INDIVIDUALIZED ASSESSMENT OF INJURY RISK

Gary Wilkerson, EdD, ATC

Evidence-Based Approach to Injury Prevention

- Documentation of Injury Incidence Rate (Injuries/Exposures)
- Identification of Injury Risk Factors (Predictive Model for Injury Occurrence)
- Development and Implementation of Strategies to Reduce Injury Risk
- Confirmation that Risk Reduction Program Decreases Injury Incidence Rate
Identification of Injury Risk Factors

- Risk factors identified by analysis depend upon:
  - **Injury definition** (broad vs. restrictive)
  - **Demands imposed by activity** (sport, playing position)
  - **Population** (gender, age, performance level)

- Prediction accuracy (validity + precision) depends upon:
  - Cohort size and number of criterion-positive (injured) cases

Examples:
- Football (FCS) – Core or LE Joint Sprain or Muscle Strain
- Football (BCS) – Core or Hip/Groin Muscle Strain
- Multi-Sport Cohort – Core or LE Joint Sprain or Muscle Strain
- Football (FCS) – Lateral Ankle Sprain or Syndesmosis Sprain

Research Evidence: Injury Risk Factors

1. **Volume of Exposure to High-Stress Activities**
   - Frequency (and duration) of participation in games
     - Games played and/or status on team (starter vs. non-starter)
   - **Gender – Sport – Position – Level of Competition**
     - Team vs. individual sport: Running mileage, pitch count, etc.

2. **Previous Injuries**
   - Incomplete recovery of pre-injury functional capabilities
     - Higher risk if < 6 months prior
   - Pre-existing functional deficiency may have contributed
     - Oswestry Disability Index, IKDC Knee Score, FAAM-S Score
3. Anthropometric Characteristics
- Body mass to height relationship
  - BMI, COM height, Estimated Mass Moment of Inertia
- Structural alignment of joints
  - Foot Width Index, Q-angle

4. Joint Stability
- General joint hypermobility
  - Beighton scale
- Ligament laxity
  - Arthrometer (KT1000)

5. Neuromuscular Performance Capabilities
- Core muscle endurance and position sense
  - Wall Sit Hold, Horizontal Trunk Hold
- LE mobility + postural balance (dynamic COM control)
  - Y-Balance (Anterior) Test, FMS Lunge Test
- Strength/Power (relative to uninvolved or antagonist)
  - Isokinetic dynamometer
6. Reaction Time
- Reactive (simple) motor response
  - Drop-stick test
- Mental processing of visual input + motor response (choice)
  - ImPACT neurocognitive test (composite reaction time)

7. Psychosocial Stress
- Anxiety, depression, apathy, insomnia, etc.
  - Life Events Survey for College Athletes

Decision to Take Action

- **Consequence of the choice** (risk vs. benefit)
  - Severity of loss associated with an adverse outcome
  - Degree of benefit that may be derived

- **Confidence in the outcome** (desirable vs. undesirable)
  - **Objectively known** probabilities
    - Games of chance (coin flips, dice, cards, roulette)
  - **Subjectively estimated** probabilities
    - Absolute determination of event likelihood impossible, due to the multitude of factors influencing it (treatment outcome)
Objective Probability

- The expected frequency of occurrence of a specified event in relation to the set of possible events
  - Always associated with some degree of uncertainty
  - Expressed as a proportion (or percentage)
    - Coin toss: 2 possible events: Head or Tail
      - .5 probability for either one (1/2)
    - Probability of Heads on consecutive coin flips
      - 2 consecutive tosses: (.5)^2 = .25
      - 3 consecutive tosses: (.5)^3 = .12
      - 4 consecutive tosses: (.5)^4 = .06
      - 5 consecutive tosses: (.5)^5 = .03

Relative Risk (RR) vs. Odds Ratio (OR)

- Relative Risk (or Risk Ratio):
  - Ratio of the **probability** for a specified outcome (injury) for one group in relation to the probability for another group
    - Low-risk group vs. High-risk group
    - If the probability is the same for both groups, RR = 1.0

- Odds Ratio:
  - Ratio of the **odds** for a specified outcome (injury) for one group in relation to the odds for another group
    - If the odds are the same for both groups, OR = 1.0
## Probability vs. Odds

- The likelihood for occurrence of a given outcome
  1. Expressed as proportion or percentage (proportion x 100)
  2. Expressed in terms of odds “for” vs. “against” outcome

### Probability vs. Odds of “Heads” on both of 2 coin flips:

- 4 possibilities:
  - HH
  - HT
  - TH
  - TT
  - Probability = 1/4  = .25
  - Odds “for” = 1/3 = .33
  - Odds “against “ = 3:1

## What is the level of risk?

- Exposure-Outcome Association

  - Substantial:  $RR \geq 3.0$  $OR \geq 8.0$
  - Moderate:    $RR \geq 1.5$  $OR \geq 4.0$
  - Meaningful:  $RR \geq 1.1$  $OR \geq 2.0$
Prediction of Core or LE Sprain or Strain
2009-2011 Football Seasons (N=256)

Relative Risk vs. Odds Ratio
Starter Status ≥ 1 Game

<table>
<thead>
<tr>
<th>Starter Status ≥ 1 Game</th>
<th>Core/LE Sprain-Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Injury</td>
</tr>
<tr>
<td>YES (106)</td>
<td>63</td>
</tr>
<tr>
<td>NO (128)</td>
<td>40</td>
</tr>
<tr>
<td>Total (256)</td>
<td>103</td>
</tr>
</tbody>
</table>

Sensitivity = 61% Specificity = 72%

- 103/256 cases sustained Core or LE sprain or strain in 2009-2011 (40%)
- 63/106 who started ≥ 1 game sustained Core or LE sprain or strain (59.4%)
- High-Risk Group: Odds of injury = .594 / .406 = 1.46
- 40/150 who did not start in any game sustained Core or LE sprain or strain (26.7%)
- Low-Risk Group: Odds of injury = .267 / .733 = .36

Relative Risk = .594 / .267 = 2.2  Odds Ratio = 1.46 / .36 = 4.0

Injury Risk: Games vs. Practices

Volume of Exposure to High-Stress Activities

- Injuries per 1000 athlete-exposures (over 16 years)
  - 15 NCAA sports
    - Game injury rate: 13.8
    - Practice injury rate: 4.0
      - Pre-season: 6.3
      - In-season: 2.3
    - 3.5 X diff.
  - Football (all 3 divisions combined)
    - Game injury rate: 36.0
    - Practice injury rate: 3.8
      - Pre-season: 7.2
      - In-season: 2.1
    - 9.5 X diff.

