Comparison of Knee-Joint Moments in Male and Female College Soccer Players During a Single-Leg Landing

J. Craig Garrison, Joe M. Hart, Riann M. Palmieri, D. Casey Kerrigan, and Christopher D. Ingersoll

Context: Although kinematic analyses are helpful in describing movement differences between genders, kinetic data might further explain the predisposing factors contributing to potential injury during athletic landing maneuvers. Objective: To determine whether there are differences in knee moments between male and female varsity college soccer players during a single-leg landing. Design: Preexperimental with static group comparison. Setting: Motion-analysis laboratory. Participants: 16 varsity college soccer players (8 men, 8 women). Intervention: Subjects performed 5 single-leg landings from a height of 60 cm. Main Outcome Measures: Peak internal rotation, valgus, varus, and extension knee moments calculated from raw ground-reaction forces and kinematic data. Results: Significant gender differences were present ($P = .020$), with men exhibiting 31% greater mean peak knee-varus moments than women when landing on a single leg from 60 cm ($P = .020$). Conclusions: Male soccer players demonstrate greater knee-varus moments than female soccer players during single-leg landing. This might be valuable in designing clinical treatment and prevention programs for ACL injuries. Key Words: ACL, kinetics, gender differences

Injury to the anterior cruciate ligament (ACL) is common in athletics. Although an ACL injury can occur to either gender, female athletes have been shown to be 2 to 4 times more likely to suffer from such an event.\(^1\,^2\) In soccer, the incidence rate of ACL injury is 2 times greater in females than in males,\(^3\) and females are 3 times as likely to suffer a noncontact injury.\(^1\,^2\) Noncontact mechanisms of injury often include jumping, cutting, and landing. Such movements are inherent in soccer and could place an athlete’s knee in a compromising position.\(^3\) Therefore, it is important to understand the mechanics of jumping, cutting, and landing and any gender differences there might be during these activities.

Gender differences in neuromuscular control\(^4\,^6\) and kinematics\(^7\,^11\) have been implicated as predisposing factors of ACL injury. Females demonstrate greater knee
extension,\textsuperscript{10-13} valgus angle,\textsuperscript{9,11,14} and hip internal rotation\textsuperscript{13} than males during landing activities. Although many kinematic studies have been conducted that exposed gender differences during landing, the literature does not contain as many kinetic analyses. In addition, research examining internal-rotation moments in conjunction with valgus, varus, and extension moments has not been presented in the literature as of yet. The kinematic variables are helpful to describe the motion, but without thorough kinetic information it is difficult to fully understand the mechanisms of ACL injury.\textsuperscript{15}

Females exhibit greater knee-extension and -valgus moments than males during the landing phase of stop-jump tasks, suggesting that this phase provides more stress to the ACL.\textsuperscript{16} Female volleyball players also demonstrate greater knee-extension moments than males in a 60-cm block landing.\textsuperscript{12} The combination of knee extension, genu valgus, and femoral internal rotation is believed to place the ACL in a vulnerable, and possibly damaging, position.\textsuperscript{17} Although extension and valgus moments have been measured, it is also important to examine the transverse plane of movement and knee internal-rotation moments. An examination of these variables might provide greater understanding of the potentially unwarranted stress that internal-rotation moments exert on the ACL. Therefore, the purpose of this study was to compare the internal-rotation, varus, valgus, and extension moments of the knee among male and female college soccer players during a drop landing. Our hypothesis was that the women would produce greater knee internal-rotation and valgus moments than the men when landing on a single leg from a height of 60 cm.

**Methods**

**Design**

A preexperimental design with static group comparison was used for this study. The independent variable was gender, and the dependent variables were mean peak knee-joint moments (varus, valgus, extension, and internal rotation).

**Subjects**

Eight male (age 19.3 ± 1.5 years, height 182.9 ± 2.4 cm, mass 77.1 ± 6.9 kg) and 8 female (age 22.1 ± 2.4 years, height 168.6 ± 6.8 cm, mass 61.8 ± 3.2 kg) varsity college soccer players volunteered for this study. Subjects had no history of knee injury within the preceding year and were healthy during the time of testing. The study was approved by the human-investigation committee at the University of Virginia. Each subject signed an informed-consent form before participation.

**Instrumentation**

A force plate (AMTI OR 6-7, Watertown, Mass) was used to collect raw ground-reaction forces (GRF), which were sampled at 1080 Hz. A 10-camera (M2 series) motion-analysis system (Vicon, Oxford Metrics, London, UK) was synchronized with the force plate and simultaneously captured the 3-D position of the markers at 120 Hz.
Testing Procedures

Sixteen retroreflective markers were placed bilaterally on the lower extremities according to the Vicon Clinical Manager protocol before subjects practiced the landing task. They were placed on each posterior superior iliac spine, anterior superior iliac spine, lateral midthigh, lateral condyle of the femur, lateral midcalf, lateral malleolus, posterior calcaneus, and second metatarsal. After being given an opportunity to practice the landing task until they felt comfortable, subjects performed 5 trials of single-leg drop landing from a 60-cm platform. The 5 trials were averaged for data analyses. Subjects were instructed to stand on the left leg and drop off of the platform, without jumping or lunging, onto the force plate (Figure 1). On landing, subjects were instructed to hold the position for up to 1 to 2 seconds without losing their balance. Landing occurred on the dominant leg (right leg) for each individual, which was determined by asking the subject which leg he or she would use to kick a ball. A rest period of 30 to 60 seconds took place between trials.

