The Use of 3D Motion Capture in ACLR and Athletic Groin Pain Rehabilitation

Brendan Marshall PhD
Overview

- Background
- SSC testing battery
- Research findings
- Rehabilitation
ACL Injury Epidemiology

- <1% of total injuries in football (Ekstrand J., 2014)
- ACL injury every 2 seasons in a pro football squad
- 6.5 months before team training in pro football
- 6-27% risk of re-injury or contralateral injury (Shelbourne et al., 2014; Paterno et al. 2010)
- 75% non contact (Agel et al. 2005)
ACL injury mechanism

Of all non contact ACLs:

- **70%** change of direction cutting
  (Cochrane et al. 2006)

- **24%** landing
  (Walden 2014)
Biomechanical Risk Factors

- ACL injury ~40 ms after initial contact
- Knee flexion
- Knee valgus
- Tibial internal rotation

Koga et al. 2010
Biomechanical Risk Factors

Knee abduction moment during landing predicts ACL injury risk in female athletes (Myer 2005)

205 athletes pre-screened and tracked

9 had ACL rupture, they had:

- 2.5 times greater knee valgus moment
- 20% higher ground reaction force

Drop Jump
A contralateral ACL injury is strongly related to modifiable postsurgical risk factors (Hewett et al. 2013)
3D Marker Set
3D Motion Capture

Capturing and evaluating the kinematics (angles) and kinetics (forces) of movement
ACL Rehab Pathway

- 3D Testing
- Isokinetic testing
- Physio review
- Surgeon review
ACL Testing Battery

Jump ability is an important contributor to performance in field sports (Torres-Unda et al., 2013; Gabbet et al., 2011)

Excellent insight into power output
\[ r = 0.82 \] (Marshall and Moran. 2015)

Relationship with jump height
- Ankle power: \[ r = 0.32 \]
- Knee power: \[ r = 0.33 \]
- Hip power: \[ r = 0.61 \]
Landing – Contralateral injury risk

n = 30, 6 month post ACLR

60% landed with contralateral limb first
17% involved limb first

↑ Ground Reaction Force 20%
↑ Knee valgus angle 90%
↑ Knee valgus moment 54%
↑ Knee internal rotation 31%

p < 0.05
Landing – Contralateral injury risk

Adapted strategy to ‘protect’ the operated side, increasing the risk of contralateral injury

Implication:
Don’t neglect the contralateral side when rehabilitating
Single-legged landings are a common mechanism of ACL injury (Kimura et al., 2012)

Landing technique influences:
- ACL loading
- Anterior knee pain

Drop landing
Landing Technique and ACL Loading

Laughlin et al. 2011 Journal of Biomechanics

Participants were asked to perform ‘stiff’ and ‘soft’ landings

Soft landings:

ACL force (11%)
ACL Testing Battery

Knee abduction moment during landing predicts ACL injury risk in female athletes (Myer 2005)

Single and double leg version

Useful as a performance measure

Drop Jump
Multi-planar landing activity particularly stressing frontal plane control (Hickey et al. 2009)

Trunk control

Poor neuromuscular control of the trunk a predictor of ACL injury (Zazulak et al. 2007)

Excessive lateral trunk flexion increases knee internal valgus moments during single-leg landing (Kimura et al. 2014)

Hurdle Hop
ACL Testing Battery

A challenging test with a clear performance outcome

However, quality of movement control is often overlooked
(Paterno et al 2010)

Is movement control distinct from movement performance?

Maximal Hop
Hop for Distance Study

- Good control: n = 16
- Poor control: n = 14
No significant ($P > 0.05$) difference in jump distance

<table>
<thead>
<tr>
<th>Good control (n = 14)</th>
<th>Poor control (n = 16)</th>
<th>Difference</th>
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<tbody>
<tr>
<td>171.3 ± 25.0cm</td>
<td>168.8 ± 23.8cm</td>
<td>2.5cm ($P = 0.79$)</td>
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</table>

Hop for Distance Study
Power generation and movement control are distinct qualities

Implication:

Important to assess dynamic movement control as a distinct return to play criteria

An overreliance on performance outcome may result in a return to play with deficient control and an increased injury risk

(Myer et al 2005, Hewett et al. 2013)
Cutting is a common mechanism of ACL injury (Kristianslund et al. 2013)