### Previous Injury

- **Soccer players (Czech Republic); any injury; N=254**
  - History of >6 previous injuries – **OR=2.8** (95% CI: 1.2 – 6.2)

- **High school football players; any injury; N=717**
  - History of previous injury – **OR=1.8** (95% CI: 1.1 – 3.1)
    - *Adjusted: Years of playing experience

- **Physically active young adults (Netherlands); any injury; N=139**
  - History of previous injury – **OR=9.4** (95% CI: 2.8 – 31.6)
    - *Adjusted: Exposure time, life events, exhaustion, anxiety, personality dominance

### Prediction of Core or LE Strain or Sprain

#### 2009 Football Season (N=83)

- Have you previously sustained a **Knee injury** that required use of crutches and/or prevented participation in sports activities for two or more days?
  - No = 0  Yes = 1
- Have you previously sustained a **Foot/Ankle injury** that required use of crutches and/or prevented participation in sports activities for two or more days?
  - No = 0  Yes = 1

<table>
<thead>
<tr>
<th>Previous Knee &amp; Foot/Ankle Injury</th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both + (2)</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>1 or 0 +</td>
<td>32</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>44</td>
</tr>
</tbody>
</table>

- Sensitivity: .18  Specificity: .98

- 39/83 players sustained Back or LE injury in 2009 (47%)
- 7/8 with previous Knee + Foot/Ankle injuries sustained Back or LE injury (87.5%)
  - Odds of injury = .875 / .125 = 7.0  (Odds 7:1)
- 32/75 without previous Knee or Foot/Ankle injury sustained Back or LE injury (42.7%)
  - Odds of injury = .427 / .573 = .745  (Odds 3:4)

Relative Risk = .875 / .427 = 2.1  Odds Ratio = 7.0 / .745 = 9.4
Injury Risk

- Neuromuscular Performance Capabilities
  - Overlap with previous injuries (incomplete recovery)
    - Joint-specific surveys for self-rating of function level (0-100)
      - Foot and Ankle Ability Measure – Sport Subscale
      - International Knee Documentation Committee Survey
      - Oswestry Disability Index (Low Back Dysfunction)
    - Muscle strength/endurance
    - Postural balance and mobility (dynamic COM control)
      - Functional Movement Screen
      - Star Excursion Balance Test → Y-Balance Test

PPE Survey
- Recent Sprain/Strain Hx
- Game Exposure
Alteration of posture changes the center of mass location over the base of support

Generation of muscle tension required to counteract external moments acting on joints

“The ability to control the position and motion of the trunk over the pelvis & legs to allow optimum production, transfer, control of force and motion.”

Kibler et al, Sports Med, 2006

Fatigue resistance of core muscles and neuromuscular activation patterns may be more important than strength/power.
2009 Starting Point – Test Selection

  - Back Extension, Trunk Flexion, & Side-Bridge Holds
    - 75 college-age subjects (31 male & 44 female)
      - Mean age = 23
    - 5 consecutive days: test-retest reliability
      - ICC = .97 - .99

<table>
<thead>
<tr>
<th>Test</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back Extension</td>
<td>146 ± 51</td>
<td>189 ± 60</td>
</tr>
<tr>
<td>Trunk Flexion</td>
<td>144 ± 78</td>
<td>149 ± 99</td>
</tr>
<tr>
<td>Side-Bridge Right</td>
<td>94 ± 34</td>
<td>72 ± 31</td>
</tr>
<tr>
<td>Side-Bridge Left</td>
<td>97 ± 35</td>
<td>77 ± 35</td>
</tr>
</tbody>
</table>

2009 Football Core/LE Injury Analysis

N=83

- Core Endurance Tests
  - Back Extension Hold (BEH)
  - Trunk Flexion Hold (TFH)
  - Side-Bridge Hold (SBH)
  - Wall Sit Hold (WSH)

- Joint Function Surveys:
  - Oswestry Disability Index
  - International Knee Documentation Committee (IKDC) Survey
  - Foot and Ankle Ability Measure

- Other Injury Risk Factors:
  - Previous Knee or Ankle Injury
  - Body Mass Index
  - Games Started
  - Games Played

<table>
<thead>
<tr>
<th>Injury Location</th>
<th>Total Injured Players</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Back /S-I</td>
<td>7</td>
</tr>
<tr>
<td>Groin/Thigh</td>
<td>12</td>
</tr>
<tr>
<td>Knee</td>
<td>8</td>
</tr>
<tr>
<td>Ankle/Foot</td>
<td>12</td>
</tr>
<tr>
<td>Total Injured Players</td>
<td>39</td>
</tr>
</tbody>
</table>
“Injury” Definition

- Datalys Center – NCAA Injury Surveillance System
  - Result of participation in practice session or competition
  - Required the attention of an athletic trainer or physician
  - Resulted in participation restriction for one or more days
    - 2009 Report for 2004-2009 academic years: 3rd criterion discarded
      - Distinction between timeloss and non-timeloss often arbitrary

- Core = Abdomen + Lumbo-Pelvic-Hip Complex
- Included: Core or LE muscle strain or joint sprain
- Excluded: Fractures and contusions

