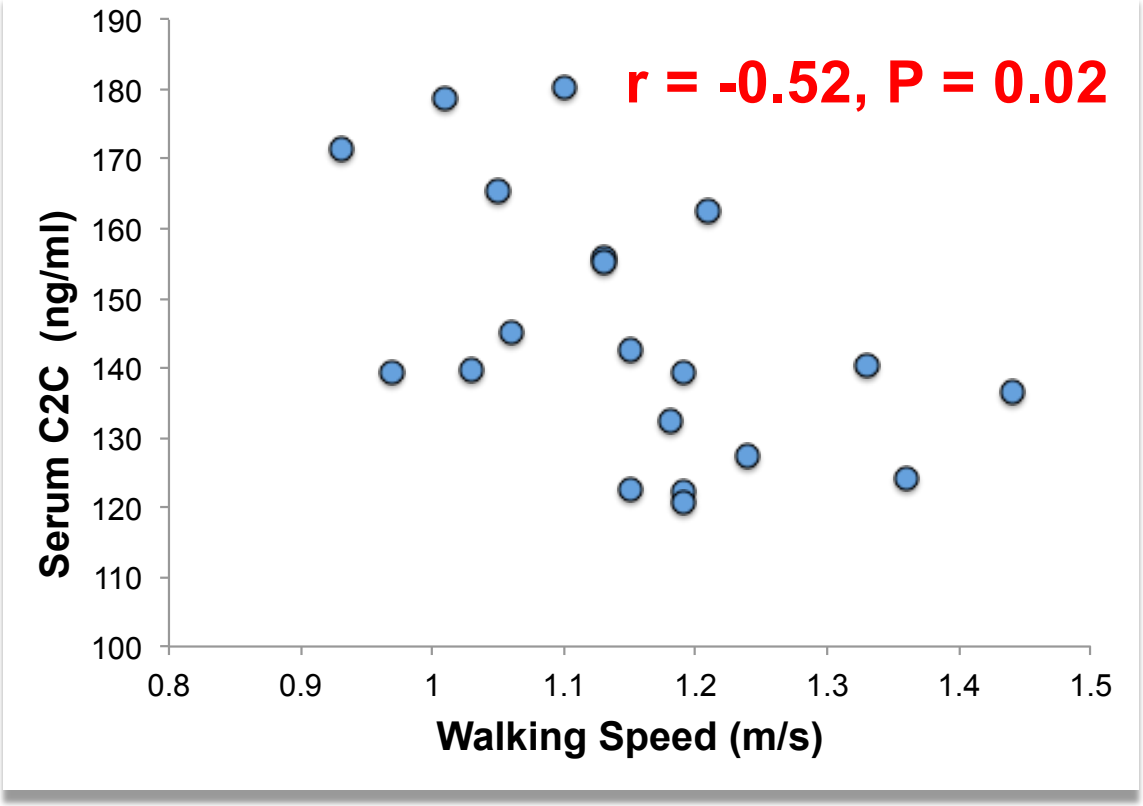
	N= 20
Sex	9 Males 11 Females
Age	22.00 ± 3.62 years
Height	171.35 ± 11.72 cm
Weight	72.73 ± 15.28 kg
Months Post Injury	45.9 ± 38.81 months
Months Post Surgery	43.25 ± 36.39
IKDC	85.02 ± 10.25 %
C2C (ng/ml)	145.09 ± 18.8
Aggrecan (µg/ml)	2.92 ± 0.74
Walking Speed	1.15 ± 0.13

Collagen Type-II Collagen Cleavage Product (C2C)



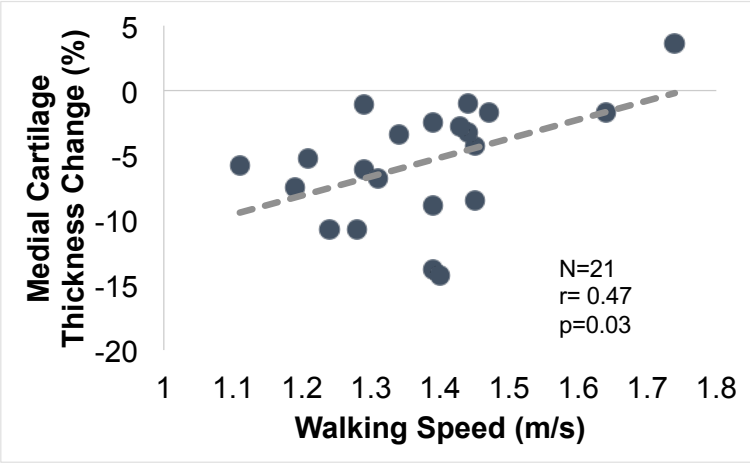
Pietrosimone et al. Arth Care Res. 2016

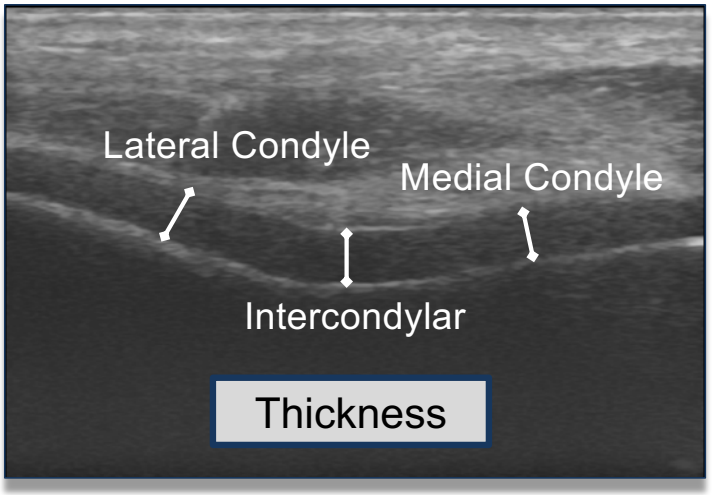
Slower Walker & Greater C2C



Pietrosimone et al. Arth Care Res. 2016

Slower Walker & Cartilage Deformation





Healthy Slower walkers undergo greater cartilage deformation

Potential Double Whammy:

Altered Cartilage Composition and Slower Walking Speeds

Harkey & Pietrosimone et al. Gait and Posture. 2018

Question #2

What Can Be Used to Detect Early Changes Related to PTOA in Our Patients?

- **Novel MRI sequences and Ultrasound** may provide important information regarding early changes in different joint tissues
- Screening with **patient-reported outcomes** may provide information about early underlying joint changes
- Changes in **habitual walking speed** may be a functional assessment tool for assessing early underlying joint changes

Managing the Risk

Question #3

How can Clinicians Decrease the Risk for PTOA Following ACLR?

- Patients with an ACL injury are at high risk for a chronic disease
- Implementing a plan early following ACL injury

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Prevention Along a Continuum

Primary Injury Prevention/ Reduction

ACL Injury

Secondary Prevention

Knee Osteoarthritis Onset

Tertiary Prevention

Disability

Guidelines For Managing the Risk of PTOA

Journal of Athletic Training 2017;52(6):610–623
doi: 10.4085/1062-6050-52.2.04

www.natajournals.org

ATOAC consensus statement

The Role of Athletic Trainers in Preventing and Managing Posttraumatic Osteoarthritis in Physically Active Populations: a Consensus Statement of the Athletic Trainers' Osteoarthritis Consortium[a]

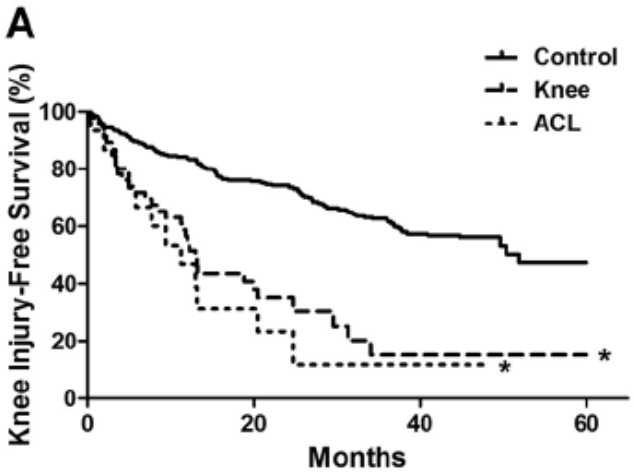
Riann M. Palmieri-Smith, PhD, ATC*; Kenneth L. Cameron, PhD, MPH, ATC†; Lindsey J. DiStefano, PhD, ATC‡; Jeffrey B. Driban, PhD, ATC, CSCS§; Brian Pietrosimone, PhD, ATC||; Abbey C. Thomas, PhD, ATC¶; Timothy W. Tourville, PhD, ATC, CSCS#; Athletic Trainers' Osteoarthritis Consortium

*University of Michigan, Ann Arbor; †Keller Army Hospital, West Point, NY; ‡University of Connecticut, Storrs; §Division of Rheumatology, Tufts Medical Center, Boston, MA; ||University of North Carolina at Chapel Hill; ¶University of North Carolina at Charlotte; #University of Vermont, Burlington

- There are no disease modifying interventions for PTOA
  - WE CAN STILL DO SOMETHING!
- Clinical trials for interventions to decrease the risk of PTOA are lacking
- Current Best Practices
  - Patient Education
  - Serial Assessment
  - Proper Strength/ Mechanics
  - Activity Modification
  - Weight Management

Need for Serial Assessment

- ACL reconstructed patients at risk of an additional knee injury until 2 year time point
- Only ~ 10% remained knee injury free at 2 years
- High susceptibility for sustaining injury for the first two years
  - Consider serial assessments at least 24 months post ACLR



Rugg et al. AJSM. 2014

Education of Our Patients

- Athletic Trainers may not explain the risk of PTOA

What do our ACLR patients think?

