The Relationship Between Knee Hyperextension and Articular Pathology in the Anterior Cruciate Ligament Deficient Knee

Michael J. Axe, Katherine Linsay, and Lynn Snyder-Mackler

The purpose of this study was to determine whether there was a relationship between knee hyperextension and intra-articular pathology in 100 consecutive patients whose sole ligament injury was an arthroscopically confirmed anterior cruciate ligament (ACL) rupture. Hyperextension of both knees was measured using a supine heel-height measurement of high reliability. There was more articular damage to the total joint, lateral joint, and lateral meniscus in patients who hyperextended than in those who did not. There was more articular damage to the total joint and medial joint in patients who were chronically ACL deficient than in those who were acutely or subacutely ACL deficient. The results demonstrate that individuals with ACL injuries whose knees hyperextend 3 cm or more sustain significantly more joint damage at the time of injury than in those whose knees hyperextend less than 3 cm. This study further defines the role of knee hyperextension in ACL injuries and offers a useful and reliable means of measuring knee hyperextension.

The anterior cruciate ligament (ACL) plays an important role in the stability of the knee joint by controlling anterior translation and rotation of the tibia on the femur. The role of this ligament varies with the mechanical and functional demands placed on the knee, but in most individuals, ACL injury compromises the stability of the knee joint. ACL rupture is often accompanied by damage to the articular surfaces (meniscal and chondral injuries) that appears to progress with time (1, 6, 8, 11, 13).

In the mid-1980s, researchers advanced the concept of a cruciate-dominant knee as one in which the ACL plays a more critical role in stability than in the average knee. Presumably, patients with cruciate-dominant knees are unable to compensate for an ACL deficiency and are more likely than those without cruciate-dominant knees to sustain articular damage if allowed to return to activity without surgical stabilization. Knee hyperextension was used as an indicator of ACL domi-
Knee Hyperextension

Knee hyperextension has also been established as one marker of joint hypermobility (5, 12). Harner et al. (10) did not find a relationship between generalized ligamentous laxity and prevalence of ACL injury; however, the contribution of generalized joint laxity to articular damage has not been investigated.

The relationship between intra-articular pathology and ACL injury has been investigated in several studies. Indelicato and Bittar (13) conducted a study of 100 cases to determine the intra-articular pathology associated with ACL injuries and to compare the pathology at the time of injury to that which develops over time. The occurrence of meniscal tears increased from 77% in the acute group to 91% in the chronic group. Furthermore, Keene et al. (15) studied arthroscopically confirmed ACL ruptures and found a high incidence of meniscal tears in chronically ACL-deficient knees.

Keene et al. (15) also investigated the ability to repair the medial meniscus as an ACL injury became more chronic. Eighty percent of the patients in the acute stage had tears that could be repaired, while only 46% of tears in the chronic group were repairable. Barber (4) and DeHaven (7) reported meniscal repair failure rates of 30% or more with continued ACL insufficiency. As Rosenberg and Sherman (20) stated, “The medial meniscal tears that occur acutely will become less repairable as times goes on” (p. 427).

The purpose of this study was to determine whether there is a relationship between knee hyperextension and intra-articular pathology after ACL injury. We hypothesized there would be more joint pathology in subjects whose uninvolved knee hyperextended (reflecting bilateral ligamentous laxity) and that the intra-articular pathology in this subset of patients would worsen with time, therefore indicating cruciate dominance.

**Methods**

**Subjects**

This was a retrospective analysis of data collected prospectively on 100 patients with ACL rupture confirmed by arthroscopy at the time of reconstruction. All patients admitted for ACL reconstruction by the principal investigator (MJA) between 1989 and 1993 were considered potential candidates for the study. Patients were excluded from the study for any of the following reasons: previous history of intra-articular pathology (meniscus or degenerative joint disease), posterior cruciate ligament injury, or Grade II or III collateral ligament injury. Patients were enrolled according to these criteria beginning with those who underwent surgery in December 1993 and proceeding back in time until a total of 100 subjects were identified.

Subjects included 32 women and 68 men (age = 24 ± 9 years) treated from late 1989 to 1993. Each patient was preoperatively examined and operatively treated by the same examiner (MJA). The patients were divided into three groups: those who underwent reconstruction within 1 month of injury (acute), those who underwent reconstruction 1–6 months after injury (subacute), and those who underwent reconstruction more than 6 months after injury (chronic).

**Procedure**

Preoperative data were recorded on a knee examination form, and operative findings were recorded on a pictorial operative record and in a written summary. Intra-
Articular pathology was graded from pictorial operative records by a single examiner (MJA) using a grading scale described by Noyes and Stabler (18) for articular surfaces and a modification of the meniscal grading scale cited by Noyes (17) to grade the degree of meniscal damage. The scales were as follows:

**Meniscal Grading Scale**
1 = normal
2 = degenerative
3 = partial/incomplete tear (<1/3)
4 = partial/incomplete tear (1/3-1/2)
5 = complete tear
6 = prior partial meniscectomy
7 = prior total meniscectomy

**Articular Surface Grading Scale**
Defect (<15 mm)
1 = normal
2 = softening
3 = fissures/fragmentation
4 = fissures/fragmentation > 1/2 surface
5 = bone

The examiner was blind to group assignment. Medial and lateral menisci, medial and lateral tibial plateaus, and medial and lateral femoral condyles were graded separately on weight-bearing surfaces only.