Subjects’ landings were monitored for symmetry and balance through visual inspection by the researcher and review of the trial in Vicon. Trials that were unsuccessful (ie, loss of balance, nontest-extremity contact with the floor, and any other adverse effects) were repeated.

Figure 1 — Subject performing the single-leg landing procedure from 60 cm.
Data Analysis

Mean peak knee moments were calculated from the raw GRF and kinematic data using a commercialized full-inverse dynamic model (VICON Clinical Manager). Joint moments were normalized to body mass and reported in Newton meters per kilogram (N \cdot m/kg). The parameters used to calculate joint moments were 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 GRF and joint-center position.

Statistical Analysis

A MANOVA was used to determine whether there was a difference between genders for a linear combination of the peak knee-joint moments. Post hoc comparisons were made using univariate ANOVAs. Data were analyzed using the Statistical Package for Social Sciences (version 11.0, SPSS Inc, Chicago, Ill) for Microsoft Windows. The significance levels for all tests were set a priori at $P \leq .05$.

Results

The MANOVA revealed a significant Gender $\times$ Moment interaction ($F_{4,11} = 4.6$, $P = .02$, $\eta^2 = .627$, $1 - \beta = .805$). Post hoc ANOVAs revealed significant differences between subjects. Greater mean peak knee-varus moments were seen in the men (2.20 ± 0.46) than in the women (1.68 ± 0.35) when they landed on a single leg from 60 cm ($F_{1,14} = 6.7$, $P = .02$, $\eta^2 = .322$, $1 - \beta = .670$; Table 1). There were no significant gender differences, however, in knee valgus ($F_{1,14} = 1.8$, $P = .19$, $\eta^2 = .116$, $1 - \beta = .244$), internal-rotation ($F_{1,14} = 2.1$, $P = .16$, $\eta^2 = .133$, $1 - \beta = .276$), or extension ($F_{1,14} = .38$, $P = .54$, $\eta^2 = .027$, $1 - \beta = .089$) moments during landing (Table 1).

Discussion

Although these data do not support the original hypotheses of greater knee internal-rotation and valgus moments in women, it is evident that significant rotary forces are being experienced at the knee. Without dissipation of these forces, the ACL could encounter considerable stress. In females, greater hip internal rotation with

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Peak Knee Moments During Single-Leg Landing From 60 cm, Mean (SD)</th>
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<tbody>
<tr>
<td></td>
<td><strong>Men</strong></td>
</tr>
<tr>
<td>Extension</td>
<td>1.271 (0.903)</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>0.401 (0.179)</td>
</tr>
<tr>
<td>Valgus</td>
<td>0.262 (0.222)</td>
</tr>
<tr>
<td>Varus</td>
<td>2.203* (0.462)</td>
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accompanying decreased lower leg internal rotation is seen with landing.\textsuperscript{13} This position of increased femoral rotation with a decreased or externally rotated tibia and a knee moving toward extension is thought to be a common mechanism of ACL injury.\textsuperscript{17} If this position is reached, the kinetics might help explain the forces driving the knee toward potential injury. By examining the joint moments in all 3 planes of motion, we can begin to develop a kinetic model of what is occurring at the knee.

The greater varus knee-joint moments seen in men suggest that they used a different landing strategy than the women. This is not likely a result of any type of training effect because both the men’s and women’s soccer teams are involved in similar strength and conditioning programs and have participated in organized soccer since an early age. In fact, the men could be using an adaptive landing strategy to avoid or minimize stress to the ACL. A larger varus moment is not uncommon in landing and has been seen previously in male recreational athletes during vertical and backward stop-jump tasks.\textsuperscript{16}

Internal-rotation, valgus, and extension moments of the knee were not found to be significantly different between the men and women in our study. These findings contradict those of landing research that examined stop-jump tasks across gender.\textsuperscript{16} In the stop-jump study, females displayed significantly larger knee-extension moments during landing from both vertical and forward jumps and larger valgus knee moments during landing from vertical and backward jumps. Variation in the results of the 2 studies could be a result of the different landing tasks. Whereas the stop-jump landings were preceded with an approach of up to 3 steps, our landing was preceded with a controlled drop from a 60-cm platform.

The lack of significant difference in knee-extension moments from our findings is similar to results from another kinetic landing study\textsuperscript{7} in which knee-extension, hip-extension, and ankle plantar-flexion moments were recorded in 12 men and 9 women during a single-leg drop landing from 60 cm. No gender differences were found for any of the joint moments. Although females land in greater knee extension than males,\textsuperscript{7,10,13} the moment acting on this knee position might not be the culprit for ACL injury. It is more than likely a combination of the moments occurring in the sagittal, frontal, and transverse planes of motion, not only at the knee but also quite possibly at the hip and ankle.

Finally, the absence of significant gender differences in knee internal-rotation and valgus moments could be explained by the task that the athletes were asked to perform. A drop landing from 60 cm might not be representative of sport-specific activity. The subjects are familiar with the procedure and do not have to react to any changes in the environment, unlike what they might encounter on the soccer field. Likewise, these subjects are elite soccer players who are quite accustomed to performing complex athletic maneuvers in a skilled manner. Both the male and female athletes participate in training programs that include strength, agility, neuromuscular, and plyometric training that prepares them dynamically for unanticipated challenges during soccer competition.

In conclusion, male varsity collegiate soccer players exhibited greater knee varus moments than female players when landing on 1 leg from a height of 60 cm. This knowledge combined with future research examining the influence of the hip on the control of the knee might provide useful information in the design of programs that focus on muscle strategies to counteract high knee moments. Such programs could be used in the clinical treatment and prevention of knee injuries.
Acknowledgments

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References