- 27% of ACLR patients discussed the risk with healthcare professional
- 65% believed that ACLR decrease the risk of PTOA
- Australians (36%) were more likely to believe OA was a major health concern than US patients (7%)

Bennell & Pietrosimone et al. Arth Care Research. 2016

Treat ACL Injured Patients	ACL Injury Increases the Risk of OA	Its appropriate for ATs to explain the risk	Do you explain the risk	Do you provide strategies to decrease the risk of OA
93%	90%	97%	71%	71%

Pietrosimone et al. J Ath Train. 2017

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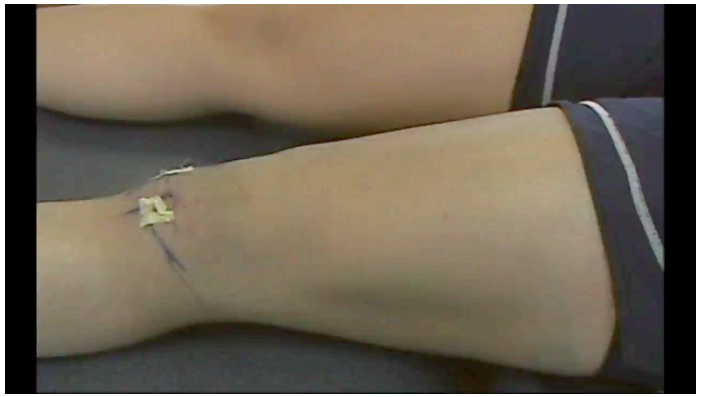
Key Aspects of Education

- Understanding that they are living with the risk of a chronic disease

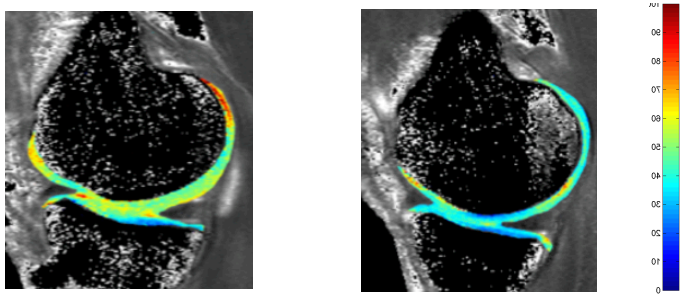
- Methods for Management
  - Compliance with Rehabilitation after Returning to Play
  - Awareness of Joint Fragility – Possible Activity Restriction
  - Awareness of Novel Treatments

- Spend more of their life as a non-athlete than a competitive athlete

Quadriceps Weakness following Knee Injury

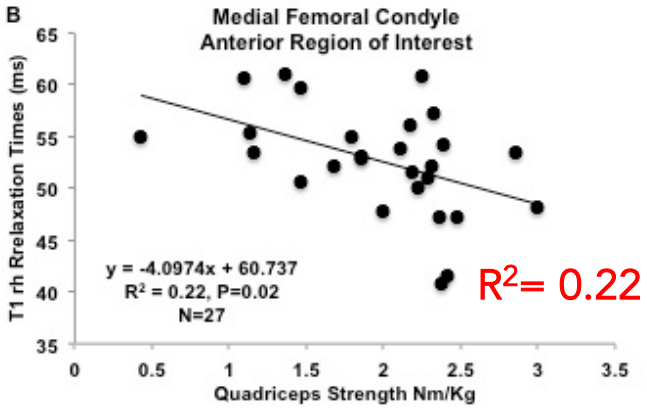


Pietrosimone et al. *Clin Biomech* 2014



ACL Reconstructed Limb

Contralateral Limb

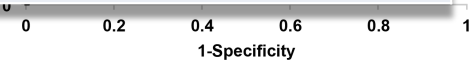


Pietrosimone et al. *KSTTA* 2019

Muscle Strength & Disability

Uninjure

Gender (N=96)	**62 (64.6%) Females** **34 (35.4%) Males**
Graft Type	56 (58.3%) Patellar Tendon Autograft 37 (38.5%) Semitendinosus/ Gracillis Autograft 3 (3.1%) Allograft
History of a Concomitant Meniscus Surgery with Anterior Cruciate Ligament Reconstruction (ACL-R)	50 (52.1%) Yes 42 (43.8%) No 4 (4.2%) Unknown
Months Since ACLR Surgery	20 (45) months
Age	21 (4) years
Quadriceps Strength Normalized to Body Weight (QSBW)	2.74 (0.69) Nm/kg
Quadriceps Strength Limb Symmetry Index (QLSI)	94.28 (15.41)%



Pietrosimone et al. MSSE. 2016.

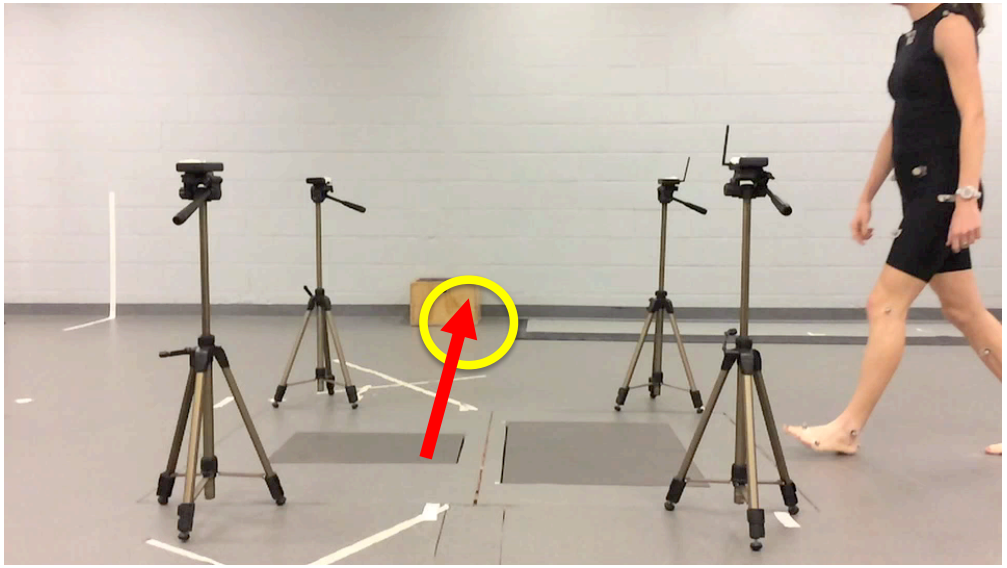
Maximizing Strength & Optimizing Mechanics

Changing strength may not result in altered gait biomechanics

- Pietrosimone et al. 2010 (Knee Osteoarthritis)
- Lepley AS & Pietrosimone et al. 2016 (ACLR)
- DeVita et al. 2018 (Knee Osteoarthritis)
- Davis-Wilson and Pietrosimone et al. 2019 (Knee Osteoarthritis)
- Capin et al. 2019 (ACL injury and ACLR)

