Osteoarthritis: Preventing & Protecting Joint Health

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No Disclosures
Main Points for Today

- **Understand Risk** of Posttraumatic Osteoarthritis (PTOA) following ACL Injury
- **Detecting Risk** of PTOA in patients with an ACL Injury
- **Managing Risk** of PTOA in patients with an ACL Injury

Understand – Detect – Manage

Understanding the Risk

**Question #1**

Why Should Athletic Trainers Care About Knee Osteoarthritis (OA)?

- OA is a Major Healthcare Concern
- OA is the Consequence of Traumatic Knee Injury
- ATs Already Treat Early OA
Burden of Musculoskeletal Disease


Knee Injury Drives Joint Pain

Knee Osteoarthritis by the Numbers

11th Leading Cause of Disability Worldwide

4.9% of US Population with Symptomatic Knee OA

55 Median Age of Knee OA
Losina et al. Arthritis Care Res. 2013

17.1 Million Years Lived with Disability in 2010

Knee Osteoarthritis & Mortality

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

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

Neogi and Zhang. Epidemiology of Osteoarthritis. 2013
Posttraumatic Osteoarthritis

12 % of OA Cases Occur Following Injury

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

Difficult to Characterize Early OA

Multiple Tissues
• Bone
• Cartilage
• Synovia
• Fat Pad
• Meniscus
• Ligaments

Not a Single Pathway to Progression

Osteoarthritis is an End Result
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

ACL Deficient
  - n= 337

Decade 1
  - ACL Reconstructed n= 2500
  - Decade 1 36%

ACL Deficient
  - n= 337
  - Decade 1 34%

Posttraumatic OA Following ACL

2015 Clint Thompson Award for Clinical Advancement

Population Study - Olmsted Co, MN
- 144, 260 Individuals in 2010
- January 1990 – December 2010
- Sanders et al. AJSM. 2016
Posttraumatic OA Following ACL

ACL Reconstructed  
n= 2500  
Decade 2  48%

2015 Clint Thompson Award for Clinical Advancement

Decade 1 - 1 in 3  Decade 2 ~ 50%

The Standard of Care

What Can We Detect PTOA?  How Can we Manage PTOA Early?

Day 1  Day 2-9 Months  9 Months – 10 years  10 Years

ACL Injury  ACLR & Rehab  Physical Activity  Knee OA
Is There a Perception Problem?

- 40% of ATs unaware of PTOA
- 37% OA not Major Health Concern
- Underestimated Prevalence of PTOA in 1st Decade Post ACLR
- Overestimated the Benefit of ACLR in Reducing PTOA

Pietrosimone et al. J Ath Train. 2017

Impact of Clinical Experience

<table>
<thead>
<tr>
<th>Years of ATC Experience</th>
<th>1-5</th>
<th>6-10</th>
<th>11-15</th>
<th>16-20</th>
<th>21+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aware of PTOA</td>
<td>53%</td>
<td>54%</td>
<td>52%</td>
<td>69%</td>
<td>75%</td>
</tr>
<tr>
<td>Explain Risk of OA</td>
<td>60%</td>
<td>76%</td>
<td>73%</td>
<td>77%</td>
<td>80%</td>
</tr>
<tr>
<td>Provide Preventive Strategies to patients</td>
<td>58%</td>
<td>76%</td>
<td>71%</td>
<td>77%</td>
<td>81%</td>
</tr>
</tbody>
</table>

Potential Solution: Integrate PTOA prevention into entry-level athletic training education.
Detection of the Risk

Question #2
How can Athletic Trainers 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

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

Preoperative Differences
Lateral compartment = 5.4mm
ACL Between Limb Difference - 0.32mm
Controls Between Limb Difference -0.01mm

Preoperative Differences
Normal ranges from 95% CI of controls
31.6% ACLR demonstrated abnormal JSN
Normal changes between 0.01 (MC) & 0.02 (LC)

