Lower Extremity EMG in Male and Female College Soccer Players During Single-Leg Landing

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Context: Gender differences in muscle activity during landing have been studied as a possible contributing factor to the greater incidence of anterior cruciate ligament injuries in women. Objective: To compare root-mean-square (RMS) electromyography (EMG) of selected lower extremity muscles at initial contact (IC) and at peak knee internal-rotation (IR) moment in men and women during landing. Design: Preexperimental design static-group comparison. Setting: Motion-analysis laboratory. Participants: 16 varsity college soccer players (8 men, 8 women). Main Outcome Measures: EMG activity of the gluteus medius, lateral hamstrings, vastus lateralis, and rectus femoris during landing. Results: When RMS EMG of all muscles was considered simultaneously, no significant differences were detected between genders at IC or at peak knee IR moment. Conclusion: Male and female college soccer players display similar relative muscle activities of the lower extremity during landing. Gender landing-control parameters might vary depending on the technique used to analyze muscle activity. Key Words: anterior cruciate ligament, muscle activity, knee moment

Women have been shown to suffer injury to the anterior cruciate ligament (ACL) more often than men in sports such as basketball and soccer. Specifically, in soccer, women have a higher incidence of ACL injury than men and are 3 times as likely to suffer a noncontact mechanism of injury. In soccer, athletes run, jump, cut, and land. Any of these maneuvers can place the knee in a precarious situation with excessive stress to the ACL. Landing is believed to be one of the primary mechanisms for noncontact ACL injury in female athletes. Gender differences in muscle activity have been

studied as a possible contributing factor to increased ACL injury in women. Although gender discrepancies in muscle activation during landing are seen in the literature, the activity of the muscles at or around peak knee-joint moments has not been investigated. This information might be useful in explaining how athletes recruit their muscles to dissipate the potentially injurious joint moments experienced during athletic maneuvers.

During landing, the weight of the body is decelerated over the lower extremity through muscle activity of the trunk, hips, and legs. Several studies have examined the influences of muscle activity on landing. In these studies, the quadriceps and hamstrings are the muscles of focus, whereas the more proximal influence of the gluteal muscles has been largely ignored. The gluteals work eccentrically to directly affect the amount of femoral internal rotation and adduction that occurs as an athlete attempts to slow down the body in a landing maneuver. Based on the femoral movement that transpires, the knee joint, and subsequently the ACL, is indirectly affected.

Examination of gender differences in muscle activity during jumping and landing tasks can involve different techniques such as timing of onset and peak activity. When subjects perform an abrupt horizontal deceleration on 1 leg (while catching a ball thrown at chest level), similar quadriceps activation is seen across genders in both onset time of muscle activity at initial contact and overall duration of the muscle-burst activity. Women, however, display less synchronous peak hamstring activity than men do at initial contact, suggesting decreased protection to the ACL. With the knee in a flexed position, hamstring-muscle orientation is such that it pulls the tibia in a posterior direction in relation to the femur, thereby reducing strain to the ACL. It has also been suggested that women with intrinsic knee-joint laxity stabilize their knees through a compensatory measure of lateral hamstring-muscle activation. When knee-joint laxity was tested with an instrumented arthrometer, women demonstrated greater anterior tibial-translation values than those of men, with concomitant decreased joint proprioception as subjects attempted to detect movement into knee extension. Despite these differences from the men, the women produced greater peak amplitude and area of the lateral hamstrings before landing on their test leg from a height of 25.4 cm.

Kinetic gender differences at the knee have been examined in athletic maneuvers of stop-jump tasks and volleyball landings. Recreational women athletes produced larger knee-extension moments than men did when executing forward and vertical stop-jump tasks. Likewise, in a study of college volleyball players, women exhibited greater knee-extension moments than those of their male counterparts as they landed from a simulated 60-cm-block landing. In addition, differences in energy absorption and peak power have been noted during landing from a height of 60 cm. A landing pattern of greater energy absorption from the knee, with less contribution from the hip, was used by the women. These findings
suggest a more upright landing posture and a greater knee-extension torque in women but don’t explain how athletes are responding from a muscular standpoint to potentially important kinetic time intervals. This information might be helpful in understanding the internal muscle forces that men and women use to overcome peak knee-joint moments experienced during stressful situations at the knee. Therefore, the purpose of this study was to compare normalized root-mean-square (RMS) electromyography (EMG) of the gluteus medius, lateral hamstrings, vastus lateralis, and rectus femoris at initial contact and at peak knee internal-rotation (IR) moment in men and women during drop landings.

Methods

Design

A 2-group static-comparison design was used in this study. The independent variable was gender. The dependent variables were the RMS EMG of the gluteus medius, lateral hamstrings, vastus lateralis, and rectus femoris muscles.