Just because you fix jump-landing doesn't mean gait biomechanics will improve

Pffeifer & Pietrosimone et al. Clin Biomech. 2018



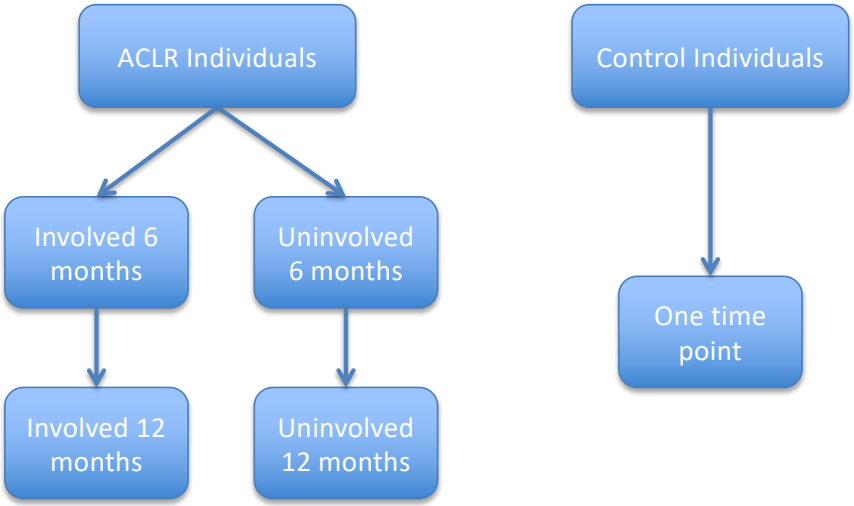
Optimizing Loading and Decreasing a Stiffen Knee Strategy is Important

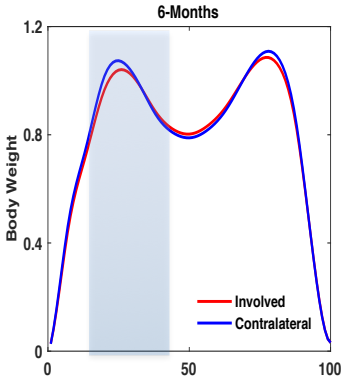
Walking Biomechanics 6 and 12 months post-ACLR

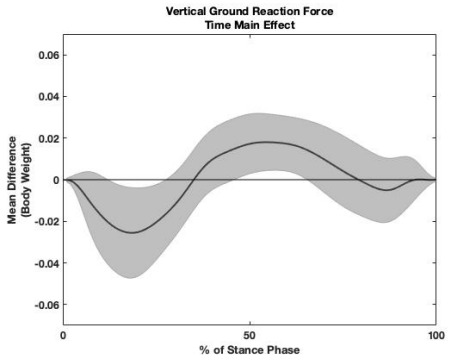
Study Design: Longitudinal cohort-control

30 ACLR individuals at 30 uninjured controls

Davis-Wilson & Pietrosimone et al. MSSE. 2020





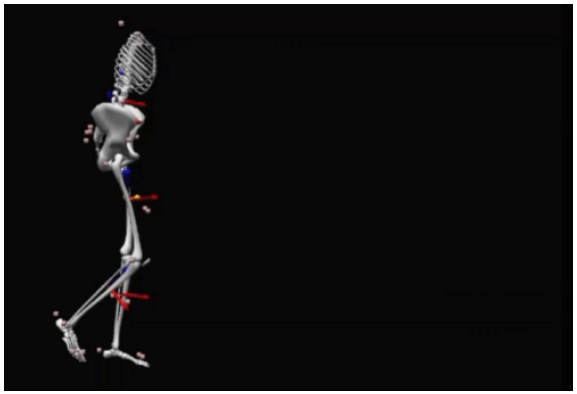


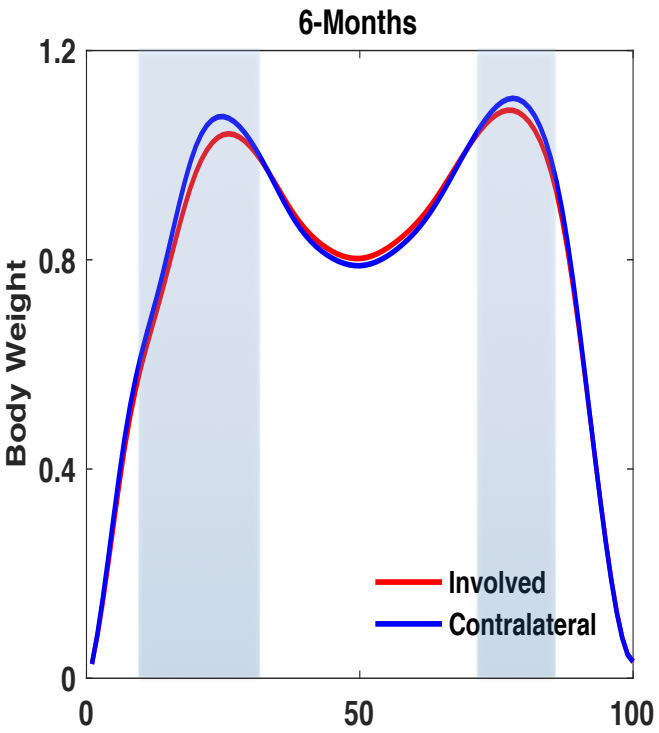
National Institute of Arthritis and Musculoskeletal and Skin Diseases

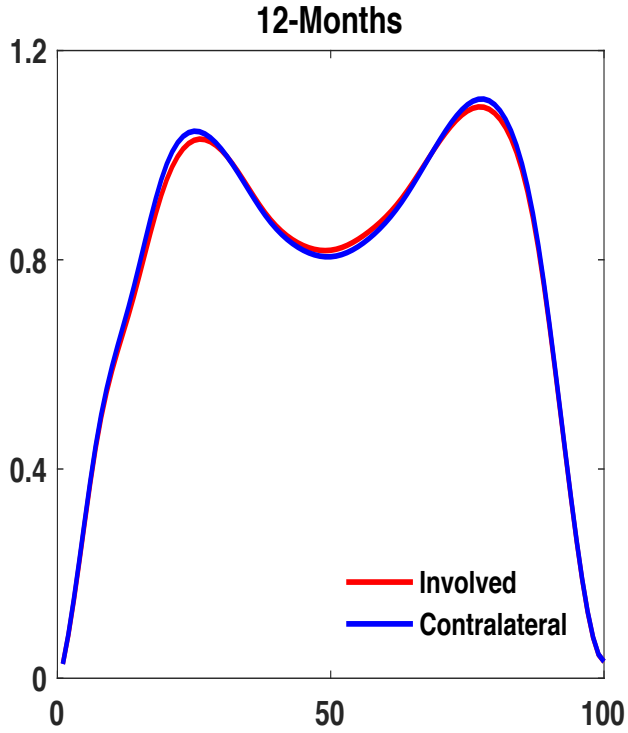
NATA Research & Education Foundation

NC TraCS Institute

Vertical Ground Reaction Force Loading Becoming Symmetrical?







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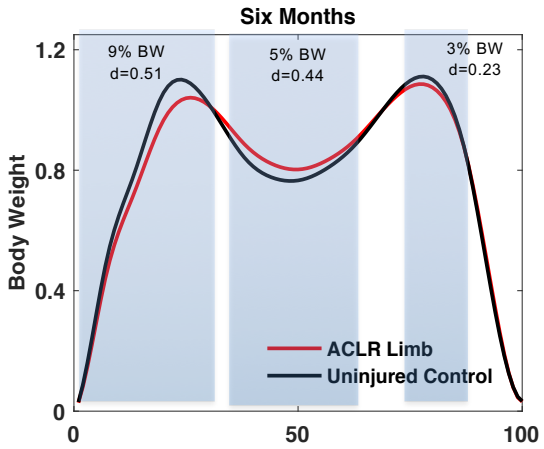
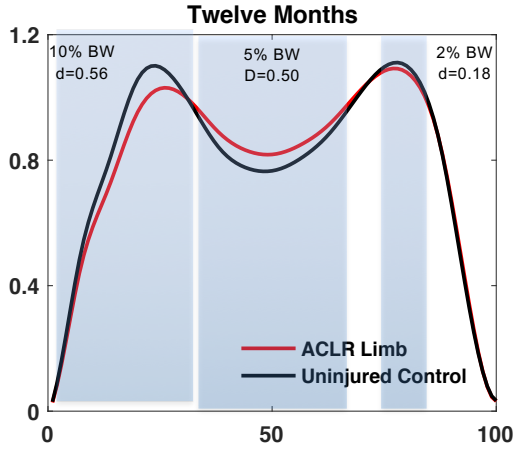
ACLR Limb Compared to Controls

