ACL INJURY / RE-INJURY PREVENTION
IDENTIFYING RISK FACTORS AND PROGRAMMING FOR INJURY PREVENTION
MATT JORDAN, M.Sc., CSCS
PhD Candidate, Faculty of Medical Science, University of Calgary
Director of Strength and Conditioning, Canadian Sport Institute-Calgary
Director of Sport Science | Sport Medicine, Canadian Alpine Ski Team
2014-12-16

PRESENTATION OVERVIEW
- Identify modifiable (trainable) risk factors for ACL injury
- Consequences of ACL injury
- Programming for ACL injury / re-injury prevention

A database of ski racers with French Alpine Ski Team was analyzed
- Of 379 athletes registered, 28% suffered at least one ACL injury
- 50% of top ranked skiers suffered ACL injury

More than 30% of top ranked skiers suffered ACL re-injury

ACL INJURY
- Female athletes at greater risk (4-6x male counterpart) (Kendall et al., 1998; Myer et al., 2009; Prodromos et al., 2008)
- Non-contact injury occurs in transitional zones (i.e. deceleration of the BCM) (Byrne et al., 1996)
- Increased risk for non-contact ACL injury attributable to risky biomechanics and altered intermuscular coordination (Hewett et al., 2005; Zebis et al., 2009)

NON-CONTACT ACL INJURY
15-01-16

FORCES THAT LOAD THE ACL

Anterior shear load on the tibia ***
Valgus loading
Tibial internal rotation
0-30° and 90° + knee flexion
Aggressive quadriceps contraction / hamstring inactivation

ACL RISK FACTORS: LANDING MECHANICS

- Rapid eccentric deceleration (landing jumps / changing direction) high risk sport movement
- Hard landing (Stewart et al., 2005)
- Greater posterior vGRF
- Small angles of knee flexion / quad strength dominant (Garrido et al., 2006; Cody et al., 2000; Storer et al., 2004)
- Time frame of injury < 50 ms (Hewett et al., 2005)
- Highlights importance of pre-activation strategies and rapid muscular force development

ACL RISK FACTORS: HAMS / QUADS

- Female athletes may have altered H/Q activation and reduced hamstrings strength (Zebis et al., 2009; Zebis et al., 2011)
- ACL injured females increased VL-ST activity difference (Zebis et al., 2009)
- ACL injured females had lower hamstrings strength but no difference in quadriceps strength compared to matched male controls (Myer et al., 2009)
- Quadriceps dominant landings linked to increased ACL loading (Bessier et al., 2003; Demorat et al., 2004; Marshall et al., 2004)

HAMSTRINGS – AN ACL AGONIST

- Hamstrings important ACL agonist (decreases ACL loading) (Mac Williams et al., 1999; Markolf et al., 2004)
- Assists by preventing anterior translation of tibia b/w 30-90° flexion but not in extension (Mac Williams et al., 1999; Sharp et al., 2004)
- Medial hamstrings / medial quadriceps (VM) important for ACL unloading and medial joint compression (anti-valgus) (Zebis et al., 2008)
- H/Q co-contraction increases valgus/varus stiffness (Mac Williams et al., 1999)

MECHANISMS OF INJURY

(C二十年, Fotopsho)
SLIP AND CATCH

SLIP AND CATCH MECHANISM

INJURY PERIOD (60 ms)

<table>
<thead>
<tr>
<th>TIME (ms)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNEE JOINT ANGLE</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

Knee Flexion

Valgus

Internal Rotation

- Rapid increase in knee flexion 26° to 63°

Rapid Increase

Bere et al., 2011

The American Journal of Sports Medicine

41.5 (2013): 1067-1073.

Barone et al., 1999; Herzog & Read, 1993; Markolf et al., 2004; Prodromos et al., 2008

LANDING BACK WEIGHTED

- Skier out of balance and backward in flight
- Lands on ski tails
- Boot and knee extensor torque cause anterior translation of tibia

IMPORATANCE OF THE HAMSTRINGS

FQAMSTRINGS

FANTERIOR SHEAR

QUADRICEPS

FACL

FACL

IMPORTANCE OF THE HAMSTRINGS

IMPORTANCE OF THE HAMSTRINGS

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SUMMARY OF MECHANISMS

- Range of knee flexion
- Skier out of balance
- Lateral to medial knee joint loading (valgus loading)
- Twisting load (internal rotation of tibia)
- Back to front load on tibia (anterior displacement of tibia)
- Time frame of injury (< 60 ms)

RISKS FACTORS FOR ACL INJURY

- Equipment
- Speed
- Changing snow conditions
- Course setting
- Physical factors (e.g. fitness, strength)