Lee et al. (2014) - ACLR patients exhibited greater knee abductor and internal rotator moments
Movement in response to a sudden stimulus may elicit different and more sport specific movement patterns (O’Connor et al. 2009)
6 and 9 Month Testing
6 and 9 Month Testing

**Power**

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<tr>
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<th>CMJ (Height) (CM)</th>
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**Strength**

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**ROM**

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## ACL Periodisation

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<td>Hyper trophy</td>
<td>Linear</td>
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<td>Power</td>
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<td>Periodisation Overview</td>
<td>Linear</td>
<td>Reverse Linear</td>
<td>Relative Flat Model: Build Volume Through Sets</td>
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<td>Development</td>
<td>Accelerate</td>
<td>Intensity</td>
<td>Power</td>
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<td>Periodisation Strength</td>
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<td>Intensity</td>
<td>Lifts Per Week</td>
<td>Strength Per Week</td>
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<td>Anatomical Adaptation</td>
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<td>Conjugate Periodisation</td>
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<td>Notes</td>
<td>Movement Competance</td>
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<td>Single Leg Control &amp; Hip Strategy</td>
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**ACLX Rehabilitation**

**Training Blocks 1-3**

<table>
<thead>
<tr>
<th>Strength Testing</th>
<th>Movement Competencies &amp; Anatomical Adapt</th>
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</thead>
<tbody>
<tr>
<td><strong>Strength Themes</strong></td>
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<tr>
<td>Range of Motion</td>
<td>H, H, M</td>
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<tr>
<td>Neuromuscular Control</td>
<td>H, H, M</td>
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<td>Hypertrophy</td>
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<tr>
<td>Strength</td>
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<tr>
<td>Power</td>
<td>L Jump-Land / Reactive, L Jump-Land / Reactive</td>
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</table>

Sample training exercises:
balance (eyes closed), goblet squat (high box), below knee dead lift
## ACLR Rehabilitation

### Training Blocks 4-6

<table>
<thead>
<tr>
<th>Strength Testing</th>
<th>Movement Competencies &amp; Hypertrophy</th>
<th>8RM (WK 20)</th>
<th>5RM &amp; Power Tests (WK 24)</th>
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<tr>
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<td>Strength Themes</td>
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<td>Strength</td>
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<tr>
<td>Power</td>
<td>L Jump-Land / Reactive</td>
<td>L Jump-Land / Reactive</td>
<td>M Reactive &amp; Speed Strength Transition</td>
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</tbody>
</table>

Sample training exercises:
Leg press, front squat, box jump (hold), single leg rebound jumps
ACL Rehab Pathway

Efficient return to chosen sport
Symptom free return to performance
Reduce the risk of re-injury
3D Motion Capture and Groin Pain Rehabilitation

Overview

- Background
- SSC testing battery
- Research findings
Epidemiology

- 10% of all attendees at sports medicine practises (Ryan et al., 2014)
- 24% of academy gaelic footballers (Glasgow., 2011)
- 8-18% of all football injuries (Hölmich, 1998)
- 445 days average duration of symptoms before attending SSC groin clinic

Behind only fracture and joint reconstruction in lost playing time (Brooks 2005)
Biomechanical factors

- disturbed stabilisation of the hip and pelvis (Holmich 1999; Cowan 2004)
- abnormal distribution of forces in the region (Pizzari 2008; Rabe 2010)
- complex aetiology (Holmich 1999; Cowan 2004)
- restricted hip range of motion (Verrall 2005a; Verrall 2007a)
Rapid change-of-direction/cutting associated with groin injury
(Holmich et al. 2014)
Traditional groin pain assessment:

Lack of Specificity
Biomechanical factors associated with time to complete a change of direction cutting maneuver.