2009 Prediction of Back or LE Injury

“Injury” = Missed OR Limited Practice

<table>
<thead>
<tr>
<th>Oswestry Disability Index</th>
<th>Injury</th>
<th>No Inj</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 6</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>&lt; 6</td>
<td>26</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>44</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p = .055
Sensitivity = .33 Specificity = .84
+LR = 2.10 –LR = .79
Odds Ratio = 2.10/.79 = 2.64
90% CI: 1.10 - 6.36
Relative Risk = .650/.413 = 1.58
90% CI: 1.09 - 2.27
Oswestry Disability Index (0-100 score)

Pain Intensity
- Score of 0-100 reflects intensity of pain
- Scores indicate:
  - 1-10: Minor pain
  - 11-30: Moderate pain
  - 31-50: Severe pain
  - 51-80: Very severe pain
  - 81-100: Extreme pain

Standing
- Score of 0-100 reflects ability to stand
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

Personal Care (Washing, Dressing, etc.)
- Score of 0-100 reflects ability to manage personal care
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

Sleeping
- Score of 0-100 reflects ability to sleep
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

Lifting
- Score of 0-100 reflects ability to lift
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

Social Life
- Score of 0-100 reflects ability to engage in social activities
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

Walking
- Score of 0-100 reflects ability to walk
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

Sitting
- Score of 0-100 reflects ability to sit
- Scores indicate:
  - 0: No pain
  - 1: Mild pain
  - 2: Moderate pain
  - 3: Severe pain
  - 4: Very severe pain
  - 5: Extreme pain

2009 4-Factor Injury Prediction Model

Cumulative Injury Incidence Comparison
Initiation of Pre-Season Practices to End of 11-Game Season

2010 Core & Lower Extremity Strains/Sprains

Hi Risk: ≥2 Risk Factors
Lo Risk: 0 or 1 Risk Factor

Relative Risk = (Hi Risk: 16 injuries / 18 players) / (Lo Risk: 23 injuries / 70 players)
= 0.889 / 0.329 = 2.7

3-Factor Injury Prediction Model
- Starter Status ≥ 1 Game
- ODI Score ≥ 4 Points
- WSH - Non-Dominant ≤ 41 Seconds

<table>
<thead>
<tr>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi Risk</td>
<td>16</td>
</tr>
<tr>
<td>Lo Risk</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
</tr>
</tbody>
</table>

Hi Risk Injury Odds 8:1
Lo Risk Injury Odds 1:2
Odds Ratio = 8.0/0.5 = 16

2009 – 2011
Wall-Sit Hold Modifications

2009 N = 83
Mean = 79 s SD = 34 s
≤ 60 s OR = 2.08

2010 N = 88
Mean = 61 s SD = 27 s
≤ 45 s OR = 2.18

2011 N = 85
Mean = 28 s SD = 14 s
≤ 30 s OR = 2.04
Functional Movement Screen

7 movement patterns – 0-3 rating (max score: 21)

Research evidence:
- 46 professional football players (Kiesel et al, 2007)
  - ≤ 14 prediction of 3-wk time loss injury: \( \text{OR} = 11.7 \) (95% CI: 2.5 – 54.5)
- 49 marathon runners Hoover et al, 2008)
  - ≤ 14 prediction of overuse injury: \( \text{OR} = 1.9 \) (95% CI: 0.1 – 19.3)
- 112 high school M/F basketball players (Sorenson, 2009)
  - < 14 prediction of non-contact injury: \( \text{OR} = 0.9 \) (95% CI: 0.4 – 2.4)
- 874 Marine officer candidates (O’Connor et al, 2011)
  - ≤ 14 prediction of any injury: \( \text{OR} = 2.0 \) (95% CI: 1.3 – 3.1)

Functional Movement Screen

Field-expedient screening and injury risk algorithm categories as predictors of noncontact lower extremity injury
Scan J Med Sci Sports. 2013
- Lehr ME, Plisky PJ, Butler RJ, Fink ML, Kiesel KB, Underwood FB

- 183 NCAA Division III athletes from 10 sports
- Injury definition: Noncontact, ≥1 day of time loss from sport
- Move2Perform algorithm: 7 FMS tests + YBT
  - “Normal” Risk: FMS ≥14, YBT ≥ gender/sport/age standard, no asymmetries apparent, no pain during testing, injury-free for ≥ 1 year
  - Low-Risk (Normal or slight); High-Risk (moderate or substantial)
- 23% (42/183) injured; \( \text{RR} = 3.4 \) (95% CI: 2.0 – 6.0)
# Core + Lower Extremity Sprains & Strains

## NCAA Division I-BCS Football  \( N = 74 \)

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Back Strain</td>
<td>1</td>
</tr>
<tr>
<td>Abdominal Strain (Sport Hernia)</td>
<td>3</td>
</tr>
<tr>
<td>Hamstring Strain</td>
<td>11</td>
</tr>
<tr>
<td>Groin Strain</td>
<td>9</td>
</tr>
<tr>
<td>Hip Flexor Strain</td>
<td>3</td>
</tr>
<tr>
<td>Quadriceps Strain (Distal Thigh)</td>
<td>1</td>
</tr>
<tr>
<td>Knee Sprain</td>
<td>10</td>
</tr>
<tr>
<td>Calf Strain</td>
<td>1</td>
</tr>
<tr>
<td>Ankle Sprain</td>
<td>10</td>
</tr>
<tr>
<td>Foot Sprain</td>
<td>1</td>
</tr>
<tr>
<td>Toe Sprain (Sesamoiditis)</td>
<td>1</td>
</tr>
</tbody>
</table>

* 35 players sustained 51 core or LE strains/sprains
  - 14 players sustained 2 injuries
  - 1 player sustained 3 injuries

## FMS: Deep Squat

![Deep Squat Diagram]