Tourville et al. AJSM. 2013

Detect Early Joint Changes

Tourville et al. AJSM. 2013,
Osteoarthritis and Cartilage
Kraus 2011,
Osteoarthritis and Cartilage
Kraus 2011,
Metabolic Alterations & ACL Injury

Search Strategy

- Searched Pubmed and Web of Science: "ACL AND (blood OR urine OR synovial fluid OR serum OR plasma OR biomarkers)"
- Initial search: 777
- Full text review: 56
- Final Included: 20
  - ACLD: 12
  - ACLR: 8

Harkey et al. Osteoarthritis and Cartilage. 2015

Changes in Cartilage Composition

Takeaway: Type II collagen and proteoglycan alterations commonly observed following ACL injury and ACLR. Inflammatory cytokine response inconclusive.

No Clear Early Soluble Biomarker of PTOA Following ACLR

Harkey et al. Osteoarthritis and Cartilage. 2015
There is **No CURRENT Accepted MRI Definition of Pre-OA**

MRI Findings Can Provide Clues Of Abnormal Changes

**Initial MRI Findings**

**Femoral Bone Marrow Lesions**
- 63% have BML on the lateral condyle following ACL injury

**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

**T1ρ MRI relaxation times were found to be greater in the articular cartilage overlaying bone contusions two months post ACLR**

Bolbos et al. Osteoarthritis and Cartilage. 2009

**T1rho relaxation times are associated with proteoglycan density & T2 with Collagen Orientation**

Rautiainen et al. Mag Reson in Med. Epub

**Decreased proteoglycan density is associated with OA progression and OA onset**

Regatte et al. Acad Radiol. 2002

**T2 Mapping relaxation times (collagen orientation) greater in the articular cartilage overlaying bone contusions at preoperative time point**


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Cartilage Composition

**Within Years 1 & 2**

Pietrosimone et al. NATA. 2016
12 Months Post- ACLR
**T1ρ MRI & ACL Injury**

Within Years 1 & 2

- **12-16 months** post in medial tibia and femoral cartilage compared to contralateral
  Theologis et al. KSSTA. 2014

- **1 year** post in posterior lateral tibial cartilage compared to controls
  Li et al. Radiology. 2011

- **2 years** post in medial femoral cartilage compared to controls
  Su et al. Osteoarthritis & Cartilage. 2013

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**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

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Change in cartilage thickness over 2 years after acute ACL injury

Frobell RB. J Bone Joint Surg Am. 2011
Assessing Cartilage with Ultrasound

Structural Outcomes: Thickness & Area
Thicker Cartilage Following ACLR

Cross-Sectional Area

<table>
<thead>
<tr>
<th>Cross-Sectional Area (mm²)</th>
<th>ACLR</th>
<th>Contralateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>96.7</td>
<td>85.7</td>
</tr>
<tr>
<td>105</td>
<td>2.61</td>
<td>2.46</td>
</tr>
<tr>
<td>90</td>
<td>2.46</td>
<td>2.29</td>
</tr>
<tr>
<td>85</td>
<td>2.24</td>
<td>2.0</td>
</tr>
<tr>
<td>80</td>
<td>2.0</td>
<td>2.2</td>
</tr>
<tr>
<td>75</td>
<td>2.2</td>
<td>2.4</td>
</tr>
<tr>
<td>70</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>65</td>
<td>2.6</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Thickness

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Med Thick</th>
<th>Lat Thick</th>
<th>Int Thick</th>
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</thead>
<tbody>
<tr>
<td>3.0</td>
<td>2.61</td>
<td>2.36</td>
<td>2.24</td>
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<tr>
<td>2.8</td>
<td>2.46</td>
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<tr>
<td>2.6</td>
<td>2.29</td>
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</table>

*Different than ACLR Limb

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

Harkey et al. 2017 NATA Annual Meeting

Curvature of Bone

- 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
Possible MRI Summary Timeline

