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## Effect of High-Grade Pre-operative Knee Laxity on Outcomes of ACL Reconstruction

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### Abstract

**Background**—Knee laxity in the setting of suspected ACL injury is frequently assessed through physical examination using the Lachman, pivot-shift, and anterior drawer tests. The degree of laxity noted on these examinations may influence treatment decisions and prognosis.

**Hypothesis**—We hypothesized that increased pre-operative knee laxity would be associated with increased risk of subsequent revision ACL reconstruction and poorer patient-reported outcomes two years postoperatively.

**Study design**—Cohort study.

**Methods**—From an ongoing prospective cohort study, 2333 patients who underwent primary isolated ACL reconstruction without collateral or posterior cruciate ligament injury were identified. Patients reported by the operating surgeons as having an International Knee Documentation Committee Grade D Lachman, anterior drawer, or pivot-shift examination were classified as having a high-grade laxity. Multiple logistic regression modeling was used to evaluate whether having high-grade pre-operative laxity was associated with increased odds of undergoing revision ACL reconstruction within two years of the index procedure, controlling for patient age, sex, Marx activity level, level of competition, and graft type. Multiple linear regression modeling was used to evaluate whether having high-grade pre-operative laxity was associated with poorer IKDC or KOOS-QOL scores at a minimum 2 years postoperative, controlling for baseline score,

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patient age, ethnicity, sex, BMI, marital status, smoking status, sport participation, competition level, Marx activity rating score, graft type, and articular cartilage and meniscus status.

**Results**—Pre-reconstruction laxity data were available for 2325 patients (99.7%). Two year revision data were available for 2259 patients (96.8%) and patient-reported outcomes were available for 1979 patients (84.8%). High-grade pre-operative laxity was noted in 743 patients (31.9%). The mean postoperative IKDC score was  $81.8 \pm 15.9$  and the mean KOOS-QOL score was  $72.0 \pm 22.0$ . The presence of high-grade pre-reconstruction laxity was associated with significantly increased odds of ACL graft revision (OR=1.87, 95% CI: 1.19 – 2.95,  $p = 0.007$ ). The presence of high-grade pre-reconstruction laxity was not associated with any difference in postoperative IKDC ( $\beta = -0.56$ ,  $p = 0.44$ ) or KOOS-QOL ( $\beta = 0.04$ ,  $p = 0.97$ ).

**Conclusion**—The presence of high-grade pre-reconstruction knee laxity as assessed by manual physical examination under anesthesia is associated with significantly increased odds of revision ACL surgery, but has no association with patient-reported outcome scores at 2 years following ACL reconstruction.

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## Introduction

The anterior cruciate ligament (ACL) is frequently injured in young, athletic patient populations. Knee laxity in the setting of a possible ACL injury is frequently assessed by the treating physician through physical examination using the Lachman,<sup>33</sup> pivot-shift,<sup>8, 16</sup> and anterior drawer tests.<sup>20</sup> These physical examination tests frequently demonstrate increased laxity when the ACL is ruptured, but the degree of increased laxity varies from patient to patient. In addition to aiding the physician in correctly diagnosing an ACL injury, the degree of laxity noted on these examinations may influence treatment decisions and prognosis.<sup>10, 17</sup>

Patients with a relatively high degree of knee laxity after sustaining an ACL injury may represent a subset of patients with concomitant injuries in addition to the ACL tear.<sup>19</sup> Prior work has demonstrated that patients with lateral meniscus injury are more likely to demonstrate a higher-grade pivot shift, while medial meniscus injury is associated with increased anterior laxity.<sup>24</sup> In addition to meniscal injury, increased laxity may also be associated with increased risk of capsular injury, particularly in the anterolateral aspect of the knee.<sup>32, 34</sup> This high-grade laxity patient population may be at increased risk for poor outcome following ACL reconstruction and may therefore represent a population in which the performance of additional stabilization procedures may improve outcomes.<sup>17, 30</sup>

The purpose of this study was to determine whether high-grade laxity of the injured knee as assessed by the surgeon during an exam under anesthesia prior to ACL reconstruction is associated with revision risk or patient-reported outcomes following ACL reconstruction. We hypothesized that increased pre-operative knee laxity would be associated with increased risk of revision ACL reconstruction and poorer patient-reported outcomes at two years postoperative.