<table>
<thead>
<tr>
<th>Movement</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Upper torso is parallel with shins or toward vertical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Femur is below horizontal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Knees are aligned over feet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Dowel does not extend past feet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Performance with knees on 2x6 board*
FMS: Hurdle Step

AUC = .57

<table>
<thead>
<tr>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1</td>
<td>12</td>
</tr>
<tr>
<td>&gt; 1</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
</tr>
</tbody>
</table>

Sensitivity: .34  Specificity: .79

RR: 1.41  OR: 2.02

FMS: In-Line Lunge

AUC = .59

<table>
<thead>
<tr>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1</td>
<td>12</td>
</tr>
<tr>
<td>&gt; 1</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
</tr>
</tbody>
</table>

Sensitivity: .34  Specificity: .79

RR: 1.41  OR: 2.02
FMS: Shoulder Mobility

AUC = .55

FMS: Active Straight-Leg Raise

AUC = .51
FMS: Push-Up

AUC = .45

3 2 1
• Male performs one rep. with thumbs aligned with chin
• Female performs one rep. with thumbs aligned with chin
• Body is lifted at one unit (no leg in back or speed)
• Feet remain dorsiflexed
• Male is unable to perform one rep. with hands aligned with chin
• Female is unable to perform one rep. with thumbs aligned with chin

FMS: Rotary Stability

AUC = .51

3 2 1
• Performs one correct unilateral repetition while keeping spine parallel to board
• Knee and elbow must be in line over the board
• Male is unable to perform diagonal repetition
• Performs one correct diagonal repetition while keeping spine parallel to board
• Knee and elbow must be in line over the board
• Male is unable to perform diagonal repetition
Core + Lower Extremity Sprains & Strains

<table>
<thead>
<tr>
<th>Functional Movement Screen</th>
<th>Injury</th>
<th>No Inj</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 14</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>&gt; 14</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>39</td>
</tr>
</tbody>
</table>

Fisher’s exact p = .221

Sensitivity: .63  +LR: 1.23
Specificity: .49  -LR: .76
RR: 1.29  OR: 1.61

Football Core + Hip/Groin Muscle Strains

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Back</td>
<td>1</td>
</tr>
<tr>
<td>Abdominal (Sport Hernia)</td>
<td>2</td>
</tr>
<tr>
<td>Sport Hernia + Hamstring</td>
<td>1</td>
</tr>
<tr>
<td>Hamstring</td>
<td>7</td>
</tr>
<tr>
<td>Hamstring + Groin</td>
<td>3</td>
</tr>
<tr>
<td>Groin</td>
<td>6</td>
</tr>
<tr>
<td>Hip Flexor</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total Cases (Players)</strong></td>
<td><strong>23</strong>*</td>
</tr>
</tbody>
</table>

* 8 cases sustained another lower extremity strain or sprain
### Football Core + Hip/Groin Muscle Strains

#### Functional Movement Screen

<table>
<thead>
<tr>
<th></th>
<th>Injury</th>
<th>No Inj</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 14</td>
<td>13</td>
<td>29</td>
</tr>
<tr>
<td>&gt; 14</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>51</td>
</tr>
</tbody>
</table>

Fisher’s exact $p = .588$

- Sensitivity: .57
- Specificity: .43
- $RR: .99$
- $OR: .99$

#### Football Core + Hip/Groin Muscle Strains

<table>
<thead>
<tr>
<th>Position Category*</th>
<th>Injury</th>
<th>No Inj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi Risk</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Lo Risk</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>51</td>
</tr>
</tbody>
</table>

Fisher’s exact $p = .133$

- Sensitivity: .83
- Specificity: .59
- $RR: 4.04$
- $OR: 6.79$
Core + Hip Muscle Strains

Wall Sit Hold – Average R & L

<table>
<thead>
<tr>
<th></th>
<th>Injury</th>
<th>No Inj</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 20 s</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>&gt; 20 s</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>51</td>
</tr>
</tbody>
</table>

Fisher’s exact p = .006
Sensitivity: .83  +LR: 1.69
Specificity: .51  -LR: .34
RR: 3.24  OR: 4.94

Football Core + Hip/Groin Muscle Strains

* Hi Risk Position AND WSH-Avg R & L ≤ 20 sec

2-Factor Prediction Model

<table>
<thead>
<tr>
<th></th>
<th>Injury</th>
<th>No Inj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both Positive</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>0 or 1 Positive</td>
<td>8</td>
<td>41</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>51</td>
</tr>
</tbody>
</table>

Fisher’s exact p < .001
Sensitivity: .65  +LR: 3.33
Specificity: .80  -LR: .43
RR: 3.68  OR: 7.69
(90% CI: 2.03 - 6.67)  (90% CI: 3.05 - 19.38)

AUC = .66

AUC = .78

(90% CI: 2.03 - 6.67)  (90% CI: 3.05 - 19.38)
Football Core + Hip/Groin Muscle Strains

2009 – 2011 Football Core/LE Sprains & Strains

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Back Strain/S-I Sprain</td>
<td>9</td>
</tr>
<tr>
<td>Abdominal/Hip Flexor/Groin Strain</td>
<td>36</td>
</tr>
<tr>
<td>Hamstring Strain</td>
<td>15</td>
</tr>
<tr>
<td>Quadriceps Strain (Distal Thigh)</td>
<td>3</td>
</tr>
<tr>
<td>Knee MCL Sprain</td>
<td>10</td>
</tr>
<tr>
<td>Knee ACL Tear</td>
<td>3</td>
</tr>
<tr>
<td>Knee PCL Tear</td>
<td>1</td>
</tr>
<tr>
<td>Knee Meniscus/Osteochondral Lesion</td>
<td>3</td>
</tr>
<tr>
<td>Knee Hyperextension Sprain</td>
<td>1</td>
</tr>
<tr>
<td>Patello-Femoral Sprain/Subluxation</td>
<td>3</td>
</tr>
<tr>
<td>Achilles Tendon Strain</td>
<td>1</td>
</tr>
<tr>
<td>Lateral Ankle Sprain</td>
<td>27</td>
</tr>
<tr>
<td>Syndesmosis (High Ankle) Sprain</td>
<td>10</td>
</tr>
<tr>
<td>Medial Ankle Sprain</td>
<td>1</td>
</tr>
<tr>
<td>Mid-Foot Sprain</td>
<td>6</td>
</tr>
<tr>
<td>First Metatarsophalangeal Sprain</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total Core + LE Injuries</strong></td>
<td><strong>132</strong></td>
</tr>
</tbody>
</table>