THE INJURY / RE-INJURY CYCLE

(Bere et al., 2011; Bere et al., 2011; Ferguson, 2009; McConkey, 1996; Natri et al., 1999; Pujol et al., 2007)

FUNCTIONAL ASYMMETRY

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(Option et al., 2012)
FUNCTIONAL ASYMMETRY

ACL-RECONSTRUCTED SKIER

ACL-R Limb
Unaffected Limb

FORCE (N)

0 200 400 600 800 1000

TIME (s)

10.0 10.5 11.0

14.0 14.5 15.0

UNINJURED SKIER

FORCE (N)

0 200 400 600 800 1000

TIME (s)

12.5 13.0 13.5

16.0 16.5 17.0

Lower limb asymmetry in mechanical muscle function: A comparison between ski racers with and without ACL reconstruction

M. S. Jordan, R. Lapointe, S. Al-Rawi

Sports Performance Laboratory, The University of Calgary, Calgary, Alberta, Canada, Department of Kinesiology and Physical Education, University of Calgary, Calgary, Alberta, Canada

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Due to a high incidence of anterior cruciate ligament (ACL) injuries in skiers, this study aims to examine mechanical muscle function in ACL-reconstructed and uninjured ski racers. The study utilized Camper and Logitech MyoPro systems, with concentric and eccentric jumps from both knees. The ACL-reconstructed group showed significantly lower force production in the eccentric phase compared to the uninjured group. This finding indicates a potential muscle weakness and an increased risk of injury in these athletes. The study also observed a heightened risk of re-injury due to the asymmetry observed in the ACL-reconstructed group. The research further highlights the importance of rehabilitation strategies focusing on muscle symmetry and strength.

RELATIONSHIP BETWEEN FUNCTIONAL ASYMMETRY AND MUSCLE ASYMMETRY

Table 1. Subject characteristics (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Status</th>
<th>Mean (%)</th>
<th>95% Confidence Interval (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All CMJ concentric</td>
<td>ACL-R</td>
<td>0.3</td>
<td>-1.5 to 2.1</td>
</tr>
<tr>
<td>All CMJ eccentric</td>
<td>ACL-R</td>
<td>0.6</td>
<td>-1.5 to 2.7</td>
</tr>
<tr>
<td>All SJ phase 1</td>
<td>ACL-R</td>
<td>1.0</td>
<td>-1.5 to 3.5</td>
</tr>
<tr>
<td>All SJ phase 2</td>
<td>ACL-R</td>
<td>1.0</td>
<td>-1.5 to 3.5</td>
</tr>
<tr>
<td>All muscle mass</td>
<td>ACL-R</td>
<td>1.0</td>
<td>-1.5 to 3.5</td>
</tr>
<tr>
<td>All muscle mass</td>
<td>Control</td>
<td>0.3</td>
<td>-1.5 to 2.1</td>
</tr>
</tbody>
</table>

*P < 0.001; **P < 0.001

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IDENTIFYING AT RISK SKIERS: KINETIC IMPULSE ASYMMETRY INDEX

<table>
<thead>
<tr>
<th>MUSCLE MASS AI</th>
<th>CMJ CONCENTRIC PHASE KI ASYMMETRY INDEX (%)</th>
<th>SJ LATE PHASE KI ASYMMETRY INDEX (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninjured</td>
<td>Female: n=51, Age=20.6±2.3 years, Body Mass = 67.8±11.5 kg</td>
<td></td>
</tr>
<tr>
<td>Injured</td>
<td>Male: n=20, Age=20.1±1.7 years, Body Mass = 78.7±16.5 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alpine skiing, luge, soccer, rugby, wrestling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assessed at the start of the off-season preparatory period and throughout training (1x/week)</td>
<td></td>
</tr>
</tbody>
</table>

IDENTIFYING AT RISK ATHLETES

- N = 71 athletes
- Females: n=51, Age=20.6±2.3 years, Body Mass = 67.8±11.5 kg
- Males: n=20, Age=20.1±1.7 years, Body Mass = 78.7±16.5 kg
- Alpine skiing, luge, soccer, rugby, wrestling
- Assessed at the start of the off-season preparatory period and throughout training (1x/week)

ACL INJURIES 2010 – 2014 = NONE
ACL RE-INJURIES = NONE
LOWER BODY RE-INJURIES = 2

ODDS OF INJURY 1.2x (95% CI = 1.1-1.4x) (P<0.01)

STRATEGIES FOR ACL INJURY/RE-INJURY PREVENTION

TRAINING CONSIDERATIONS

WHERE IS THE BREAKDOWN?