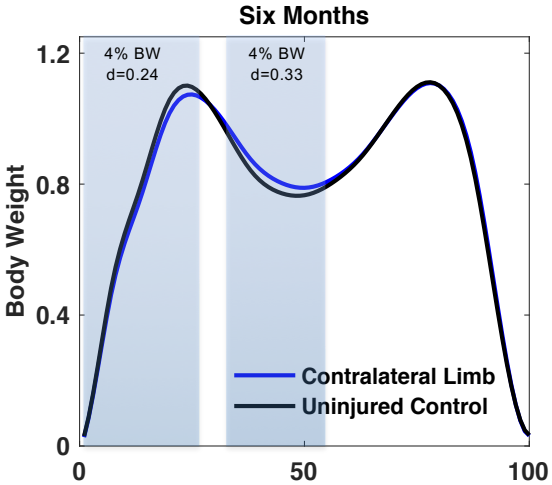
ACLR Limb Underloaded at 6 and 12 Months Post-ACLR

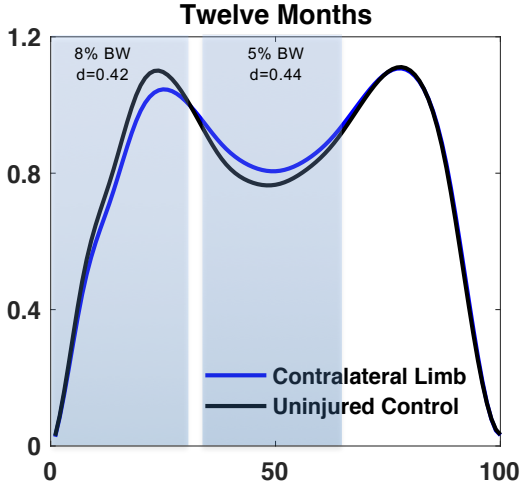




Contralateral Limb Compared to Controls

Contralateral Limb Greater Underloading 12 Months Post-ACLR

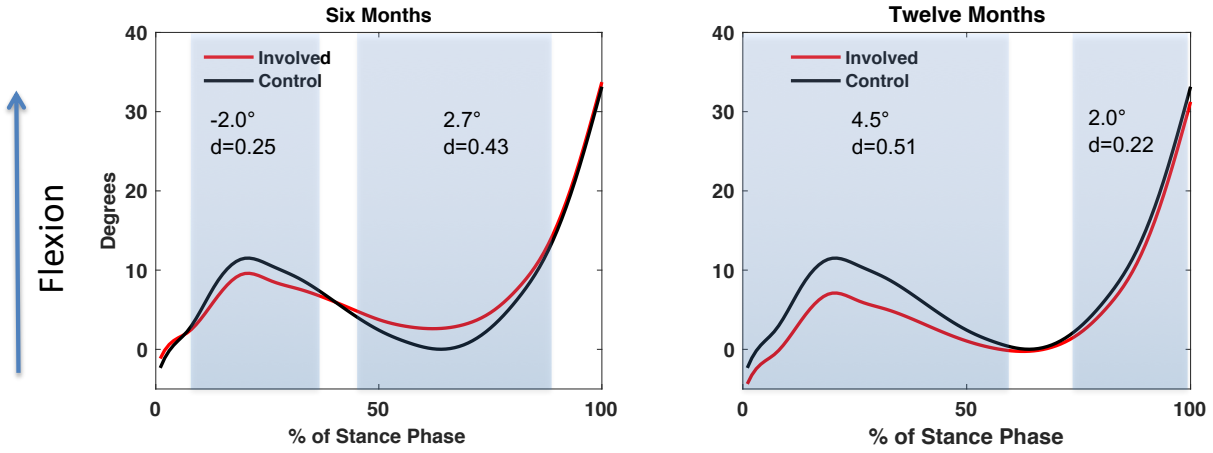




Knee Flexion Angle

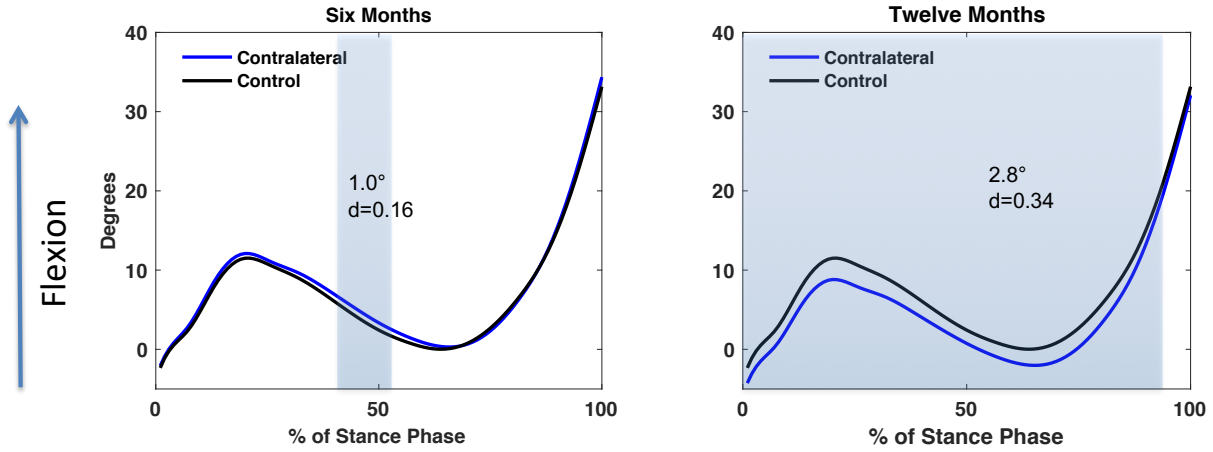
ACLR Limb
Compared to Controls

ACLR Limb Lesser Knee Excursions
at 6 and 12 Months Post-ACLR



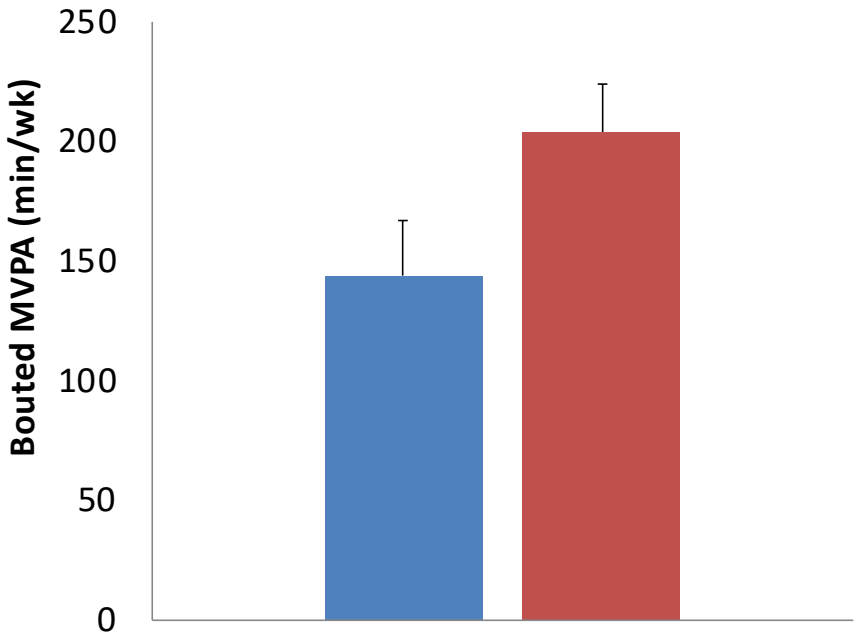
Contralateral Limb
Compared to Controls

Contralateral Limb more Extended
at 12 Months Post-ACLR

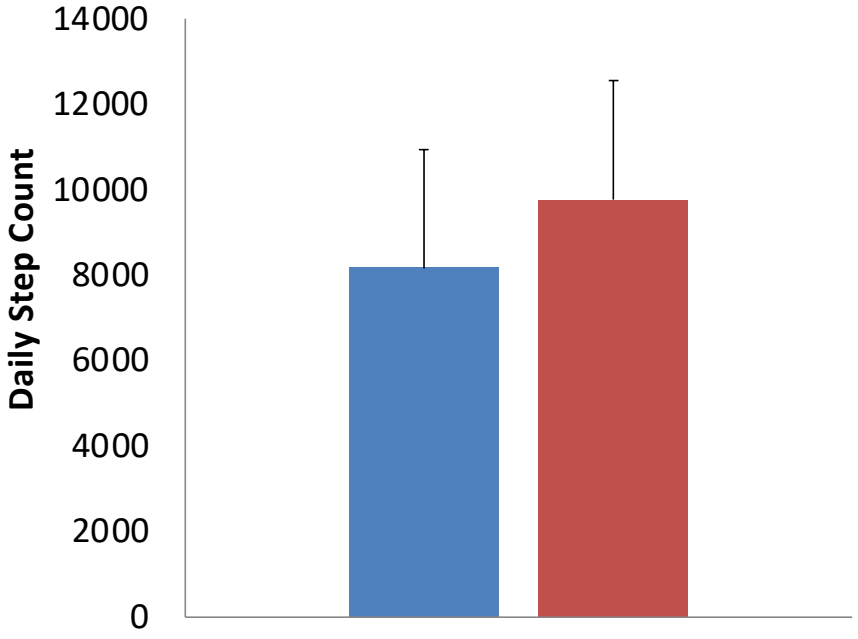


Cumulative Loading

Mod/ Vigorous PA



Daily Step Count



Adapted from a Slide Presented by Dr. Kuenze

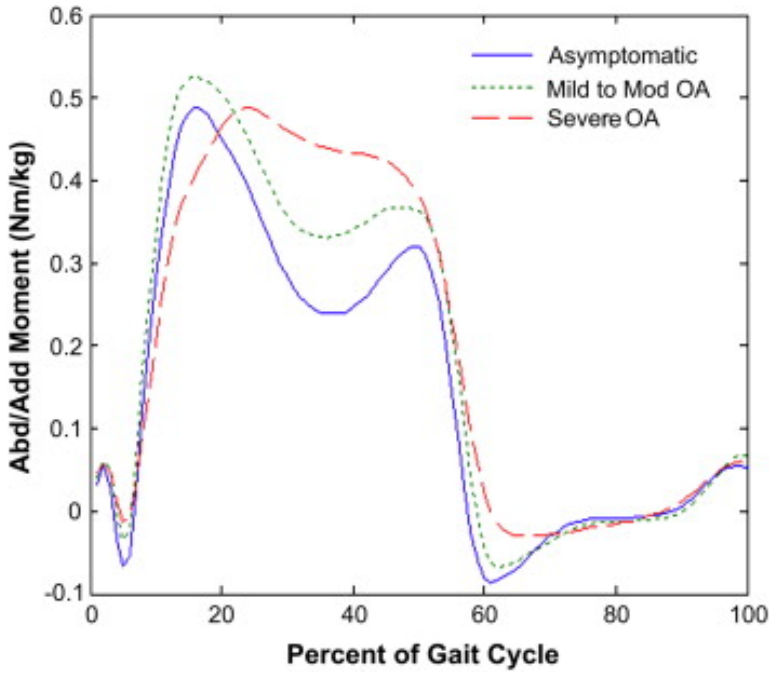
Bell et al. *Am J Sports Med.* 2017
Kuenze et al. *Phys Ther in Sport.* 2019

Summary of Gait Alterations following ACLR

- ACLR gait demonstrates Underloading early following ACLr
  - Lesser peak vGRF
  - Lesser peak knee extension moment
  - Stiffer Knee Flexion