## Methods

### Patients

Institutional Review Board approval was obtained at participating institutions. From an ongoing prospective cohort study, 2859 patients who underwent ACL reconstruction between 2002 and 2008 were identified. Following exclusion of those undergoing revision surgery (321) or simultaneous bilateral reconstructions (13), as well as those with associated grade 2 or 3 collateral ligament injuries (167) or PCL tears (25); 2333 patients were eligible for inclusion in the study (Figure 1).

### Data Extraction

Demographic data (age, sex, ethnicity, marital status, and body mass index [BMI]); smoking status; knee laxity during examination under anesthesia prior to ACL reconstruction; sport at injury; level of competition; graft type; information regarding meniscus and articular cartilage status; pre-operative and 2 year postoperative subjective International Knee Documentation Committee (IKDC),<sup>11</sup> Knee injury and Osteoarthritis Outcome Score Knee-Related Quality of Life (KOOS-QOL),<sup>28</sup> and Marx activity rating scores;<sup>23</sup> and the incidence of subsequent revision ACL reconstruction were collected. Ethnicity was recorded and collapsed into the categories of white, black, other, or unknown. Marital status was recorded as single, married, or other. Smoking status was classified as either recent smoker (current smoker or quit within 6 months) or not recent smoker (nonsmoker or quite greater than 6 months ago). Sport at injury was classified as football, soccer, basketball, other, or none. Level of competition was dichotomized as competitive (high school, collegiate, or professional) or recreational. Graft type was classified as patellar tendon autograft, hamstring tendon autograft, quadriceps autograft, or allograft. Hybrid grafts containing both autograft and allograft material were classified as allografts. Meniscus status was determined at the end of the index procedure and classified as intact, meniscectomy (partial or complete), meniscus repair, or untreated stable tear for both the medial and lateral meniscus. Articular cartilage status in each of the three compartments (medial, lateral, patellofemoral) was assessed according to the modified Outerbridge Classification.<sup>26</sup> Due to poor reported reliability of differentiation between grade 2 and 3 lesions,<sup>22</sup> the grade for each compartment was dichotomized based on the worst score in that compartment as low- (modified Outerbridge 0 or 1) or high-grade (modified Outerbridge 2, 3, or 4) cartilage injury. Knee laxity was assessed according to the IKDC classification system (Table 1).<sup>9</sup> Patients noted by the operating surgeon to have a Lachman or anterior drawer examination greater than 10mm different from the contralateral side, or a 3+ pivot-shift were classified as having high-grade laxity.

### Statistics

Multiple logistic regression modeling was used to evaluate whether high-grade pre-reconstruction laxity was associated with risk of subsequent revision ACL reconstruction. Other variables evaluated as potential confounders or effect modifiers of the relationship of interest included patient age, sex, ethnicity, smoking status, marital status, and BMI; Marx activity rating score at reconstruction; sport at injury; level of competition; graft type; medial and lateral meniscus status; and articular cartilage status. A forward selection modeling

procedure was utilized with variables sequentially added to the model and kept in the model if they resulted in a change in the odds ratio of the variable of interest of greater than 0.05. The final model included patient age, sex, BMI, Marx activity rating score, level of competition, and graft type. The presence of interactions between all included predictors was evaluated and no significant interactions were identified. Based on the 8 degrees of freedom required to model these potential predictor variables, the 94 “events” (revision ACL reconstructions) recorded during the 2 year follow-up period provided sufficient power for this analysis. The analysis was repeated using high-grade Lachman, high-grade pivot-shift, and high-grade anterior drawer as the dependent variable.

Multiple linear regression modeling was used to evaluate whether high-grade pre-reconstruction laxity was associated with subjective IKDC score or KOOS-QOL at two years postoperative, controlling for baseline score; patient age, sex, ethnicity, smoking status marital status, and BMI; Marx activity rating score at reconstruction; sport at injury; level of competition; graft type; medial and lateral meniscus status; and articular cartilage status. The presence of interactions between all included predictors was evaluated and no significant interactions were identified. The analysis was repeated using high-grade Lachman, high-grade pivot-shift, and high-grade anterior drawer as the dependent variable.