* 29 players sustained >1 injury during same season
40% of players (103/256) sustained at least 1 injury during a given season (2009 – 2011)
**Back & LE Strain/Sprain Incidence**  
**2009 – 2011 Seasons**


<table>
<thead>
<tr>
<th>Injury Category</th>
<th>Estimated # of Injuries (National)*</th>
<th>% of Estimated Total Injuries</th>
<th>Injury # per 1000 Player-Exposures†</th>
<th># of Injuries</th>
<th>Injury # per 1000 Player-Exposures‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Back/S-I</td>
<td>10,159</td>
<td>3.8%</td>
<td>0.40</td>
<td>9</td>
<td>0.50</td>
</tr>
<tr>
<td>Hip/Groin</td>
<td>15,859</td>
<td>5.9%</td>
<td>0.63</td>
<td>36</td>
<td>2.09</td>
</tr>
<tr>
<td>Thigh</td>
<td>27,746</td>
<td>10.4%</td>
<td>1.09</td>
<td>18</td>
<td>1.05</td>
</tr>
<tr>
<td>Knee</td>
<td>42,883</td>
<td>16.1%</td>
<td>1.69</td>
<td>21</td>
<td>1.22</td>
</tr>
<tr>
<td>Lower Leg</td>
<td>11,474</td>
<td>4.3%</td>
<td>0.45</td>
<td>1</td>
<td>0.06</td>
</tr>
<tr>
<td>Ankle/Foot/Toe</td>
<td>45,655</td>
<td>17.1%</td>
<td>1.80</td>
<td>47</td>
<td>2.73</td>
</tr>
<tr>
<td>Total Back + LE</td>
<td>153,776</td>
<td>57.6%</td>
<td><strong>6.06</strong></td>
<td>132</td>
<td><strong>7.67</strong></td>
</tr>
</tbody>
</table>

* Estimated Total Injuries: 266,943  † Estimated Player-Exposures: 25,369,771 ‡ Player-Exposures: 17,208

---

**2009 – 2011 Combined Analysis**  
**Wall-Sit Hold N=256**

<table>
<thead>
<tr>
<th>Year</th>
<th>WSH Test Version</th>
<th>Cut-Point</th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Bilateral Equal Wt.</td>
<td>≤88 sec</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>2010</td>
<td>Unilateral Fig-4 (Non-Dominant)</td>
<td>≤41 sec</td>
<td>43</td>
<td>89</td>
</tr>
<tr>
<td>2011</td>
<td>Unilateral Hip Flex (Average)</td>
<td>≤30 sec</td>
<td>103</td>
<td>153</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p = .007  
Sensitivity = .58  Specificity = .58  
+LR = 1.39  −LR = .72  
Odds Ratio = 1.39/.72 = 1.94  
90% CI: 1.27 - 2.97  
Relative Risk = 457/.347 = 1.49  
90% CI: 1.15 - 1.92
2009 – 2011 Combined Analysis
3-Factor Prediction Model  N=256

1) Starter (≥1 game)  2) Hi ODI (≥4)  3) Lo WSH (≤88-41-30 s)

Core + LE Strains & Sprains (103)

<table>
<thead>
<tr>
<th>3-Factor Model</th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2 Factors</td>
<td>58</td>
<td>30</td>
</tr>
<tr>
<td>0 or 1 Factor</td>
<td>45</td>
<td>123</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>153</td>
</tr>
</tbody>
</table>

Fisher's Exact One-Sided p < .001
Sensitivity: = .56  Specificity = .80

Odds Ratio: 2.87/.54 = 5.28
90% CI: 3.31 – 8.44

Relative Risk: = .659/.268 = 2.46
90% CI: 1.93 - 3.14

Confidence Interval Function

≥ 2 of 3 Risk Factors (Starter, WSH, ODI)

Relative Risk = 2.46 (90% CI: 1.93 – 3.14)
Odds Ratio = 5.28 (90% CI: 3.31 – 8.44)

2009 – 2011 Combined Football Data (N=256)
Predictors of Core/LE Strain or Sprain

2009 – 2011 Football N=256

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Cut-Point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>P</th>
<th>RR</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter Status ≥ 1 game</td>
<td>.61</td>
<td>.72</td>
<td>&lt;.001</td>
<td>2.23</td>
<td>4.03</td>
<td></td>
</tr>
<tr>
<td>ODI Score ≥ 4 points</td>
<td>.41</td>
<td>.77</td>
<td>002</td>
<td>1.60</td>
<td>2.32</td>
<td></td>
</tr>
<tr>
<td>Wall Sit Hold ≤ 88-41-30 s</td>
<td>.58</td>
<td>.58</td>
<td>.007</td>
<td>1.49</td>
<td>1.94</td>
<td></td>
</tr>
</tbody>
</table>

Logistic Regression Result

<table>
<thead>
<tr>
<th>Factor</th>
<th>Cut-Point</th>
<th>P</th>
<th>Adj. OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter ≥ 1 game</td>
<td>&lt;.001</td>
<td>4.22</td>
<td></td>
</tr>
<tr>
<td>Hi ODI ≥ 4 points</td>
<td>.006</td>
<td>2.26</td>
<td></td>
</tr>
<tr>
<td>Lo WSH ≤ 88-41-30 s</td>
<td>.005</td>
<td>2.22</td>
<td></td>
</tr>
</tbody>
</table>