- Symmetry may be due to bilateral underloading
  - Walking speed
  - Neuromuscular Compensations
- Cumulative loading may also be decreased in patients with ACLR

Hypothesis: Excessive Joint Loading Causes PTOA

Greater Medial Compartment Loading



Rutherford et al. Osteoarthritis & Cartilage 2008

Higher impact loading caused more cartilage damage

Ewers et al. J Biomech. 2002

Higher Knee Adduction Moments in Knee OA patients

Astephen et al. J Orthop Res. 2008

Mundermann et al. Arthritis Rheum. 2005

Higher Loading Rates in ACLR vs Controls

Co et al. J Orthop Res. 1993

Noehren et al. MSSE. 2013

Higher Loading Rates on ACLR Limb compared to contalateral Limb

Blackburn et al. J Biomech. 2016

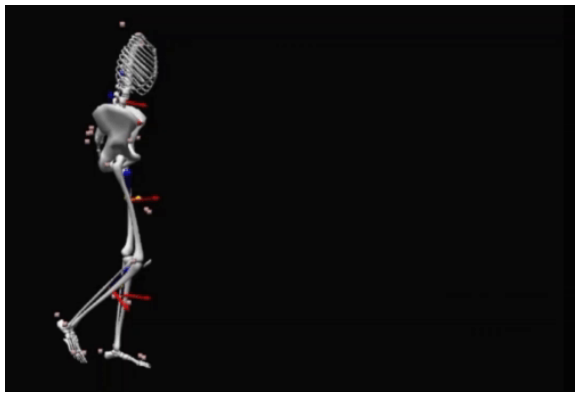
Associations Between Biomechanics and Biomarkers

Participants	11 (58%) Women 8 (42%) Men
Age	21.63 ± 3.42 years
Months Post ACLR	37.95 ± 29.27
IKDC	84.5±10.8%
ACL Graft Type	13 (69%) Patellar Tendon Autografts 5 (26%)Semitendinosus/ Gracilis Autografts 1 (5%) Allograft

