The Effect of Fatigue on Neuromuscular Risk Factors for Knee Injury: A Systematic Review
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Background
- 2.5 million athletes report to the emergency room each year with a knee injury, representing one of the most commonly injured joints.\(^1\)
- Fatigue can have a significant effect on injury; however, the effect of fatigue on these risk factors is largely unknown (see Figure 2).
- Risk factors for injury during sport can be divided into two separate categories:
  - Internal risk factors: physical deficiencies, physical fitness, previous injury, psychological factors, physical build, age & sex.
  - External risk factors: type of sport, venue, equipment, weather conditions, and other athletes.\(^2\)
- In an effort to prevent the fatigue-related knee injuries, we must establish the effect fatigue has on neuromuscular risk factors, including electromyographic activity (EMG) of knee musculature, postural stability, and proprioception (see Figure 3).

Methods
- Systematic review: Pubmed, Embase, and CINAHL
- Highlighted inclusion criteria:
  (1) Healthy active individuals ages 17-39 years
  (2) Measurable fatigue as an intervention pre and post fatigue protocol (see Figure 1)
  (3) Outcomes measured post-fatigue protocol: electromyography, postural stability, and proprioception
- Highlighted exclusion criteria:
  (1) Previous lower limb reconstruction or any injury occurring in previous six months
  (2) Outcomes including: joint kinematics, ground reaction forces, joint kinetics, or strength

Purpose
- To examine the evidence that fatigue affects neuromuscular risk factors for knee injury including electromyographic activity (EMG) of the knee musculature, postural stability, and proprioception.

Results

<table>
<thead>
<tr>
<th>Neuromuscular Risk Factor Studied</th>
<th>Outcome Measure</th>
<th>Articles</th>
<th>Significant Results Post Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Decreased hamstring &amp; anterior tibialis activation, increased gastrocnemius &amp; soleus activation, &amp; increased quadrieps/hamstring coactivation, w/ greater effect in females</td>
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<tr>
<td></td>
<td>EMG during Gait</td>
<td>Ballantyne et al. 2011; Kells, Lissiotis, 2009; Kells et al. 2011</td>
<td>Increased vastus medialis &amp; biceps femoris activation during treadmill running</td>
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<td>EMG during Eccentric Contraction</td>
<td>Longore et al. 2015</td>
<td>Increased vastus lateralis &amp; rectus femoris activation in lunges as compared to squats</td>
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</table>
|                                  | Static & Dynamic Balance Recovery | Dickin et al. 2008; Johnston et al. 1998; Mademli et al. 2008; Whyte, 2015 | Balance impairments in both AP and ML directions
|                                  |                                   |                                                                          | Increased mean COP
|                                  |                                   |                                                                          | Decreased postural stability when both unilateral & bilateral knee extensors were fatigued       |

Analysis of Risk Factors
- Delay in glutus medius activation
- Decreased hamstring & anterior tibialis activation, increased gastrocnemius & soleus activation, & increased quadrieps/hamstring coactivation, w/ greater effect in females
- Increased vastus medialis & biceps femoris activation during treadmill running
- Increased vastus lateralis & rectus femoris activation in lunges as compared to squats
- Balance impairments in both AP and ML directions
- Decreased balance skill and star balance test performance in both women & men
- Decreased peak force
- Increased mean COP
- Decreased postural stability when both unilateral & bilateral knee extensors were fatigued

Clinical Relevance
- The examination of risk factors for musculoskeletal injury is an essential step in injury prevention.
- The evidence outlined in this systematic review demonstrates how fatigue negatively affects neuromuscular characteristics – potentially providing insight for interventions that target fatigue.
- Possible prevention strategies include:
  - Physical training programs that attempt to reduce the effects of fatigue on risk factors for injury
  - Nutritional interventions
  - Sleep, rest, and other activities designed for recovery
- Future research is necessary to examine these interventions.

Acknowledgements / References
4. Photos courtesy of Dr. Timothy Sell

Figure 1: Inclusion Criteria for Fatigue Protocol Assessment

PRE-TEST
Fatigue defined as completing exercise until:
- +50% decrease in MVC
- Peak torque drops below 50%
- Jump height decreases by 30%
- Unable to complete full ROM at 50% of 1 RM
- Unable to maintain 60/min on cycle ergometer
- Squatting drops 4 cycles behind set pace of metronome

Assess EMG, postural stability, and/or proprioception

FATIGUE PROTOCOL

Reassess EMG, postural stability, and/or proprioception

POST-TEST

Figure 2: Workload Injury Aetiology Model (from Windt and Gabbett, 2016)

Figure 3: Variables Examined (EMG, Postural Stability, and Proprioception)