Can the system find the right solution?
Can the motor system generate the right solution?
TRAINING FOR INJURY PREVENTION

**MOTOR CONTROL**
- Unilateral Deceleration
- Bilateral Deceleration
- Core Control
- Muscle Pre-Activation / Anticipation
- Expected / Unexpected Events
- Rested and Fatigued

**NEUROMUSCULAR FACTORS**
- Deceleration Strength
- Positional Strength
- Bilateral Force Symmetry
- Rate of Force Development (Explosive Strength)
- Thigh Muscle Strength Curve
- Inter-Muscular Synergy and Muscle Balance

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**WARM UP**
**ACTIVATION**
**MOTOR CONTROL**
**PRIMARY LIFTS**
**SECONDARY LIFTS**
**ASSISTANT CIRCUIT**

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**MOTOR CONTROL**

- Use a variety of loads and velocities but ensure some specificity
- Identify compensation strategies - ‘we are designed to compensate’
- Groove motor patterns under expected conditions
- Challenge system with fatigue conditions or unexpected conditions
- Performed daily as a part of warm up and in combination with activation exercises

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**WARM UP**

Quotidian movement assessment
Dynamic warm up
Mobility

**ACTIVATION**
1. Omni Prone Plank
2. Omni Side Plank
3. Mini Band Mummy Walks
4. Mini Band Full Squats

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**MOTOR CONTROL**

1. Jump Rudiment
2. Double Leg Freeze Drops
3. Single Leg Drops
4. Single Leg Drops Eyes Closed

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**LOWER BODY STRENGTH**

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STRENGTH DEVELOPMENT

→ Don't train on top of poor technique
→ Develop range of motion appropriately
→ Use a combination of uni-lateral and bilateral lifts
→ Develop positional strength AND positional rapid force production

NEUROMUSCULAR FACTORS

→ Lower body symmetry
→ Train to be ambidextrous
→ Strengthen ACL agonists
→ Identify periods of strength development and strength maintenance
→ Performed 1-2x / week as a part of microcycle

ESSENTIAL MOVEMENTS

→ Full range of motion unilateral / bilateral exercises
→ Hamstring (closed chain / open chain)
→ Hip abductor strength
→ Quadriceps strength balance (VM vs. VL)

ZONE TYPE REPETITION RANGE RELATIVE INTENSITY TRAINING EFFECT
1 SSC 6-10 BW – 20% REACTIVE STRENGTH
2 DYNAMIC EFFORT 3-8 30% - 80% EXPLOSIVE STRENGTH / MECHANICAL POWER
3 REPEATED EFFORT 6-15 60% - 85% MUSCLE HYPERTROPHY / WORK CAPACITY
4 MAXIMAL EFFORT 1-6 85% - 100% MAXIMAL MUSCLE STRENGTH

PRIMARY Lifts

1. Full Power Clean
2. Full Back Squat

SECONDARY Lifts

3. Full Depth Single Leg Squat Off Box
4. Band Resisted Romanian Dead Lift
**ASSISTANT CIRCUIT**

**HAMSTRING / QUADRICEPS STRENGTH BALANCE**

5A. Heel Elevated Step Down

5B. Eccentric Leg Curl

5B. Band Hip Abduction

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**FATIGUE**

→ Ski related injuries occur in a fatigued state (Bere et al., 2013)

→ Fatigue leads to risky biomechanics in landing (Kernozek et al., 2008)

→ Alterations in hamstrings/quadriceps co-contraction observed in an acutely fatigued state (Zebis et al., 2011)

→ Evaluating neuromuscular function in the ACLR athlete under fatigue (Myer et al., 2006)

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**BALANCE AND LOWER BODY MOTOR CONTROL**

→ Does an exercise **require** balance or **train** balance

→ New and unpredictable movements train balance

→ The **best** movement = the **new** movement

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**SUMMARY**

→ ACL injury affects many athletes (ski racers, recreational skiers, female athletes in field sports)

→ We can identify modifiable (trainable) risk factors

→ Programming for injury prevention is multi-faceted

→ Daily motor control component

→ Strengthening component

→ Strategies can be very effective for injury prevention
ACKNOWLEDGEMENTS

Canadian Sport Institute-Calgary
Own the Podium
Dr. Walter Herzog
Dr. Per Aagaard
Dr. Steve Norris
The Herzog Group (Azim Jinha)
Scott Maw, Stu McMillan, Jer Barnert, Dan Pfaff
The CSI-Calgary S & C Team

THANK YOU

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