Design

Cross-sectional

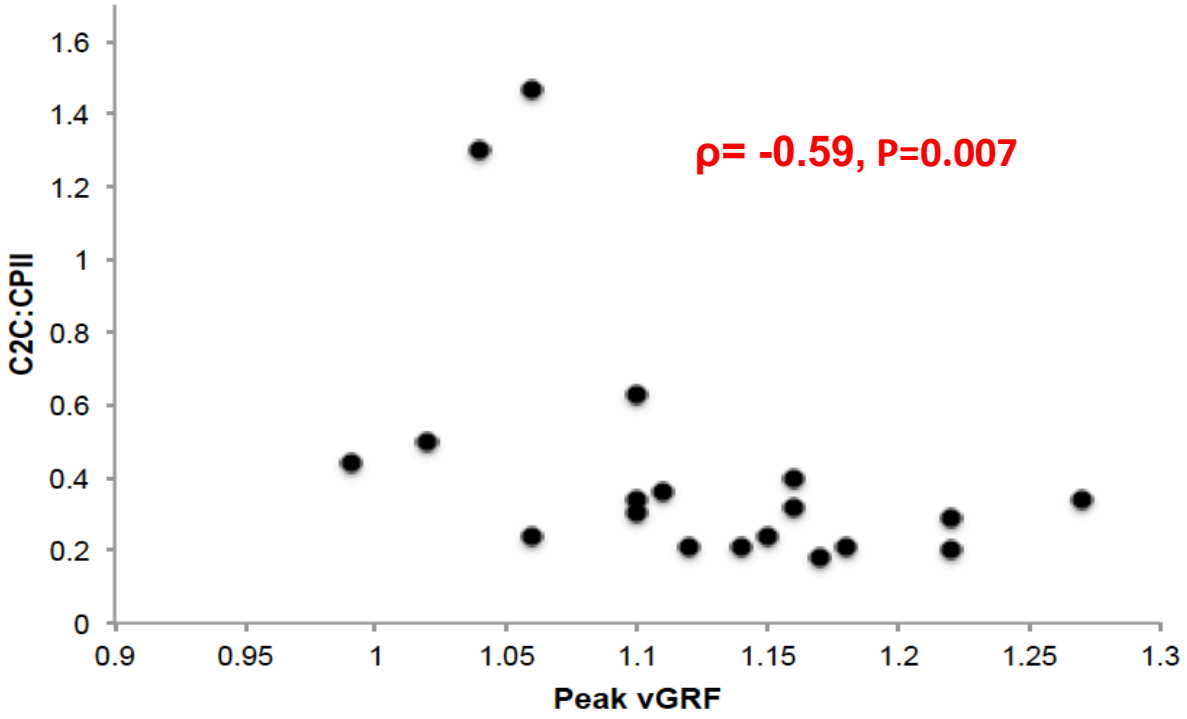
Blood Draw



Gait Biomechanics

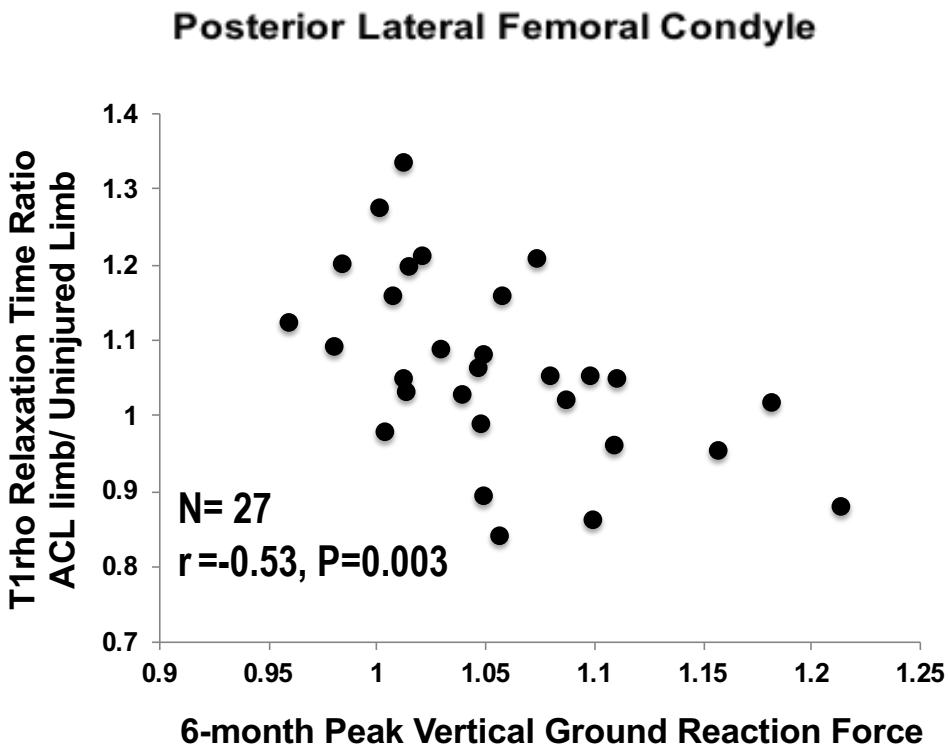
Pietrosimone et al. AJSM. 2016

More Cartilage Turnover in Off-Loaders



Pietrosimone et al. AJSM. 2016

Lesser Loading at 6 Months Post-ACLR and T1ρ MRI

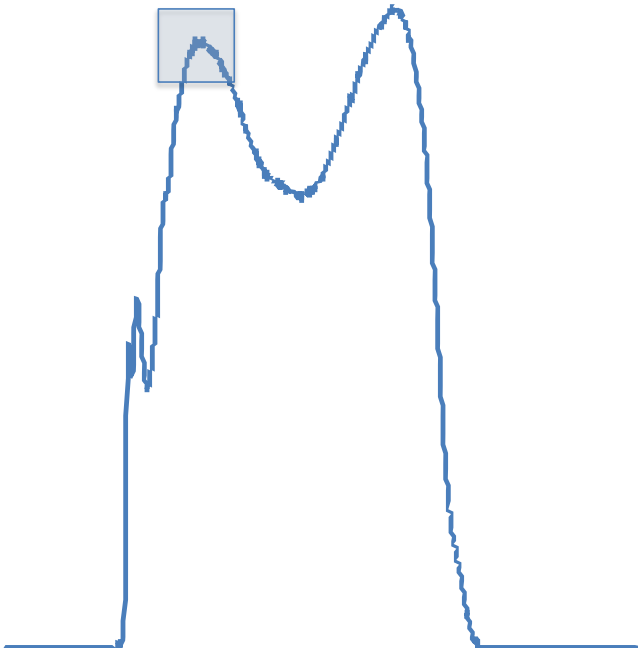


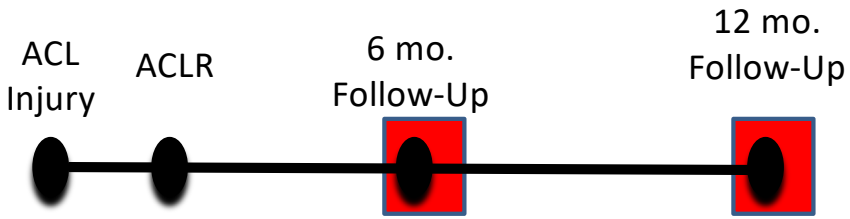
Pfeiffer and Pietrosimone et al. MSSE. 2019

<u>Outcomes Demonstrating Similar Associations</u>

Lesser Vertical Ground Reaction Force
Lesser Knee Adduction Moment
Lesser Knee Flexion Excursion

Loading & Patient Reported Outcomes



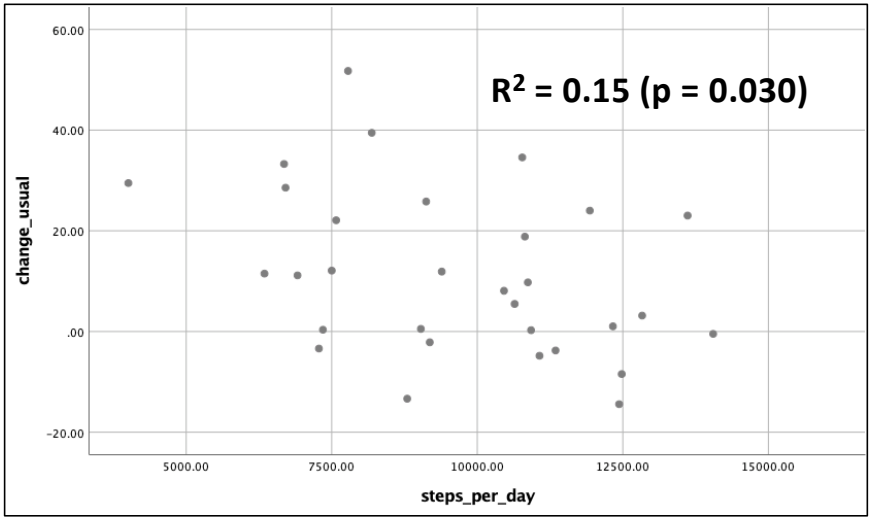


KOOS Subscale N=25	R^2 After accounting for meniscal status and gait speed
KOOS Pain	**0.42 (>0.001)**
KOOS Symptoms	0.09 (0.154)
KOOS ADL	**0.21 (0.017)**
KOOS Sport	**0.23 (0.017)**
KOOS QOL	**0.33 (0.004)**

Pietrosimone et al. Journal of Othro Research. 2018

Lesser Steps Per Day & Cartilage Breakdown

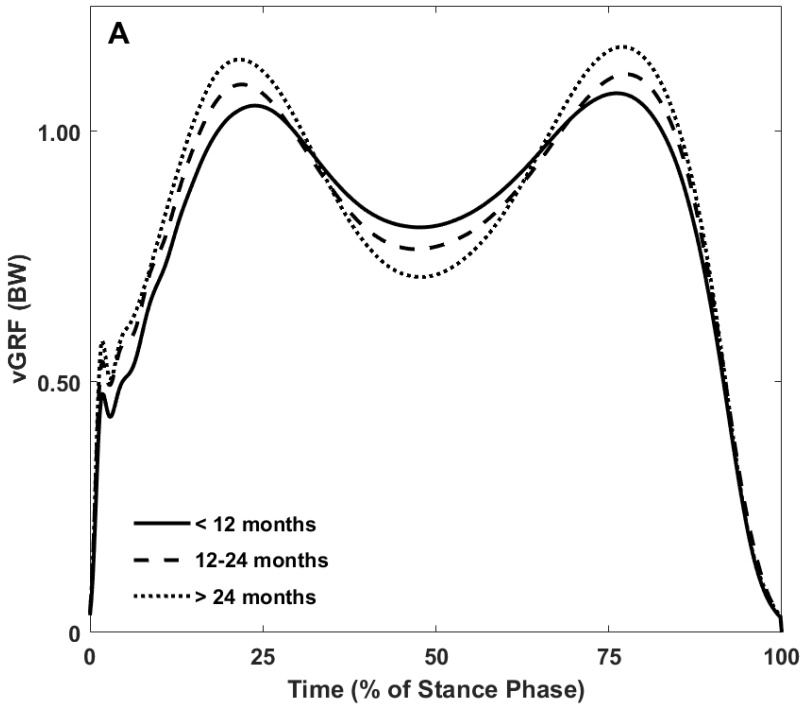
- Cross-sectional study in participants with primary unilateral ACLR
  - At least 6 months post-ACLR
- N=31



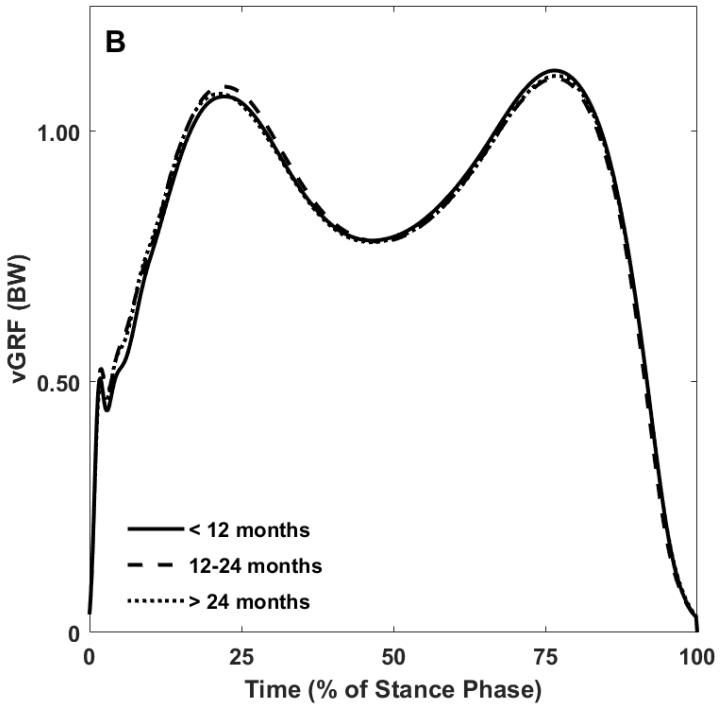
Davis-Wilson & Pietrosimone et al. ACSM 2020

What is Bad Biomechanics?