Model $\chi^2 = 43.64; p < .001$

Nagelkerke $R^2 = .212$

2009 – 2011 Combined Analysis

N=256 Starter Status Stratification

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Injury</th>
<th>No Injury</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9</td>
<td>47</td>
<td>16%</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
<td>76</td>
<td>32%</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>25</td>
<td>64%</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>5</td>
<td>72%</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>153</td>
<td>40%</td>
</tr>
</tbody>
</table>
Possible Explanation for Association of ODI ≥ 4 with Core/LE Injury Occurrence

- Multifidus cross-sectional area reduces rapidly after low back injury

- Recovery does not spontaneously occur after resolution of LBP and resumption of normal activity (arthrogenic muscle inhibition)

- Multifidus atrophy can exist in highly active, elite athletes!!!

- Muscle inhibition decreases ability to control external moments

- Effects magnified by high-velocity body mass displacement

2009 – 2011 Combined FB Analysis
Survey Score Prediction Model N=256

1) Lo IKDC (≤ 98)  2) Lo FAAM-S (≤98)  3) Hi ODI (≥4)

<table>
<thead>
<tr>
<th></th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2 Factors</td>
<td>41</td>
<td>24</td>
</tr>
<tr>
<td>0 or 1 Factor</td>
<td>62</td>
<td>129</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>153</td>
</tr>
</tbody>
</table>

Odds Ratio = 3.55
90% CI: 2.17 – 5.82
Relative Risk = .631/.325 = 1.94
90% CI: 1.54 - 2.45

Sensitivity: .74
Specificity: .51
Odds Ratio: 2.93

Sensitivity: .40
Specificity: .84
Odds Ratio: 3.55

AUC = .66
2011-12 UTC 10-Sport Analysis

<table>
<thead>
<tr>
<th>Sport</th>
<th>Gender</th>
<th>n</th>
<th>Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>M</td>
<td>87</td>
<td>32</td>
</tr>
<tr>
<td>Wrestling</td>
<td>M</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>Basketball</td>
<td>M</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Cross Country</td>
<td>M</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Tennis</td>
<td>M</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Golf</td>
<td>M</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Basketball</td>
<td>F</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Cross Country</td>
<td>F</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Tennis</td>
<td>F</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Golf</td>
<td>F</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>198</td>
<td>89</td>
<td></td>
</tr>
</tbody>
</table>

Predictor | Cut-Point | P-value | Adj. OR |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FAAM-S</td>
<td>≤ 95</td>
<td>.021</td>
<td>2.43</td>
</tr>
<tr>
<td>HTH</td>
<td>≤ 26 s</td>
<td>.004</td>
<td>2.06</td>
</tr>
<tr>
<td>TFH</td>
<td>≤ 135 s</td>
<td>.047</td>
<td>1.88</td>
</tr>
<tr>
<td>WSH</td>
<td>≤ 29 s</td>
<td>.053</td>
<td>1.61</td>
</tr>
</tbody>
</table>

4-Factor Model

<table>
<thead>
<tr>
<th>Factors +</th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 3</td>
<td>35</td>
<td>17</td>
</tr>
<tr>
<td>0 - 2</td>
<td>50</td>
<td>88</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
<td>105</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p < .001
Odd's Ratio = 2.543 / .702 = 3.62 95% CI: 2.06 – 6.39
Relative Risk = .673 / .362 = 1.86 95% CI: 1.45 – 2.37
2011-12 UTC 10-Sport Analysis

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Cut-Point</th>
<th>Core / LE Sprains and Strains Injury</th>
<th>No Injury</th>
<th>Total</th>
<th>Injury Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAAM-S</td>
<td>≤ 95 points</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>HTH</td>
<td>≤ 26 s</td>
<td>1</td>
<td>24</td>
<td>40</td>
<td>64</td>
</tr>
<tr>
<td>TFH</td>
<td>≤ 135 s</td>
<td>2</td>
<td>24</td>
<td>37</td>
<td>61</td>
</tr>
<tr>
<td>WSH</td>
<td>≤ 29 s</td>
<td>3</td>
<td>31</td>
<td>17</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>85</td>
<td>105</td>
<td>190</td>
<td></td>
</tr>
</tbody>
</table>

Risk Factor Cut-Point
FAAM-S ≤ 95 points
HTH ≤ 26 s
TFH ≤ 135 s
WSH ≤ 29 s

ImPACT Neurocognitive Reaction Time

- Pre-season assessment of college athletes at 18 universities
  - 80 non-contact ACL tear cases (45 female, 35 male)
  - 80 matched controls (gender, height, weight, age, sport, position)
- Non-contact ACL tear cases compared to controls –
  - Lower verbal memory and visual memory scores
  - Slower processing speed and reaction time

**Reaction Time**
- Cases: 570 ms
- Controls: 530 ms
**2011 ImPACT Reaction Time Composite**

Wilkerson GB. Neurocognitive reaction time predicts lower extremity sprains and strains.