## Results

Complete pre-reconstruction laxity data were available for 2325 patients (99.7%) that formed the study cohort. Baseline patient characteristics are summarized in Table 2. A total of 743 of 2325 patients (32.0%) demonstrated high-grade laxity on at least one physical examination test (Figure 2). High-grade pivot-shift was most common, which occurred in 617 patients (30.0% of females, 23.6% of males), with a high-grade Lachman noted in 334 patients (14.8% of females, 13.9% of males) and a high-grade anterior drawer noted in 233 patients (10.7% of females, 9.4% of males).

Two-year revision data were available for 2259 patients (96.8%) and patient-reported outcomes were available for 1979 patients (84.8%). ACL graft revision was performed in 94 patients (4.2%). Revision was performed in 39 patients (5.4%) in the high-grade laxity group and 55 patients without high-grade laxity (3.6%). In the multiple logistic regression model, the presence of high-grade pre-reconstruction laxity on at least one physical examination test was associated with significantly increased odds of ACL graft revision (OR=1.87, 95% CI: 1.19 – 2.95,  $p = 0.007$ ). Similarly, high-grade pivot-shift (OR=1.84,  $p = 0.011$ ) and Lachman (OR=2.27,  $p = 0.003$ ) were associated with increased risk of revision. The relationship between high-grade anterior drawer and revision surgery did not reach statistical significance (OR=1.70,  $p = 0.12$ ) (Table 2). Those with high-grade laxity on any two or all three of the physical examination tests also demonstrated increased odds of revision surgery (Table 3). The finding that no modeled interactions between predictor variables were statistically significant indicates that patient age, sex, BMI, Marx activity rating score, level of competition, and graft type did not influence failure risk in the high-grade laxity group more or less than in the other patients in the study.

The mean postoperative IKDC score was  $81.8 \pm 15.9$  and the mean KOOS-QOL score was  $72.0 \pm 22.0$ . The mean IKDC score was  $82.1 \pm 15.6$  in the high-grade laxity group and  $81.4 \pm 16.5$  in the group without high-grade laxity. The mean KOOS-QOL score was  $72.0 \pm 21.9$  in the high-grade laxity group and  $71.9 \pm 22.0$  in the group without high-grade laxity. In the multiple linear regression model, the presence of high-grade pre-reconstruction laxity was not associated with any difference in postoperative IKDC ( $\beta = -0.56$ ,  $p = 0.44$ ) or KOOS-QOL ( $\beta = 0.04$ ,  $p = 0.97$ ). Similarly, no association was found between these patient-reported outcome scores and high-grade pivot-shift, Lachman, or anterior drawer (Table 4).

## Discussion

The key finding of this study is that the presence of high-grade pre-operative knee laxity as assessed by manual physical examination under anesthesia was associated with significantly increased odds of revision ACL surgery within 2 years. We are aware of no previous studies that evaluate this relationship. Knee laxity should be considered along with other previously identified risk factors including age,<sup>1, 14, 29</sup> graft factors (autograft versus allograft<sup>7, 13, 14</sup> and hamstring graft size<sup>18, 21</sup>), and activity level<sup>1, 14</sup> when assessing risk of revision ACL surgery.

The increased risk of revision surgery in the high-grade laxity patient population makes this population an important group for further study. These patients may represent a subset of patients in whom to study the efficacy of ancillary stabilization procedures that could augment standard intra-articular ACL reconstruction. Some authors have suggested that additional augmentation procedures in such patients to control high-grade laxity may improve outcomes.<sup>17, 25</sup> These extra-articular procedures have seen increased interest in recent years<sup>30</sup> following wide dissemination of the anatomy and function of the anterolateral ligament of the knee,<sup>3, 34</sup> but high-quality data are lacking regarding surgical indications and outcomes. Further studies evaluating the effects of the addition of extra-articular procedures to intra-articular ACL reconstruction should carefully evaluate and consider pre- and postoperative knee laxity.