Symptomatic

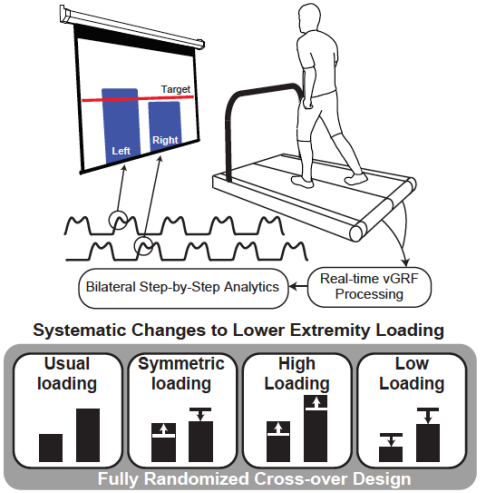


Asymptomatic

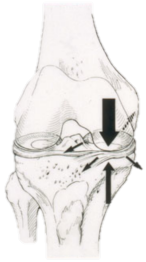


Pietrosimone & Seeley. Med Sci Sport and Exerc . 2018

Comprehensive Evaluation of of Over, Under and Symmetrical Loading



Patients between 6-12 Months ACLR



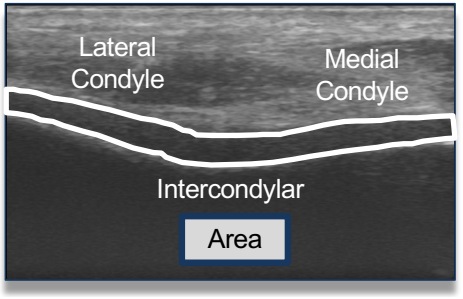
Gait Biomechanics & EMG Models of Contact Forces

Acute and Delayed Serum COMP Changes

NIAMS National Institute of Arthritis and Musculoskeletal and Skin Diseases
National Institutes of Health, Department of Health and Human Services

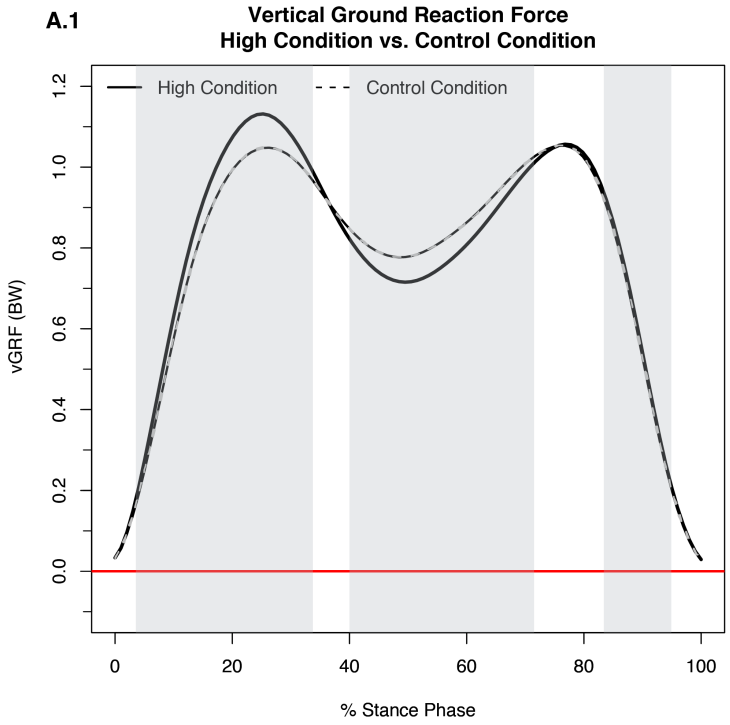
1R21AR0074094 -01

Ultrasound Measures of Acute Cartilage Deformation

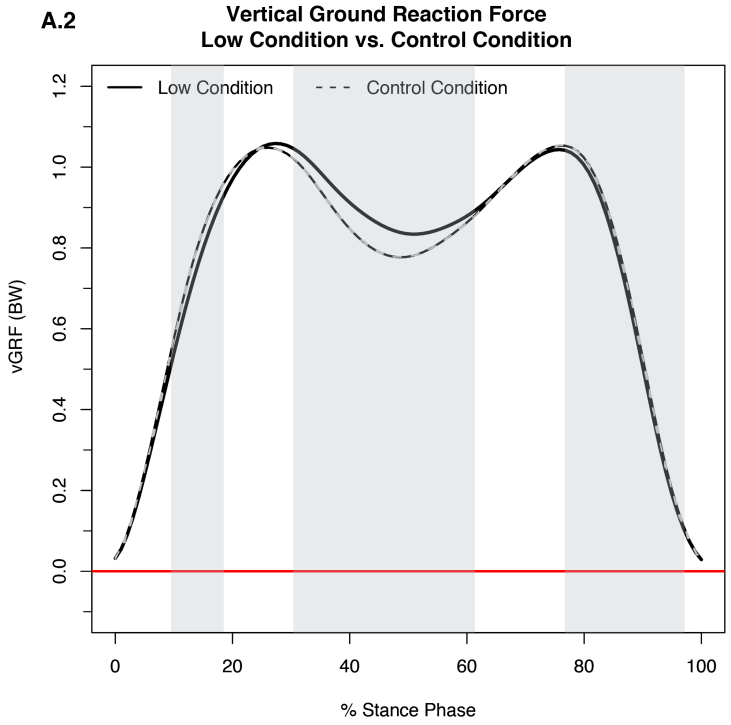


Feedback cueing Greater vs Lesser Loading

Cueing 5% Greater vGRF



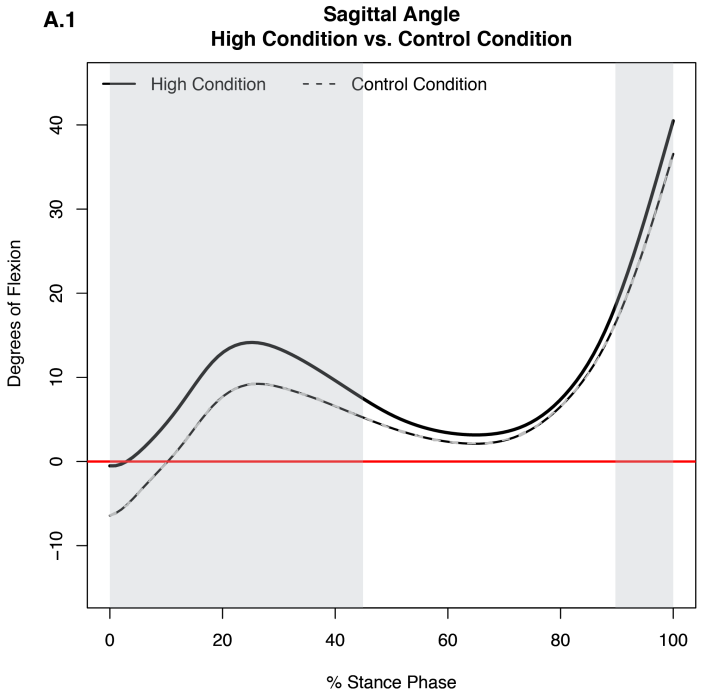
Cueing 5% L esser vGRF



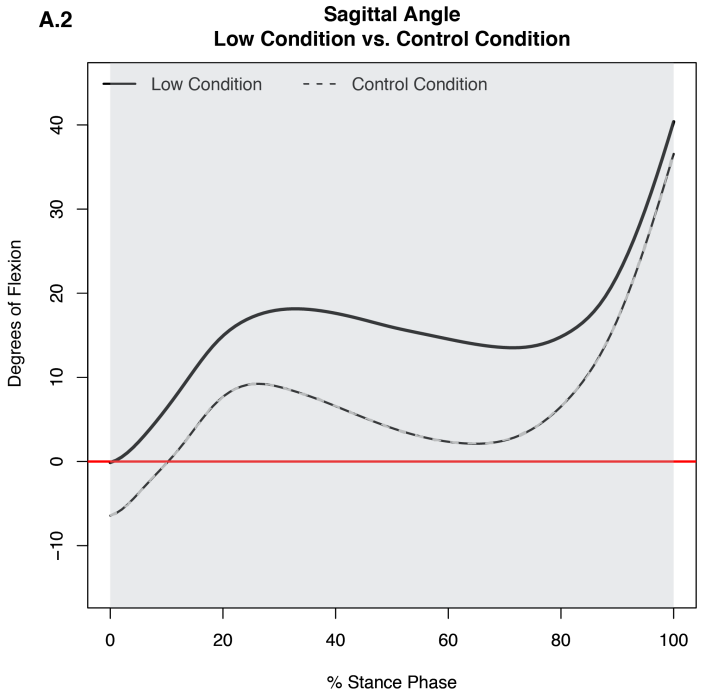
Pickett and Pietrosimone et al. In Review