Subjects

Sixteen varsity college soccer players (8 men, age 19.3 ± 1.5 years, height 182.9 ± 2.4 cm, mass 77.1 ± 6.9 kg; 8 women, age 22.1 ± 2.4 years, height 168.6 ± 6.8 cm, mass 61.8 ± 3.2 kg) volunteered for the study. All but 1 of the subjects competed at the Division I level and were healthy and without lower extremity injury within the preceding year. The 1 subject who was an exception to Division I was an all-conference player at the Division III level. None of the subjects had a history of an ACL repair on their dominant lower extremity. Each subject gave informed consent before testing. The study was approved by the Human Investigations Committee at the University of Virginia.

Instrumentation

A 16-channel EMG system with preamplified double-differential EMG electrodes (Motion Lab Systems MA-300-16, Baton Rouge, La) was used to measure the muscle activity at a sampling rate of 1080 Hz. The input impedance of the amplifier was >100 MΩ, with a common-mode rejection ratio of >100 dB and a signal-to-noise ratio of 50 dB. To calculate mean peak knee moments, raw ground-reaction forces were collected at 1080 Hz with a force plate (AMTI OR 6-7, Watertown, Mass) while a 10-camera motion-analysis system (Vicon, Oxford Metrics, London, UK) simultaneously captured reflective markers at 120 Hz.
Measurement

All data were collected simultaneously through the Vicon workstation, and collection began with contact of the force plate. EMG data were processed with AcqKnowledge™ software (BIOPAC Systems, Inc, Santa Barbara, Calif), and each window of muscle activity was full-wave rectified and filtered with a high- and low-pass filter (10 and 500 Hz). The RMS for all 4 muscles was then calculated from the processed EMG using a 3-millisecond window within a RMS algorithm. An RMS measurement was chosen to provide an overall estimate of relative muscle activity at critical points in time during the landing maneuver. Data were normalized to 1 static single-leg stance of equivalent duration (80 milliseconds = initial contact, 40 milliseconds = IR moment). Single-leg stance was selected for normalization because it represents a functional measure of EMG activity.

Mean peak knee internal-rotation moments were calculated from the raw ground-reaction force and kinematic data through a commercialized full-inverse dynamic model (Vicon Clinical Manager), normalized to body mass, and reported in Newton meters per kilogram (N · m/kg). Joint moments were calculated from the parameters of mass and inertial characteristics of each lower extremity segment, the derived linear and angular velocities and accelerations of each lower extremity segment, and estimates of ground-reaction force and joint-center position.

Procedures

Sixteen reflective markers were placed on the right and left lower extremities of each subject according to the Vicon Clinical Manager protocol before data collection at the following landmarks: anterior superior iliac spine, posterior superior iliac spine, lateral midthigh, lateral condyle of femur, lateral midcalf, lateral malleolus, posterior calcaneus, and the head of the second metatarsal. Subjects were given an opportunity to practice the landing task until they felt comfortable. They were instructed to stand on their left leg and drop from the platform without lunging or jumping (Figure 1). Five consecutive trials of single-leg landing onto the force platform were performed from a height of 60 cm, and the mean of the trials was used for analysis. Each individual landed on his or her right leg and maintained balance for up to 2 seconds. The right leg was chosen because it was the dominant leg (the leg that would be used for single-leg jumping activities) for each subject.

Double-differential EMG preamplifier electrodes were placed over the right lower extremity muscle bellies of the gluteus medius, rectus femoris, vastus lateralis, and biceps femoris. The muscles were palpated to ensure correct electrode placement. The EMG pack and wires were attached with Velcro™ to the posterior aspect of a vest worn by the subject.
was collected during the landing procedure and analyzed for 80 milliseconds around (40 milliseconds before and 40 milliseconds after) initial contact and for 40 milliseconds around (20 milliseconds before and 20 milliseconds after) mean peak knee internal-rotation (IR) moment. This joint moment was selected to examine the muscle activity of the lateral hamstrings at this point in time, based on research that has demonstrated a significant reduction in IR of the tibia from an applied hamstring load.20,21

**Statistical Analysis**

A MANOVA was used to determine whether there were gender differences for a linear combination of all the normalized RMS EMG activity. Univariate ANOVAs were used for post hoc comparisons, and the alpha level was set a priori at $P < .05$. 

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**Figure 1**  Subject performing a single-leg drop landing from a height of 60 cm. Root-mean-square EMG was collected at initial contact and peak knee internal-rotation moment.
Results

Means and standard deviations of RMS-EMG activity at initial contact and mean peak knee IR moment for all 4 muscles are given in Table 1. When all dependent variables were considered simultaneously, no significant differences were detected between genders in RMS EMG at initial contact ($F_{4,11} = 2.28, P = .126, \eta^2 = .454, 1 – \beta = .475$) or at peak knee IR moment ($F_{4,11} = 0.959, P = .467, \eta^2 = .259, 1 – \beta = .213$).