Age, sex, number of months from injury to surgery, mechanism of injury (contact or noncontact), and maximum knee hyperextension measurements were recorded on the knee data sheet. Hyperextension of both knees was measured with the patient in a supine position, the knees maximally extended, and the foot in a neutral position. The examiner held the forefoot with one hand and stabilized the distal segment of the femur on the table with the other hand while the assistant measured the distance from the posterior border of the heel to the table in centimeters. Repeated testing of knee hyperextension of 20 injured and healthy knees demonstrated an intraclass correlation coefficient (ICC) of .94 using formula 2.1 of Shrout and Fleiss (21), indicating this to be a reliable measure of knee hyperextension. The uninvolved knee measurement was used in the analysis.

**Data Management**

Composite measurements for medial joint compartment, lateral joint compartment, and total joint were calculated from the scores for each of the weight-bearing surfaces. The medial femoral condyle, medial tibial plateau, and medial meniscus grades were summed for the medial compartment score; the lateral femoral condyle, lateral tibial plateau, and lateral meniscus grades were summed for the lateral compartment score. The medial compartment and lateral compartment scores were added to form the total joint score. All data were entered into a commercial statistical program (SYSTAT, Inc., Evanston, IL) and analyzed by independent examiners.
Data Analysis

Nonlinear estimation was used to fit the plot of joint pathology as a function of hyperextension of the noninjured knee. A critical value of 3 cm was identified as a break point in the data, and the patients were subsequently divided into two groups: Those with hyperextension equal to or greater than 3 cm were placed in the “hyperextension” group, and those with less than 3 cm of hyperextension were placed in the “no-hyperextension” group.

Analysis of covariance (ANCOVA) with time from injury to surgery as the covariate was used to analyze the effect of chronicity on the group differences. ANCOVA with mechanism of injury as the covariate was used to analyze the effect of mechanism of injury on group differences. In addition, analysis of variance (ANOVA) was used to evaluate the differences among medial compartment, lateral compartment, and total joint pathology by time from injury to surgery.

Results

Data were incomplete for two patients, which eliminated them from the study. The hyperextension group consisted of 28 patients. Their average scores for intra-articular defects of the total joint, lateral compartment, and medial compartment were 11.32, 6.07, and 5.25, respectively. In comparison, for the 70 patients in the no-hyperextension group, the average scores for intra-articular defects of the total joint, lateral compartment, and medial compartment were 9.9, 5.24, and 4.65, respectively.

The ANCOVA revealed a significant group difference for the total joint score ($p < .05$) but no significant difference for the lateral and medial compartment scores ($p > .05$). There was no effect of chronicity on the analysis, indicating that the effect of hyperextension on intra-articular pathology is independent of time from injury to surgery ($F = 1.62, p > .05$). There was also no difference attributable to the mechanism of injury (contact or noncontact), indicating that the effect of hyperextension on intra-articular pathology is independent of mechanism of injury in the case of isolated ACL rupture ($F = .007, p > .05$).

An ANOVA of the medial and lateral meniscal scores demonstrated a significant main effect of hyperextension for the lateral meniscus and of chronicity for the medial meniscus. The hyperextension group had an average score of 3.57 for lateral meniscal defects, whereas the no-hyperextension group had an average score of 2.81 for lateral meniscal defects, a significant difference ($p < .05$). The percentages of lateral and medial meniscal tears in the acute, subacute, and chronic stages for both hyperextension and no-hyperextension groups are presented in Table 1. The highest incidence of lateral meniscal tears occurred in the acute stage for both groups and remained relatively constant over time. The number of medial meniscal tears increased by more than 200% from the acute to chronic stage for both groups. Chronicity significantly affected the amount of intra-articular damage to the medial compartment ($p < .05$) but not the lateral compartment.

Discussion

The major findings of this study are that (a) articular damage to the lateral compartment is disproportionately affected by hyperextension, and (b) the effects of hyper-
Table 1  Meniscal Injuries by Groups (Values in Percentages)

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<th></th>
<th>No hyperextension</th>
<th>Hyperextension</th>
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<tbody>
<tr>
<td></td>
<td>Lateral</td>
<td>Medial</td>
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<tr>
<td>Acute</td>
<td>57</td>
<td>21</td>
</tr>
<tr>
<td>Subacute</td>
<td>46</td>
<td>38</td>
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<tr>
<td>Chronic</td>
<td>40</td>
<td>80</td>
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extension on articular pathology appear to occur at the time of ACL injury and do not worsen over time. Therefore, our hypothesis that articular pathology would increase over time to a greater degree in knees that hyperextend than in those that do not (indicating cruciate dominance) was not supported by our data. There was, however, a significantly greater amount of articular pathology at the time of injury in those who hyperextend 3 cm or more than in those who did not.