<table>
<thead>
<tr>
<th>ACL Injury</th>
<th>Month 6</th>
<th>Month 12</th>
<th>Month 18</th>
<th>Month 24</th>
<th>Month 30</th>
<th>Month 36</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traumatic BML</td>
<td></td>
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<tr>
<td>Chronic BML</td>
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<tr>
<td>Compositional Changes in Cartilage</td>
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<td></td>
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<tr>
<td>Cartilage Thickening</td>
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<tr>
<td>Cartilage Thinning</td>
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<tr>
<td>Femoral Bone Flattening</td>
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</tbody>
</table>

Patient-Reported Outcomes

Knee Injury and Osteoarthritis Outcomes Score

International Knee Documentation Committee Index
Patient- Reported Outcomes

Knee Injury and Osteoarthritis Outcomes Score
Roos et al. Health Qual Life Outcomes. 2003

Method 1: KOOS knee-related quality of life (QoL) ≤ 87.5
AND two or more of the other subscales:
   KOOS pain ≤ 86.1,
   KOOS symptoms ≤ 85.7,
   KOOS activities of daily living (ADL) ≤ 86.8,
   KOOS sports and recreation (“sport/rec”) ≤85.0

Method 2: KOOS knee pain ≤72 points (2 SD < Mean)

Method 3: KOOS pain Minimal Clinically Important Difference
   • 6.1 points in athletes after ACL reconstruction
     Salavati M. Osteoarthritis and Cartilage. 2011
   • 8 and 10 points for patients with Knee OA
     Roos EM. Health Qual Life Outcomes. 2003

Using KOOS Cut-Off Scores

• Multicenter Orthopaedic Outcomes Network (MOON)

• Significant Disability Found at 2 and 6 Year Follow-ups

• There is no accepted self-reported definition but these cut-off scores can provide a basis for determining significant changes over time

• Model 1 Identified the Most Patients

<table>
<thead>
<tr>
<th>Method</th>
<th>Year 2 N=1530</th>
<th>Year 6 N=1506</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1 KOOS QoL≤ 87.5 + 1 KOOS Other Subscale</td>
<td>43%</td>
<td>39%</td>
</tr>
<tr>
<td>Method 2 KOOS Pain ≤ 72</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>Method 3 KOOS Pain change of 10</td>
<td>12%</td>
<td></td>
</tr>
</tbody>
</table>

Wasserstein et al. Osteoarthritis Cartilage. 2015
KOOS & Cartilage Composition

<table>
<thead>
<tr>
<th>KOOS Score</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>-0.54</td>
</tr>
<tr>
<td>Activities of Daily Living</td>
<td>-0.56</td>
</tr>
<tr>
<td>Sports Function</td>
<td>-0.62</td>
</tr>
<tr>
<td>Quality of Life</td>
<td>-0.59</td>
</tr>
</tbody>
</table>

N= 18, Unilateral ACLR

Pietrosimone et al. OARSI. 2016
Manuscript in Review

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

Can Walking Speed Predict PTOA?
Slower Walkers and T1ρ

Participants: 9 males, 11 females

<table>
<thead>
<tr>
<th>Age</th>
<th>22.05 ± 3.93 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>177.47 ± 12.58 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>75 ± 13.91 kg</td>
</tr>
<tr>
<td>BMI</td>
<td>23.63 ± 2.39 kg/m²</td>
</tr>
<tr>
<td>Days between ACL injury and ACLR</td>
<td>32.35 ± 14.17 days</td>
</tr>
<tr>
<td>6 month Following ACLR Walking Speed</td>
<td>1.30 ± 0.12 m/s</td>
</tr>
</tbody>
</table>

Study Design

Pfeiffer et al. In Review

Slower Walkers and T1ρ

r=-0.495, P=0.013

Pfeiffer et al. In Review
Collagen Degradation & Walking Speed

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

Pietrosimone et al. Arth Care Res. 2016

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Collagen Type-II Collagen Cleavage Product (C2C)

Slower Walker & Greater C2C

![Graph showing the relationship between serum C2C and walking speed with r = -0.52, P = 0.02](image)

Pietrosimone et al. Arth Care Res. 2016
Managing the Risk

Question #3
How can Athletic Trainers 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

Guidelines For Managing PTOA

- There are no disease modifying interventions for PTOA
  - WE CAN STILL DO SOMETHING!
- Most guidelines are for idiopathic knee OA
- Implementation methods for current guidelines are lacking
- Current Best Practices
  - Serial Assessment
  - Education
  - Exercise and Proper Strength/Mechanics
  - Weight Management

Nelson et al. Seminars Arth and Rheum. 2014
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

Improvements in jumping biomechanics are not maintained
Padua et al. AJSM.

