Fatigue and the Risk for Non-Contact ACL Injury: A Five Year Experience

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Conflict of Interest

- I affirm that I have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this presentation.
- My views may not be the same as the views of Quinnipiac University or my colleagues.
- Participants must use discretion when using the information contained in this presentation.
1. ACL injuries are a frequent event.\(^1\)

1. Approximately 70% per cent are classified as non-contact.\(^1\)

1. Females are 2 and 10 times more likely to sustain a non-contact injury than males.\(^2\)

1. Non-contact injuries occur during deceleration, landing maneuvers, change of direction maneuvers.\(^3\)

**BACKGROUND**

**Epidemiology**


1. ‘Position of no return’\(^4\):
   - Hip
     - Adduction
     - Internal Rotation
     - Decreased Flexion
   - Knee
     - Valgus
     - External Rotation
     - Decreased Flexion
   - Lateral displaced Center of Mass.\(^5\)

**BACKGROUND**

**‘At Risk’ Biomechanics**

1. ‘At Risk’ Biomechanics\(^6\):

   1. Muscular Control:\(^6\)
      - Increased quadriceps activation
      - Decreased hamstring activation
   2. Fatigue:
      - Majority of ACL injuries occur towards the end of half or game.\(^7\)


1. ACL prevention programs have been proven to be effective at reducing the risk for sustaining a non-contact injury. The injury rate remains high.
   - Potential explanations are the programs are:
     - Too time consuming
     - Very complex
     - Not implemented correctly

**BACKGROUND**

1. The effectiveness of the programs are assessed using non ‘game-like’ paradigms.

1. The amount of training and its impact on the ACL is not fully known.

**Aim of Project**

1. To determine how “at-risk” biomechanics are affected by fatigue utilizing a ‘game-like’ testing paradigm.

1. To determine the impact of training on the osseous structures and anterior cruciate ligament of the knee.
What effect does fatigue have on lower extremity and trunk kinematics?

- Subjects: 19 female and 10 male D1 soccer players.
- Each player completed a T test until they were unable to run the course within 1 s.d. of the mean of four baseline (non-fatigue) trials.
- Marker displacement histories were recorded using a 10 camera motion analysis system recording at 240 Hz.

The cuts performed at the center cone were classified.

Trunk and lower limb kinematics at 33ms post initial contact were analyzed.

RESULTS

Type of Cut

- Preferred cut was a side step.
  - Non significant increase in side step cuts with fatigue.
  - The discrepancy was greater for women.

Percentage of Side Step Cuts

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>Men</td>
<td>30%</td>
<td>20%</td>
</tr>
</tbody>
</table>
RESULTS

Hip Joint Kinematics at 33 ms

Sagittal Plane

Frontal Plane

Knee Joint Kinematics at 33 ms

Sagittal Plane

Frontal Plane

DERIVATION OF TRUNK MOMENT ARM/POSITION OF CENTER OF MASS

Direction of Cut

Lateral
Medial

Knee Joint Center

Trunk Moment Arm (Positive)

Center of Mass

DIRECTION OF CUT

Men

Women

Men

Women

Men

Women
RESULTS

Position of the Center of Mass at 33 ms

- Medial-Lateral Position
  - Trunk was more medially displaced with respect to knee at 33 ms between fatigue and post-fatigue cuts.
- Vertical Position
  - Women's trunk was more vertically displaced.
  - Men's trunk was more vertically displaced with fatigue.
  - Women's trunk was more vertically displaced during side step cuts than during crossover cuts.

Fatigue Effects

- What effect does fatigue have on the muscular control of the lower extremity?
  - Subjects: 16 female and 13 male D1 soccer players
  - Each player completed a T-test until a 5% decrement in performance was observed.
  - sEMG from the quadriceps and hamstring muscles and marker displacement histories were obtained.

RMS, EUSEBIO, MARTIN, ET AL.

10 QUADRICEPS/HAMSTRING RATIO AT 33 MS

Low Pass Filtered
10 Hz Cutoff

15 Segment Model
ZYX Euler Decomposition

Angular Position at 33ms
Post Contact

Band Pass Filtered
10 and 350 Hz Cutoffs

RMS Obtained
(250 ms Window)
Peak RMS Value of MVC

RMS Value at 33 ms

\[ \text{RMS}_{\text{ratio}} = \frac{\text{RMS}_{\text{quads}}}{\text{RMS}_{\text{hamstrings}}} \]
RESULTS

Quadriceps/Hamstring Ratio at 33ms

- Kinematics:
  - With fatigue athletes were in a more:
    - Extended hip and knee position
    - Less abducted knee position
- Muscle Activity:
  - Females, regardless of fatigue status, had a significantly greater Q/H ratio than males
  - With fatigue Q/H ratio significantly increased in females

1. Hip and Knee
   - Hip and knees become more extended with fatigue

1. Center of Mass
   - Fatigue decreases the lateral displacement of the center of mass

1. Muscular Control
   - Women use a more ‘quad dominant’ strategy
   - In women fatigue exacerbates the use of a ‘quad dominant’ strategy

Summary

1. Hip and Knee
   - Hip and knees become more extended with fatigue

1. Center of Mass
   - Fatigue decreases the lateral displacement of the center of mass

1. Muscular Control
   - Women use a more ‘quad dominant’ strategy
   - In women fatigue exacerbates the use of a ‘quad dominant’ strategy

Aim of Project

1. To determine how “at-risk” biomechanics are affected by fatigue utilizing a ‘game-like’ testing paradigm.

1. To determine the impact of training on the anterior cruciate ligament of the knee.
What effect does training have on the ACL?

- Subjects: 16 female D1 soccer players
- Each subject had two MRI examinations of their knees bilaterally:
  - Pre-season
  - Within 2 weeks of completion of season (Post-Season)
- T2 weighted sagittal images taken
  - Images used to determine presence of edema.
  - Contours of ACL used to obtain volume of ACL

**RESULTS:**

ACL Volume

- Training appears to have an effect on the ACL.
  - Over the course of a competitive season:
    - Incidence of edema increases
    - Increase in the volume of ACL is seen
- What effect does training have on the osseous structures of the knee?
- Subjects: 19 female D1 soccer players
- Each subject had three MRI examinations of their knees bilaterally:
  - Pre-season
  - Within 2 weeks of completion of season (Post-Season)
  - Within 6 weeks of completion of season (Recovery)
- Images were classified and then scored using Knee Osteoarthritis Scoring System (KOSS) by board certified radiologist.

Results:
- Training has an effect on osseous structures of the knee.
- The severity of BME increases over the span of a season.
- With rest will return to preseason levels.

KOSS Ratings of BME

- Training has an effect on osseous structures of the knee.
- The severity of BME increases over the span of a season.
- With rest will return to preseason levels.
Summary

1. Training – Competition:
   - Causes changes in the ACL
   - Impacts osseous structures

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