The hyperextension group had a significantly higher percentage of lateral meniscal tears (78%) than the no-hyperextension group (57%) in the acute phase after ACL injury. Our no-hyperextension group had an incidence of lateral meniscal tears that was very similar to that reported in other studies (8, 22). This suggests that there is a high probability of lateral meniscal damage at the time of ACL injury in those patients who hyperextend 3 cm or more. A recent study by Spindler et al. (22) suggests that the mechanism of ACL injury involves severe anterior tibial subluxation, with impaction of the posterior tibia on the anterior femur. In their sample of ACL-deficient patients examined within 3 months of injury, the authors identified significant lateral tibial plateau and lateral femoral condyle bone bruising using magnetic resonance imaging. Although the incidence of lateral joint damage in their study (57%) was also higher than medial, the absolute amount of meniscal damage (38%) was more like that of the acute and subacute no-hyperextension group in our study. Perhaps the changes that hyperextension induces in the axis of rotation of the knee alter the tibial subluxation and valgus force on the lateral joint at the time of ACL rupture and increase the incidence of lateral meniscal tears.

The lateral meniscal tears in our study were consistent with a crush type injury suggested by Spindler et al. (22); they were complex and irreparable. The significance of the increased incidence of lateral meniscal damage in these knees may be portentous. The most common operative option in these cases is partial lateral meniscectomy. A recent report by Jaureguito and colleagues (14) suggests that long-term results at a minimum of 5 years after partial lateral meniscectomy are poor as measured by functional outcome (Lysholm II score) and radiographic changes. In fact, although Jaureguito et al. reported 2-year results that were in the good to excellent range, the 5-year results were similar to those reported for total lateral meniscectomy (9). Our findings of an increased incidence of lateral meniscal injury at the time of ACL rupture in knees that hyperextend more than 3 cm may need to be interpreted in light of this new report. The poor long-term outcome after partial lateral meniscectomy may indicate a need for strategies to control hyperextension prophylactically in order to minimize intercurrent lateral meniscal damage at the time of ACL rupture.
The length of time from injury to reconstructive surgery did not increase the incidence of lateral meniscal tears for either the hyperextension or no-hyperextension group. Keene et al. (15) also found that the percentage of lateral meniscal tears did not increase over time in their study. This also suggests that lateral meniscal tears are crush or impaction injuries and are not worsened by repetitive pivoting episodes. Because the lateral joint, especially the lateral meniscus, is more at risk in those who hyperextend, minimizing exercises that cause lateral joint compression and perhaps considering bracing to unload the lateral compartment in those with lateral joint pain may improve functional outcome.

Although the medial joint was not significantly affected by hyperextension, it was affected by the chronicity of the ACL deficiency. The medial structure influenced the most by chronicity was the medial meniscus. In fact, the number of tears increased by more than 200% from the acute to chronic stage for both the hyperextension and no-hyperextension groups. This study is similar to others in the literature (8, 11, 22) in showing that long-term ACL deficiency may predispose the medial compartment to further articular degeneration. Keene et al. (15) suggested that one reason for the increase in medial meniscal damage over time may be its firm structural attachments to the tibial plateau. This rigidity may make the medial meniscus susceptible to additional damage in ACL-deficient knees for patients who experience repetitive episodes of instability or "giving way." The number of knees with chronic medial meniscal tears in our study was truly astonishing. This was a biased sample, however, in that these cases had failed nonoperative management and were scheduled for surgery. Clearly, this represents a worst-case scenario.

The present study shows that individuals with ACL injuries whose involved knee hyperextends more than 3 cm have significantly more total joint damage than those who do not hyperextend. Patients who hyperextend, however, are no more likely to progress to more joint damage than those who do not hyperextend. This study further defines the role of knee hyperextension in ACL injuries. We also tested the reliability of the supine heel-height measurement in this population. Although this measurement had been described previously, its reliability had not been examined in this patient population. Measurement of knee hyperextension using a goniometer has not proven reliable (19, 23); therefore, we believe the supine heel-height measurement represents a useful and reliable measure of knee hyperextension.

These data suggest that it is time to reexamine the concept of an anterior cruciate dominant knee as one where passive secondary restraints are less able to compensate for the absence of the ACL than in other knees. This study, as well as that of Harner and colleagues (10), leads us to conclude that if anterior cruciate ligament dominance exists, hypermobility does not characterize it. Perhaps the ability to compensate well for ACL rupture is more a factor of the ability to dynamically stabilize the knee than one of laxity alone.

References


**Note**

This study was completed as Ms. Linsay’s Honors’ Thesis in partial fulfillment of the requirements for her Degree with Distinction in the Athletic Training Program of the College of Physical Education, Athletics and Recreation at the University of Delaware.