Two prior studies have evaluated the influence of pre-operative anterior knee laxity on patient-reported outcomes. Eitzen et al. reported no correlation between preoperative anterior tibial translation (measured with a KT-2000 arthrometer) and Cincinnati knee score at two years postoperative.<sup>6</sup> Heijne et al. noted an association between increased preoperative anterior tibial translation and lower KOOS quality of life subscale scores at one year postoperative in a univariable model; however, when they performed multivariable modeling, they did not find any correlation between pre-operative laxity and outcome.<sup>10</sup> These studies both involve relatively few patients that may be subject to beta error (Eitzen et al.,  $n=60$ ; Heijne et al.,  $n=64$ ); however, the finding that pre-operative knee laxity does not influence patient-reported outcomes is confirmed by the current study. Other previously described factors including age, BMI, smoking status, articular cartilage and meniscus status are the major predictors of patient-reported outcomes following ACL reconstruction.<sup>5</sup>

The strengths of this study include a large sample size, which allowed for robust logistic regression analysis, and prospective data collection, which resulted in a very complete

dataset. The data were collected by 17 surgeons at multiple institutions, making them broadly generalizable. Further, the physical examination tests utilized to assess laxity in this study are in broad clinical use, making the findings highly relevant to practicing surgeons. This study utilizes a patient cohort in which predictors in revision surgery have been extensively analyzed,<sup>14</sup> but is the first to evaluate the potential influence of pre-operative physical examination findings on outcome of ACL reconstruction in this population.

This study has limitations. First, quantitative instrumentation was not used to measure pre-reconstruction knee laxity. Knee laxity was quantified by the treating physician during the exam under anesthesia at the time of the surgery, using the IKDC classification system. Patients reported by the operating surgeon as having a Lachman or anterior drawer examination greater than 10 mm difference from the contralateral side were classified as having a high-grade Lachman or anterior drawer respectively. Previous studies in conscious patients have demonstrated variable inter-rater reliability when using this system to assess laxity in ACL deficient knees.<sup>12, 15, 27, 35</sup> A portion of this variability is likely due to patients' guarding<sup>31</sup> and exam under anesthesia may be more reliable, particularly in regards to the pivot-shift.<sup>4</sup> While limited, these assessments do represent the method of laxity assessment most frequently used by surgeons when they make treatment decisions, making the data highly relevant. An additional limitation is the lack of post-reconstruction data regarding knee laxity. It is unknown whether patients with high-grade pre-operative laxity continue to have increased laxity following surgery. Such data could provide insight into the mechanism underlying the increased failure risk in this population and provide more insight into potential treatment options. Finally, an assessment of patients' overall ligamentous laxity with a Beighton score<sup>2</sup> or similar test would have allowed more analysis of whether the increased failure risk associated with increased laxity is related to injury factors only affecting the knee or related to generalized ligamentous laxity.

## Conclusion

The presence of high-grade pre-operative knee laxity as assessed by manual physical examination under anesthesia is associated with significantly increased odds of revision ACL surgery, but has no association with patient-reported outcome scores at 2 years following ACL reconstruction.