<table>
<thead>
<tr>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 545 ms</td>
<td>18</td>
</tr>
<tr>
<td>&lt; 545 ms</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p = .044
Sensitivity = .75
Specificity = .48
LOR = 1.45
LR = .52
Odds Ratio = 1.45/.52 = **2.79**
90% CI: 1.15 – 6.81
Relative Risk = .383/.182 = **2.11**
90% CI: 1.07 – 4.16

**AUC = .57**

---

**Injury Risk**

- **Psychosocial Stress**
  - Effect of “negative life events”
    - Reaction time slowing
    - Narrowing of peripheral vision
  - May affect anticipation of external loads

## Psychosocial Stress

- **Life Events Survey for Collegiate Athletes (LESCA)**
  - List of 69 life events
    - For every listed event experienced within the last 12 months, please rate its negative or positive effect:

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Negative Rating</th>
<th>Positive Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marriage</td>
<td>4 = Extremely Negative</td>
<td>4 = Extremely Positive</td>
</tr>
<tr>
<td>Death of male (boyfriend, girlfriend, spouse, significant other)</td>
<td>3 = Very Negative</td>
<td>3 = Very Positive</td>
</tr>
<tr>
<td>Major change in sleeping habits (increase or decrease in amount of sleep)</td>
<td>2 = Moderately Negative</td>
<td>2 = Moderately Positive</td>
</tr>
<tr>
<td>Death of a close family member (father, mother, brother/sister, grandparent/grandmother)</td>
<td>1 = Somewhat Negative</td>
<td>1 = Somewhat Positive</td>
</tr>
<tr>
<td>Major change in eating habits (increase or decrease in food intake)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Injury Risk**

  - **Psychosocial Stress - LESCA**
    - 331 high school football players
      - > 50th percentile “negative” score: OR = 1.7 (95% CI: 1.1 – 2.7)
    - 39 NCAA Division I-FCS football players
      - ≥ 14 “negative” score: OR = 3.6 (95% CI: 0.9 – 14.7)
Ankle Sprain Risk – Previous Injury

2010 + 2011 Football Ankle Sprains

- An injury that prevented participation in sports activities for 2 or more days

- Lateral Ankle Sprain or Syndesmosis (High Ankle) Sprain

<table>
<thead>
<tr>
<th></th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>History +</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>History -</td>
<td>17</td>
<td>107</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>147</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p = .290
Sensitivity = .35  \( +LR = 1.27 \)
Specificity = .73  \( -LR = .90 \)
RR = .184/.137 = 1.34  \( OR = 1.42 \)

Ankle Sprain Risk – Function Rating

Foot and Ankle Ability Measure – Sport Subscale

- 8 items – 0-4 response (Unable to do – No difficulty)
  - If one ankle presents a greater problem than the other, rate the status of the WORSE ankle.
  - If both ankles are about the same, rate the status of BOTH ankles in general.

<table>
<thead>
<tr>
<th></th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 95 )</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>&gt; 95</td>
<td>20</td>
<td>134</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>147</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p = .044
Sensitivity = .23  \( +LR = 2.63 \)
Specificity = .91  \( -LR = .84 \)
RR = .316/.130 = 2.43  \( OR = 3.09 \)
2010 + 2011 Football Ankle Sprains
2X2 Cross-Tabulation Analysis Results

<table>
<thead>
<tr>
<th>Predictor</th>
<th>N</th>
<th>Cut-Point</th>
<th>Sn</th>
<th>Sp</th>
<th>RR</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Games Played*</td>
<td>173</td>
<td>≥ 4 games</td>
<td>.85</td>
<td>.46</td>
<td>3.92</td>
<td>4.73</td>
</tr>
<tr>
<td>Starter Status</td>
<td>173</td>
<td>≥ 1 game</td>
<td>.69</td>
<td>.65</td>
<td>3.39</td>
<td>4.24</td>
</tr>
<tr>
<td>FAAM-S Score*</td>
<td>173</td>
<td>≤ 95</td>
<td>.23</td>
<td>.91</td>
<td>2.43</td>
<td>3.09</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>173</td>
<td>≥ 27</td>
<td>.81</td>
<td>.40</td>
<td>2.46</td>
<td>2.82</td>
</tr>
<tr>
<td>HS Strain Hx*</td>
<td>173</td>
<td>+</td>
<td>.46</td>
<td>.78</td>
<td>2.44</td>
<td>2.96</td>
</tr>
<tr>
<td>MMOI (Wt<em>Ht^2)</em></td>
<td>173</td>
<td>≥ 338 kg*m^2</td>
<td>.73</td>
<td>.50</td>
<td>2.39</td>
<td>2.75</td>
</tr>
<tr>
<td>Horiz Trunk Hold</td>
<td>173</td>
<td>≤ 28 sec</td>
<td>.54</td>
<td>.70</td>
<td>2.31</td>
<td>2.73</td>
</tr>
<tr>
<td>Foot Width Index</td>
<td>166</td>
<td>≥ .44</td>
<td>.60</td>
<td>.61</td>
<td>2.06</td>
<td>2.35</td>
</tr>
<tr>
<td>LB/S-I Spr/Str Hx*</td>
<td>173</td>
<td>+</td>
<td>.15</td>
<td>.93</td>
<td>1.92</td>
<td>2.25</td>
</tr>
<tr>
<td>Ankle Sprain Hx</td>
<td>173</td>
<td>≥ 2</td>
<td>.39</td>
<td>.63</td>
<td>1.06</td>
<td>1.08</td>
</tr>
</tbody>
</table>

* Retained in prediction model derived from logistic regression analysis

2010-2011 Ankle Sprain Prediction
2-Season Football Analysis (n=173)

<table>
<thead>
<tr>
<th>Predictor</th>
<th>P-Value</th>
<th>Adj. OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP ≥ 4</td>
<td>0.003</td>
<td>6.26</td>
</tr>
<tr>
<td>MMOI ≥ 338</td>
<td>0.014</td>
<td>3.59</td>
</tr>
<tr>
<td>FAAM-S ≤ 95</td>
<td>0.060</td>
<td>3.19</td>
</tr>
<tr>
<td>LB or SI Hx +</td>
<td>0.117</td>
<td>3.06</td>
</tr>
<tr>
<td>HS Hx +</td>
<td>0.056</td>
<td>2.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors +</th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 3</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>0 - 2</td>
<td>13</td>
<td>131</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>147</td>
</tr>
</tbody>
</table>

Fisher’s Exact One-Sided p < .001
Sensitivity = .50 Specificity = .89
Odds Ratio: = 8.19 90% CI: 3.78 – 17.83
Relative Risk= 4.97 90% CI: 2.86 – 8.62