Education of Our Patients

- Athletic Trainers may not explain the risk of PTOA
  Pietrosimone et al. J Ath Train. Epub

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%)

<table>
<thead>
<tr>
<th>Treat ACL Injured Patients</th>
<th>ACL Injury Increases the Risk of OA</th>
<th>Its appropriate for ATs to explain the risk</th>
<th>Do you explain the risk</th>
<th>Do you provide strategies to decrease the risk of OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>93%</td>
<td>90%</td>
<td>97%</td>
<td>71%</td>
<td>71%</td>
</tr>
</tbody>
</table>

Pietrosimone et al. J Ath Train. 2017
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

Maximizing Quadriceps Strength

Quadriceps Weakness Linked to Joint Space Narrowing
ACLR Patients with tibiofemoral joint space narrowing weaker at 4 year follow-up compared to those without narrowing
Tourville et al. AJSM. 2014

Quadriceps Weakness Increases Odds of Incidence OA
> 5700 patients (2-14 year FU)
Odds Ratio = 1.65 (1.23-2.21)
Oiestad et al. Osteoarthritis Cartilage.2015
Muscle Strength & Disability

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

Pietrosimone et al. MSSE. 2016.

Quadriceps Weakness & Stiffen Knee Gait

Radin et al. JOR. 1991
Palmieri-Smith & Thomas. ESSR. 2009
Hart et al. Clin Biomech. 2010
Early Off-Loading and Worse Outcomes

$\rho = -0.59, P = 0.007$

Pietrosimone et al. AJSM. 2016

More on this Thursday between 3:30pm - 5:30pm!!!!

Session Title: Improving Outcomes Following ACL Injury and Reconstruction: Implications for Clinical Management

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
**Activity Modification Contradictions**

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

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

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

Lo et al. Arth Care and Res. 2017

**Maintaining a Healthy Weight**

- BMI one of the most predictive risk factors for idiopathic OA
  Muraki S. Arthritis Rheum (2012)

- Persistent disability is coupled with an increased risk of undesirable weight gain following injury
  Whittaker et al. Osteoarthritis Cartilage. 2015

**Weak Association for Function**

Pietrosimone et al. ACSM. 2017

**Weak Association for Cartilage (Females)**

Lane and Pietrosimone et al. SEACSM. 2017
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

Join the Athletic Trainers’ OA Consortium

www.atoac.org
Further Information NATA 2017

REDUCING YOUR RISK FROM OSTEOARTHRITIS. WHAT YOU CAN DO, WHAT THE RESEARCH SAYS
TUESDAY, JUNE 27, 9:30-10:15 A.M
Room 330

JOURNAL OF ATHLETIC TRAINING SPECIAL OSTEOARTHRITIS ISSUE
RELEASED TUESDAY, JUNE 27

NATA RESEARCH AND EDUCATION SESSION
“Improving Outcomes Following ACL Injury and Reconstruction: Implications for Clinical Management”
Thursday, JUNE 29, 3:30pm - 5:30pm
David Bell, Brian Pietrosimone & Kurt Spindler

Dr. Adam Lepley
University of Connecticut

Dr. Hayley Erickson
University of Northern Kentucky

Dr. Michelle McLeod
College of Charleston

Matthew Harkey MS

Britney Luc-Harkey MS

Steven Pfeiffer MS
Hope Davis MA

NIAMS National Institute of Arthritis and Musculoskeletal and Skin Diseases

1R21AR067560 -01
R03AR066840-01A1

30
Thank You

brian@unc.edu
@bpietrosimone