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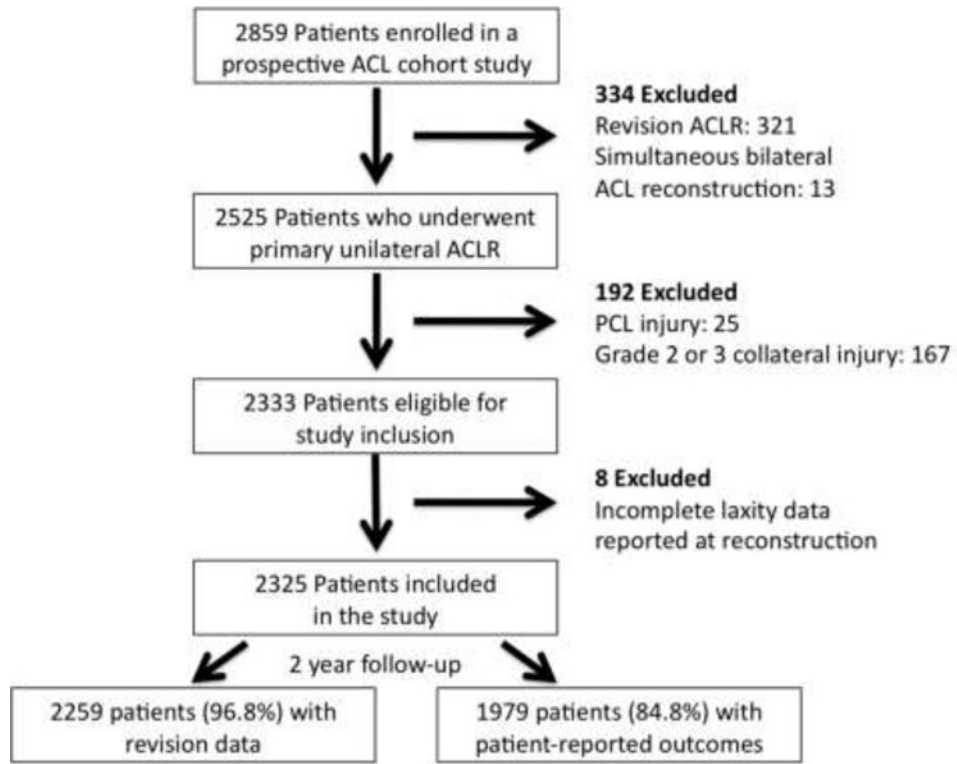


**What is known about the subject**

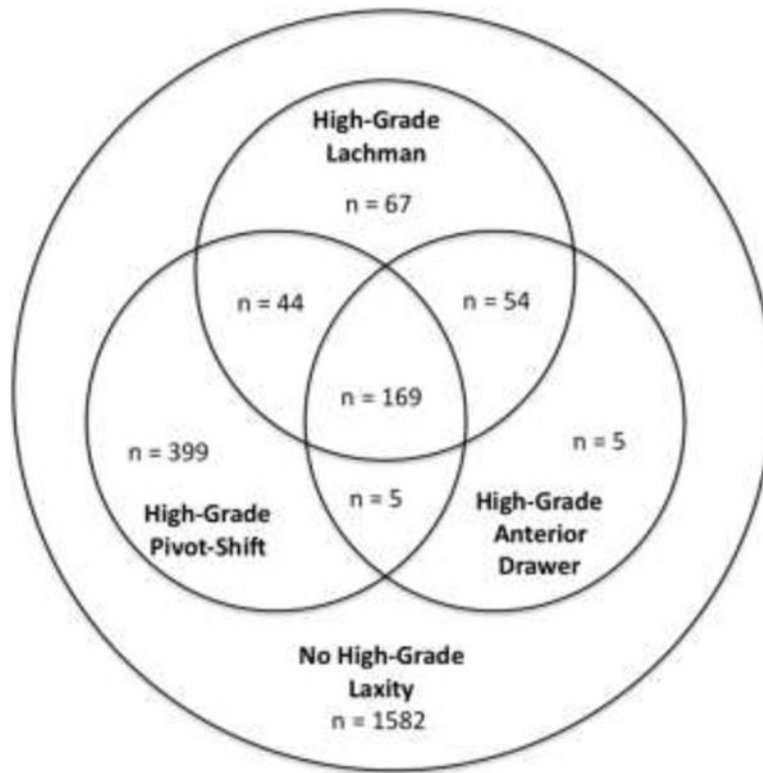
Physical examination tests frequently demonstrate increased laxity when the ACL is ruptured, but the degree of increased laxity varies from patient to patient.

**What this study adds to existing knowledge**

High-grade pre-reconstruction knee laxity is associated with significantly increased odds of revision ACL surgery. There is no association with patient-reported outcome scores at 2 years.



**Figure 1.** Flowchart demonstrating the selection of patients for study inclusion as well as loss to follow-up.



**Figure 2.** Venn diagram demonstrating the distribution of patients with high-grade laxity by physical examination test.

