Core Performance Measures and Body Segment Kinematics Following Knee Joint Loading Among Female Collegiate Athletes

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Background & Significance

- The core muscles are lumbopelvic stabilizers and, as a whole, they are the base to which limbs attach for movement (Hart, J Athl Train, 2009)

- Fatigued core muscles allow excess trunk movement, an anterior cruciate ligament (ACL) tear risk factor (Schütte, PLoS One, 2015)
  - Center-of-mass shifts outside base of support; heightened forces act on knee

- ACL injury rates vary greatly among women’s stick-carrying sports (ice hockey = 0.02 per 1000 athletic exposures; lacrosse = 0.23; field hockey = 0.11) (Agel, Clin J Sport Med, 2016)

- Identification of modifiable risk factors for ACL-tears could help reduce the incidence of the injury in women’s stick-carrying sports
Specific Aims & Hypotheses

Specific Aims:
- Identify modifiable risk factors for ACL-tears in women’s athletics, investigating core performance measures and body segment kinematics
- Determine potential reasons for disparate ACL-tear rates among women’s ice hockey, lacrosse, and field hockey, all sports that carry a stick

Hypotheses:
- Ice hockey players will have greater core strength than lacrosse and field hockey players
- Ice hockey players will have lesser lateral trunk lean and knee valgus angle than lacrosse and field hockey players during a single-leg landing task
Methods: Experimental Design & Participants

- For a one-way ANOVA, 4 participants in each group yielded 80% power
- Based on a single-leg landing task with max knee valgus difference of 16° between groups, standard deviation of 6.1° (Herrington, J Strength Cond Res, 2011)

Table 1. Participant demographics and anthropometrics

<table>
<thead>
<tr>
<th>Sport</th>
<th>n</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body Mass (kg)</th>
<th>P - Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice Hockey</td>
<td>10</td>
<td>19.3 ± 1.6</td>
<td>168.4 ± 4.9</td>
<td>68.5 ± 4.9</td>
<td>0.714</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>12</td>
<td>19.8 ± 1.1</td>
<td>167.5 ± 5.4</td>
<td>66.2 ± 4.9</td>
<td>0.501</td>
</tr>
<tr>
<td>Field Hockey</td>
<td>4</td>
<td>19.5 ± 0.6</td>
<td>168.5 ± 9.7</td>
<td>66.6 ± 8.9</td>
<td>0.621</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation. One-way ANOVA assessed intergroup differences. P ≤ 0.05 denotes statistical significance.
Methods: Procedure

Baseline Single-Leg Vertical Drop Landing

Baseline Core Strength Assessment

Core Endurance Assessment

Secondary Core Strength Assessment

Secondary Single-Leg Vertical Drop Landing

Figure 1. Sequence of events completed by participants

Stood on non-dominant leg, hopped off 30-cm box onto non-dominant leg while video camera recorded for pre-core fatigue kinematic analysis

Performed trials of trunk flexion, then extension, into a strap-fixated handheld dynamometer for pre-core fatigue strength (Adapted from Harding, SAGE Open Med, 2017)

Performed circuit of sit-ups, back extensions, side crunches, and seated trunk twists wearing weighted vest adjusted to 15% of body mass. Reps were to 36-bpm metronome cadence. Each exercise was completed until self-perceived fatigue (Adapted from Abt, J Strength Cond Res, 2007)

Performed trials of trunk flexion, then extension, into a strap-fixated handheld dynamometer for post-core fatigue strength

Stood on non-dominant leg, hopped off 30-cm box onto non-dominant leg while video camera recorded for post-core fatigue kinematic analysis
Methods: Kinematic Analysis

A: Determination of lateral trunk lean angle (LTL)
- ASIS line = line drawn from right to left ASIS; mid-point of line found
- Global vertical axis = the dashed line running though mid-point of ASIS line
- Sternal line = line drawn from ASIS line mid-point to sternal notch
- LTL = angle between global vertical axis and sternal line

B: Determination of knee valgus angle (KV)
- Femoral line = line drawn from non-dominant ASIS to knee joint center
- Tibial line = line drawn from knee joint center to distal tibia center
- KV = absolute value of 180° minus the angle between femoral and tibial lines
- Valgus angles denoted by (+)
- Varus angles denoted by (-)

Figure 2. Determination of landing joint kinematics. Joint angle calculations based on Herrington, The Knee, 2014; Boden, Am J Sports Med, 2009
**Results**

**Figure 3.** Baseline average median normalized peak trunk flexion force between ice hockey and lacrosse. *Denotes statistical significance

<table>
<thead>
<tr>
<th>Condition Variable</th>
<th>Effect size (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Valgus Angle at Initial Contact</td>
<td>0.84†</td>
</tr>
<tr>
<td>Peak Lateral Trunk Lean Angle</td>
<td>1.36†</td>
</tr>
</tbody>
</table>

**Table 2.** Effect size (Cohen's d) comparisons for kinematic measures of ice hockey vs. field hockey. † Denotes large effect size

<table>
<thead>
<tr>
<th>Condition</th>
<th>Variable</th>
<th>Effect size (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Kinematic Measurements</td>
<td>Knee Valgus Angle at Initial Contact</td>
<td>0.84†</td>
</tr>
<tr>
<td></td>
<td>Peak Lateral Trunk Lean Angle</td>
<td>1.36†</td>
</tr>
<tr>
<td>Post-Core Endurance Assessment Kinematic Measures</td>
<td>Peak Lateral Trunk Lean Angle</td>
<td>1.17†</td>
</tr>
</tbody>
</table>

**Figure 4.** Pairwise comparisons between groups for post-core endurance assessment average median normalized peak isometric trunk flexion force. *Denotes statistical significance

† Denotes large effect size
Discussion

• Ice hockey players displayed greater core strength
  • Ice hockey is more power and strength-based than lacrosse or field hockey
  • Power athletes have greater peak force and faster rate of force development (Häkkinen, *J Sports Med Phys Fitness*, 1990)
  • Allows for increased resistance to external perturbations to the trunk

• Characteristics of each sport could influence trunk strength outcomes
  • Core strength and activation is associated with balance (Calatayud, *Gait Posture*, 2015; Ruiz, *Strength Cond J*, 2005)
  • Ice hockey players skate on a low-friction surface while dynamically balancing on a narrow base of support, which is associated with heightened physical demands that may yield increased core muscle activation (Cosio-Lima, *J Strength Cond Res*, 2003)

• Large effect sizes for kinematic measures indicate field hockey players may have poorer control of frontal plane trunk and knee motions, an ACL-tear risk factor (Zazulak, *Am J Sports Med*, 2007)
Limitations

• Participants may not have been challenged by the height of the landing task
• Did not analyze sagittal plane trunk and knee positioning
• Did not establish lateral trunk flexion strength
  • Would be more directly correlated to lateral trunk lean angle
• Participant efforts during core strength and endurance assessments were self-regulated, and could have been below maximum
Clinical Significance

- The core is the base to which the extremities attach for movement
  - Core muscles are proximal stabilizers for distal segments

- Core strength is a modifiable risk factor associated with ACL tears

- Core strengthening programs could be implemented as a means to help reduce ACL-tear rates among women’s stick-carrying sports
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• Pennsylvania State University Intercollegiate Athletics Collaboration

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  • Zachary Hobson, Robert Slowik
References