Marshall BM¹, Franklyn-Miller AD, King EA, Moran KA, Strike SC, Falvey EC.
Groin Testing Battery

Examination of function in a predominantly sagittal plane movement

Lumbopelvic control

Drop landing
Example Rehab Exercise
Groin Testing Battery

Multi-planar landing activity particularly stressing frontal plane function (Hickey et al. 2009)

More excessive lateral trunk flexion influences frontal plane moments at more distal joints (Kimura et al. 2014)
Example Rehab Exercise
Groin Testing Battery - Cut

- 5 metres
- 5 metres
- 75°
- Force Plates
Groin Testing Battery - Cutting
Toward a Biomechanical Diagnosis

Cluster 1 (40%)

- Trunk external rotation
- Hip internal rotation
- Hip flexion

Cluster 2 (45%)

- Trunk side flexion
- Hip abduction

Cluster 3 (15%)

- Trunk side flexion
- Hip abduction
- Trunk forward flexion

Trunk external rotation
Hip internal rotation
Hip flexion
Cluster 1

Hip internal rotation, hip flexion

• associated with an increase in pubic symphyseal motion (Birmingham et al 2012)

• associated with femeroacetabular impingement particularly in the presence of abnormal hip morphology
Cluster 2

Hip abduction and trunk side flexion

• Dynamic hip abduction controlled by eccentric action of the adductors
Cluster 3

Trunk flexion, as well as
Hip abduction and trunk side flexion

Due to a reduced posterior chain utilisation/capacity?
Toward a Biomechanical Diagnosis

- 3 distinct movement patterns identified – biomechanical diagnoses

- 3D assessment provides additional information to tailor rehabilitation
Movement in response to a sudden stimulus may elicit different and more sport specific movement patterns (O’Connor et al. 2009)
Groin Testing Battery - Kicking
Rehabilitation

Level 1 – Lumbopelvic Control and Strength
Level 2 – Power and Linear Running
Level 3 – Multidirectional and Sports specific
Rehabilitation – Dead Lift
Rehabilitation
Post Rehab Changes

Pre Rehab

Post Rehab
Frontal Plane Kinematics Post Rehab

<table>
<thead>
<tr>
<th></th>
<th>Pre-rehab (Mean± SD)</th>
<th>Post-rehab (Mean± SD)</th>
<th>Significance (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal plane ROM (°)*</td>
<td>58.1 ± 20.7</td>
<td>53.1 ± 15.6</td>
<td>0.03</td>
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</table>

* Composite of thorax, pelvis, hip, knee and ankle
Conclusion

Poor control of the hip and pelvis, and an abnormal distribution of forces in the region, are associated with AGP (Almeida 2013, Cowan 2004, Holmich 1999)

3D analysis assists diagnosis and rehabilitation

Testing battery selected to ensure:

- Efficient return to chosen sport
- Enhance performance
- Reduce the risk of re-injury
Acknowledgements

Dr Éanna Falvey, Dr Andy Franklyn-Miller, Enda King, Dr Kieran Moran, Dr Chris Richter, Dr Siobhán Strike, Shane Gore

@benny_marshall  @SSCSantry
Isokinetic Strength Testing

Athletes have demonstrated muscle strength deficits up to 2 yrs post surgery which is a risk factor for further injury (Aune, et al 2000; Bowerman et al. 2006)

Oberlander (2013) – ACLR patients compensated for knee strength deficiencies by using a more flexed trunk on landing
Key findings:

No clear standardised strength evaluation protocol following ACLR

No consensus on an appropriate RTS strength criteria following ACLR

Proposed protocol:
5 reps of concentric knee extension and flexion at 60º/s.
Pelvis frontal plane ROM (Ecc phase)

Marshall, Franklyn-Miller, Moran, Strike, King & Falvey. JSCR, 2014
# ACLR Rehabilitation

## Training Blocks 7-9

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<tr>
<td><strong>Power</strong></td>
<td>M Reactive + Speed Strength Loaded</td>
<td>H Reactive, Speed Strength Loaded &amp; Transfer</td>
<td>H Reactive, Speed Strength Loaded, Transfer &amp; Sport Specific</td>
</tr>
</tbody>
</table>

**Sample training exercises:**
Step up, nordics, jump squat, RDL, broad jumps, drop jumps
The single leg squat (SLS) is a common test used to assess neuromuscular control (Chmielewski et al. 2007)
Effect of Fatigue

Effect of fatigue on tibial impact accelerations and knee kinematics in drop jumps. Moran KA\textsuperscript{1}, Marshall BM.
Peak thorax rotation

Marshall, Franklyn-Miller, Moran, Strike, King & Falvey. JSCR, 2014
Can a SLS provide an insight into movement control and loading in more dynamic sporting tasks?
No significant correlations between the SLS and Land or Cut for: pelvis or hip angles or moments of force
Post Rehab Changes

Pre Rehab

Post Rehab