Discussion

The identification of lower extremity muscle activation across genders in response to potentially adverse external forces about the knee during athletic situations could be helpful in understanding the mechanism of ACL injury. For that reason, we wanted to examine the activity of selected lower extremity muscles in male and female soccer players at 2 critical points in a landing maneuver. Because women land with greater hip IR, placing the knee in an internally rotated position, we hypothesized that the women in our study would generate significantly lower EMG values than those of the men at peak knee IR moment. No significant differences in relative muscle activity were seen between genders, however, suggesting that the women used a landing-control strategy similar to that of the men to account for the peak rotation torque.

Muscle activity during dynamic events can be measured in many different ways. Onset of muscle activation at initial contact and time to

<table>
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<th>Muscle</th>
<th>Initial Contact</th>
<th>Peak Knee Internal-Rotation Moment</th>
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<tbody>
<tr>
<td></td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>Gluteus medius</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>3.84</td>
<td>7.40</td>
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<td></td>
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<tr>
<td>Lateral hamstrings</td>
<td>6.13</td>
<td>8.97</td>
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<tr>
<td></td>
<td>(3.15)</td>
<td>(6.76)</td>
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<tr>
<td>Vastus lateralis</td>
<td>9.69</td>
<td>14.88</td>
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<tr>
<td></td>
<td>(3.58)</td>
<td>(6.93)</td>
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<tr>
<td>Rectus femoris</td>
<td>7.81</td>
<td>8.55</td>
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peak relative to the timing of peak tibiofemoral-joint shear force have been examined. A delay in activation of hamstrings by the men was suggested to be a protective measure to better counteract the high anterior tibial shear forces encountered during landing or deceleration. Because anterior tibial translation is considered a potential mechanism of injury for the ACL, activation of the hamstrings could potentially lessen the forces transmitted to the ligament. When RMS activity of the hamstrings was considered during a single-leg landing in normal and ACL-deficient subjects, a significant relationship was established between the hamstring activity and anterior tibial accelerations. The higher the hamstring muscle activity, the lower the anterior tibial accelerations.

Although our study did not measure anterior movement of the tibia, it did examine the RMS EMG activity of the gluteus medius and lateral hamstrings during the peak knee internal-rotation moment. The kinetics could be driving the knee toward injury, and muscle activity during this event could act as prevention. Hamstring-muscle activity is documented in decreasing anterior tibial translation and IR. The findings in our study are comparable to those of a landing study that compared muscle activation in male and female college basketball players. Average rectified EMG output was measured for the vastus lateralis, vastus medialis, lateral hamstrings, medial hamstrings, and gastrocnemius muscles at 0.5 seconds prelanding and at initial contact on the dominant leg. No significant differences were seen in medial or lateral hamstring activation between the genders.

One reason for the lack of significant gender differences in muscle activity might have to do with the subject population used in these studies. Varsity college soccer players participated in our study, whereas Fagenbaum and Darling used varsity college basketball players. At the Division I level of competition the training programs for women are analogous to those of men in basketball and soccer. Athletes in both sports most likely participate in programs that involve strength, flexibility, plyometric, and neuromuscular training. Likewise, both the men and women in our study had participated in soccer on a year-round schedule before college and in most cases had been involved with a competitive club team or even with the US junior national team. These subjects were highly skilled athletes who were accustomed to performing complicated movements and were, for the most part, anthropometrically similar. Therefore, the task that was presented to them might not have been representative of a sport-specific movement and thus did not provide enough of a stimulus to elicit gender differences in muscle activity. The more difficult and unexpected the activity, the more likely the athlete is to respond in an awkward or off-balance manner. In addition, highly trained female athletes could be less susceptible to ACL stressors because their neuromuscular system is efficient at organizing highly complex activities. If a female athlete has been previously
exposed to a potentially damaging situation during a controlled training program, it is possible that she might respond to the same situation during a competition in a more positive manner and avoid a possible injury to the knee. Research has demonstrated that a plyometric training program can decrease landing forces and increase hip-adductor firing, and a neuromuscular training program can improve dynamic balance and decrease the incidence of ACL injuries in women.

An additional limiting factor to our study was the relatively low sample size and power. When using Division I athletes, it is often difficult to recruit and test these athletes because of time constraints and restrictions placed on their participation from demanding academic and athletic schedules. Previous ACL research examining gender differences in college students, however, has been conducted using comparable sample sizes. Because of the small sample size and inherent variability of EMG data, the power was low in this study.

Although they formed a small sample, the male and female varsity college soccer players in this study displayed similar relative muscle activities of the lower extremity during landing. This is comparable to an earlier finding of no differences in hamstring activity during landing in male and female college basketball players. There might be gender differences in muscle activation during landing in certain populations, depending on the technique that is used to analyze muscle activity and the skill level of the subjects being tested.

References