**Table 1**

International Knee Documentation Committee (IKDC) Classification of Knee Laxity

	<b>Grade A</b>	<b>Grade B</b>	<b>Grade C</b>	<b>Grade D</b>
Lachman	0 to 2 mm	3 to 5 mm	6 to 10 mm	> 10 mm
Anterior Drawer	0 to 2 mm	3 to 5 mm	6 to 10 mm	>10 mm
Pivot-Shift	Equal	Glide	Clunk	Gross

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**Table 2**

Patient Characteristics (n = 2325 patients)

Age (Mean $\pm$ SD)	26.7 $\pm$ 11.1 years
Sex	Male: 1302 (56.0%) Female: 1023 (44.0%)
Ethnicity	White: 1929 (83.0%) Black: 195 (8.4%) Other: 193 (8.3%) Unknown: 8 (0.3%)
Marital Status	Single: 1500 (64.5%) Married: 656 (28.2%) Other: 84 (3.6%) Unknown: 85 (3.7%)
Body Mass Index	25.5 $\pm$ 4.9 kg/m <sup>2</sup>
Smoking Status	Nonsmoker: 2033 (87.4%) Smoker: 280 (12.0%) Unknown: 12 (0.6%)
Sport at Injury	Basketball: 508 (21.8%) Football: 299 (12.9%) Soccer: 372 (16.0%) Other: 791 (34.0%) None: 355 (15.3%)
Level of Competition	Competitive: 917 (39.4%) Recreational: 1394 (60.0%) Unknown: 14 (0.6%)
Graft Type	BTB Autograft: 1037 (44.7%) Hamstring Autograft: 881 (37.9%) Quadriceps Autograft: 3 (0.1%) Allograft: 404 (17.4%)
Medial Meniscus Status	Intact: 1389 (59.7%) Meniscectomy: 431 (18.5%) Repaired: 371 (16.0%) Stable Untreated Tear: 130 (5.6%) Unknown: 3 (0.1%)
Lateral Meniscus Status	Intact: 1217 (52.3%) Meniscectomy: 688 (29.6%) Repaired: 163 (7.0%) Stable Untreated Tear: 257 (11.1%)
Medial Articular Cartilage Status (Modified Outerbridge)	Grade 0 or 1: 1796 (77.2%) Grade 2, 3, or 4: 529 (22.8%)
Lateral Articular Cartilage Status (Modified Outerbridge)	Grade 0 or 1: 1835 (78.9%) Grade 2, 3, or 4: 490 (21.2%)
Patellofemoral Articular Cartilage Status (Modified Outerbridge)	Grade 0 or 1: 1858 (79.9%) Grade 2, 3, or 4: 467 (20.1%)

**Table 3**

Relationships between high-grade pre-reconstruction knee laxity and revision ACL surgery

High-grade laxity	Odds Ratio	95% Confidence Interval	Significance
3+ Pivot-shift	1.84	1.15 – 2.95	p = 0.011
Lachman > 10mm	2.27	1.32 – 3.90	p = 0.003
Anterior Drawer > 10mm	1.70	0.87 – 3.32	p = 0.12
Any one of the above	1.87	1.19 – 2.95	p = 0.007
Any two of the above	2.28	1.26 – 4.13	p = 0.006
All three of the above	2.07	1.00 – 4.30	p = 0.05

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**Table 4**

Relationships between high-grade pre-reconstruction knee laxity and patient-reported outcomes at 2 years postoperative

High-grade laxity	Regression Coefficient ( $\beta$ )	95% Confidence Interval	Significance
<b>Subjective IKDC Score</b>			
3+ Pivot-shift	-0.46	-1.99 – 1.06	p = 0.55
Lachman > 10mm	-0.56	-2.46 – 1.34	p = 0.56
Anterior Drawer > 10mm	-0.34	-2.54 – 1.86	p = 0.76
Any of the above	-0.56	-2.01 – 0.88	p = 0.44
<b>KOOS-QOL</b>			
3+ Pivot-shift	0.57	-1.65 – 2.79	p = 0.61
Lachman > 10mm	0.24	-2.53 – 3.03	p = 0.86
Anterior Drawer > 10mm	-0.47	-3.69 – 2.74	p = 0.77
Any of the above	0.04	-2.09 – 2.14	p = 0.97

IKDC = International Knee Documentation Committee

KOOS-QOL = Knee injury and Osteoarthritis Outcome Score – Knee-Related Quality of Life