1. ≥ 4 Games Played (11-Game Season)
2. Estimated Mass Moment of Inertia ≥ 338 kg*m^2
3. Foot and Ankle Ability Measure – Sport Subscale ≤ 95
4. Low Back or Sacro-iliac Sprain History (≥ 2 Days No Play)
5. Hamstring Strain History (≥ 2 Days No Play)

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Ankle Sprain</th>
<th>Injury Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>59</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>147</td>
</tr>
</tbody>
</table>
Core Stability – Ankle Injury Risk

- Body mass–height relationship affects ankle joint loading
  - External moment determined by mass distance from axis
    - Moment of Inertia estimate
    - Mass x Height\(^2\) kg x m\(^2\)


Core Stability – Ankle Injury Risk

- Horizontal Trunk Hold performance may be an indicator of the ability to control dynamic position of trunk mass
  - Estimated Mass Moment of Inertia \(\geq 338 \text{ kg} \cdot \text{m}^2\)
    - Sensitivity 73% Specificity 50%
    - OR = 2.75
  - Horizontal Trunk Hold \(\leq 28\) sec
    - Sensitivity 54% Specificity 70%
    - OR = 2.73

![Graph showing ankle sprain incidence vs. Horizontal Trunk Hold and Mass Moment of Inertia](image)
Medial Longitudinal Arch – Pronation

- Chippaux-Smirak Foot Width Index (FWI)
  - FWI = Line B / Line A
    - Line A: Widest portion of anterior 1/3 of foot
    - Line B: Most narrow portion of middle 1/3 parallel to Line A

<table>
<thead>
<tr>
<th>MLA</th>
<th>FWI</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>≤ .29</td>
</tr>
<tr>
<td>Normal</td>
<td>.30 - .39</td>
</tr>
<tr>
<td>Low</td>
<td>≥ .40</td>
</tr>
</tbody>
</table>

Mei-Dan et al, Foot Ankle Int, 2005

2011 Foot Width Index
Football Core/LE Sprains & Strains

<table>
<thead>
<tr>
<th>Core + LE Strains &amp; Sprains</th>
<th>Injury</th>
<th>No Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ .475</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>&lt; .475</td>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>60</td>
</tr>
</tbody>
</table>

Sensitivity: .56 Specificity: .67
Odds Ratio: 2.55 90% CI: 1.14 – 5.67
Relative Risk: 1.91 90% CI: 1.10 - 3.32

AUC = .56
Star Excursion Balance Test

- Composite Reach Distance
  - Expressed as % of leg length – ASIS to tibial malleolus
  - 8 directions (SEBT) or 3 directions (Y-Balance)

Y-Balance (SEBT) Test

- High school basketball players
  - Lower extremity injuries; Composite reach distance ≤ 94%
    - Boys + Girls (N=235) OR=3.0* (95% CI: 1.5 – 6.1)
    - Girls (N=105) OR=6.5* (95% CI: 2.4 – 17.5)
    - *Adjusted: gender, grade, previous injury, training program, tape/brace

  - Lower extremity injuries; Composite reach distance ≤ 69.5%
    - Boys + Girls (N=66) OR=5.4

- College football players (N=105)
  - Ankle & knee injuries; Anterior reach distance ≤ 68%
    - OR=5.4

References:
Postural Balance + LE Mobility

- SEBT Anterior Reach – FMS In-Line Lunge
  - Both require core stability + eccentric quadriceps control

General Joint Hypermobility

- Beighton Scale (9-point scale; R + L = 2 points)
  - British Society of Rheumatology (positive: ≥ 4 points)
    - 5th finger passive extension > 90°
    - Thumb passive abduction (with wrist flexion) to forearm
    - Elbow hyperextension > 10°
    - Knee hyperextension > 10°
    - Forward trunk flexion (knees extended) – palms to floor
  - 3 studies: 1047 subjects (contact + non-contact activities)
    - Standardized cut-point equivalent to ≥ 4 points on Beighton scale
    - Lower extremity joint injury: Combined OR=1.4 (95% CI: 0.6 – 4.9)
  - 4 studies: 1043 subjects engaged in contact activities
    - Knee injury: Combined OR=4.7 (95% CI: 0.6 – 3.7)

Core Stability Training

- No consensus definition – somewhat vague concept
- Typical components of neuromuscular control programs:
  - Conscious isolated activation of specific muscles
  - Co-contraction of antagonist muscle groups
  - Postural balancing exercises (wobble board, Swiss ball)
  - Perturbation – balance recovery activities
  - Plyometric jump training

  - Akuthota & Nadler, Arch Phys Med Rehabil, 2004

Core Stability Training – Evidence?

- The effects of isolated and integrated ‘core stability’ training on athletic performance measures
  - Reed CA, Ford KR, Myer GD, Hewett TE

- 10 randomized studies + 14 observational studies
- Lack of outcome standardization and conflicting findings
  1. Core training is rarely the sole component of a program
  2. Greatest effect documented for non-athlete subjects
  3. Randomization of competitive athletes is often unfeasible
Multifidus Training Adaptation

- Significant increase in multifidus cross-sectional area documented on CT images after 10 weeks of training
  - Resistance ~70% 1 RM; sets of 15-18 reps; 3 X per week
    - Alternating single-leg extension from 4-point kneeling position
    - Trunk extension from prone position on table
    - Double-leg extension from prone position on table
  - 5-second isometric hold between concentric lift & eccentric lowering phases of each repetition
  - No significant change in multifidus cross-sectional area of control subjects who did not perform 5-second isometric hold

Summary

- Most risk prediction models are highly specific with regard to sport, gender, age, and type of injury
- Pre-participation screening data need to be combined with injury surveillance data to develop sport-specific interventions for risk reduction
- Very little evidence is currently available to guide development of “individualized” training programs for reduction of injury risk

- Gary-Wilkerson@utc.edu