Knee Flexion Angle

Cueing 5% Greater vGRF

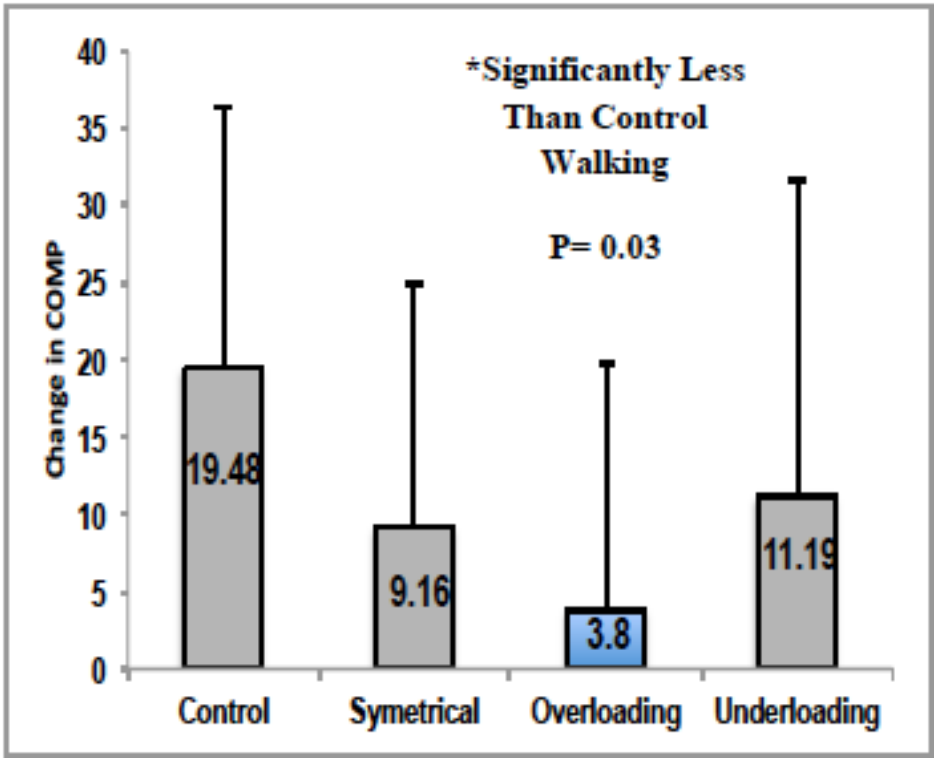


Cueing 5% L esser vGRF



Pickett and Pietrosimone et al. In Review

Change in Serum COMP



Brittney Luc-Harkey and Pietrosimone et al. NATA. 2018

Activity Modification

Encouraging exercise is important and safe

Quicke et al. Osteoarthritis & Cartilage. 2015

May need to instruct safe exercise on an individual patient basis:

- High loads/ ultra marathons
- Multiple Injuries increase risk
- Evaluate muscle strength and mechanics used to perform activities

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Activity Modification Contradictions

Overall athletics does not increase the odds of developing knee OA but certain sports may be at high risk including : elite-level long-distance running (OR = 3.3), competitive weight lifting (OR = 6.9), and wrestling OR = 3.8)

Driban et al. JAT. 2015

Athletes had significantly increased odds (2.9 [1.6, 5.4]) for developing tibiofemoral osteophytes following ACL injury

Roemer et al. Osteoarthritis and Cartilage. 2015

Habitual running does not necessarily increase OA progression in patients with knee OA

Chakravarty et al. Amer J Prev Med. 2008

Lo et al. Arth Care and Res. 2017

Risk of Multiple Injuries

General Health Questionnaire
NFL Retired Players Association

N= 2432
188 (7%) Reported a Knee Replacement
Average Age = 53.6%

Knee Replacement Prevalence
Adjusted for age and weight
* Statistically Significant

1 Knee Injury
25% (n=609)
Odds Ratio 1.78*
(1.14,2.77)

Odds Ratio 1.07
(0.68, 1.69)

2 Knee Injuries
17% (n=409)
Odds Ratio 1.91*
(1.16, 3.15)

3+ Knee Injuries
30% (n=729)
Odds Ratio 3.44*
(2.33, 5.09)

Odds Ratio 1.94*
(1.39, 2.71)

Davies and Pietrosimone et al. Under Review

Maintaining a Healthy Weight

- BMI one of the most predictive risk factors for idiopathic OA

  Muraki S. Arthritis Rheum (2012)

- Knee Injury is coupled with an increased risk of weight gain

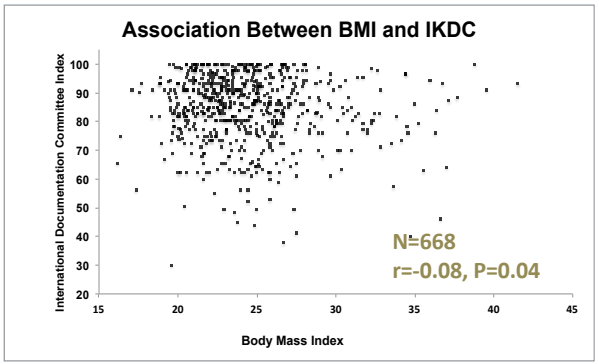
  Myer et al. Br J Sports Med. 2014

  Whittaker et al. Osteoarthritis Cartilage. 2015

- Increase in 10 lbs of body weight is 30-60lbs of force on the knee

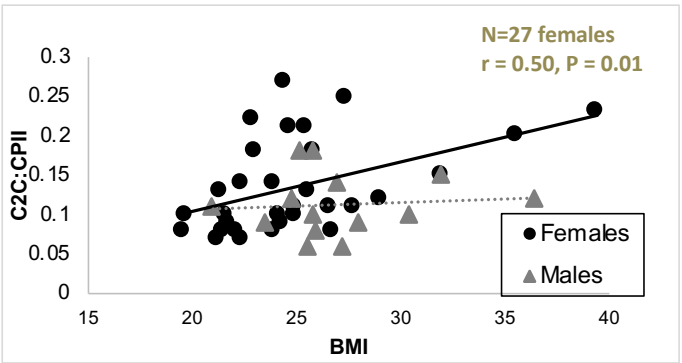
  Felson DT. J.Rheumatol. 1995

Weak Association for Function



Pietrosimone et al. KSTTA. 2018

Weak Association for Cartilage (Females)



Lane and Pietrosimone et al. JAT. 2019

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Managing PTOA Post ACLR

Understanding Risk

- OA a Major Healthcare Concern
- No Single Pathway to PTOA – Affects Multiple Tissues
- ACL reconstruction does not significantly decrease risk of PTOA
- 1 in 3 ACLR patients with radiographic PTOA in 1st decade

Detecting Risk

- **Traditional X-rays may not be sensitive**
- **No formal MRI definition for pre-OA**
- **Key MRI Features**
  - **BML**
  - **Compositional Changes**
  - **Early Cartilage Swelling**
  - **Later Cartilage Thinning**
  - **Bone Flattening**
- **Use of Self-Reported Outcomes & Walking Speed**

Managing Risk

- **Serial Assessment**
- **Educate patients about PTOA risk**
- **Sufficient & Symmetrical Strength**
- **Proper Biomechanics and Loading**
- **Smart Activity Modification**
- **Proper Body Weight**

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Check out the Athletic Trainers' OA Consortium

ATHLETIC TRAINERS' A T O A OSTEOARTHRITIS CONSORTIUM

www.atoac.org

Thank You

Brian Pietrosimone, PhD, ATC

brian@unc.edu

@bpietrosimone

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Our Mission is to Explore, Educate & Engage in
MUSCULOSKELETAL INJURY PREVENTION