Does the Lever Sign Test Have Added Value for Diagnosing Anterior Cruciate Ligament Ruptures?

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Background: Diagnosing an anterior cruciate ligament (ACL) rupture based on a physical examination remains a challenge for both surgeons and physical therapists. The lever sign test was developed to overcome the practical limitations of other tests and to optimize diagnosis. An evaluation of the measurement properties of the lever sign test is needed to make adequate interpretations in practice.

Purpose: To evaluate the reliability and diagnostic value of the lever sign test.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: A total of 94 patients were recruited between November 2014 and July 2016. Patients were included if they were at least 16 years old, suffered from knee trauma, and had indications for knee arthroscopic surgery. Lever sign, anterior drawer, Lachman, and pivot-shift test outcomes were examined by an orthopaedic/trauma surgeon and a physical therapist. A test-retest design was used to investigate interrater reliability. Moreover, the lever sign test outcomes, alone and in combination with the other diagnostic tests, were compared with arthroscopic results, which served as the gold standard for the test's diagnostic value.

Results: The lever sign test and pivot-shift test had kappa values exceeding 0.80 for interrater reliability. The kappa values for the anterior drawer test and Lachman test were 0.80 and 0.77, respectively. The lever sign test showed the highest specificity (100%) and the lowest sensitivity (39%) when compared with the other 3 tests. Moreover, its positive and negative predictive values were 100% and 65%, respectively, while an accuracy of 71% was calculated. Clustering the lever sign test parallel with the other 3 tests resulted in the highest accuracy of 91%.

Conclusion: The lever sign test appears to have high interrater reliability and is the most specific test, showing a maximal positive predictive value. A positive lever sign test result indicates an ACL rupture. These results support the added value of the lever sign test for diagnosing ACL ruptures.

Keywords: ACL; lever sign; anterior cruciate ligament; diagnosis; physical test

Both amateur and professional athletes are at a considerable risk for an anterior cruciate ligament (ACL) rupture.[15] Amateur athletes have a 0.03% to 1.62% chance of developing an ACL rupture every year, while the risk for professional athletes rises up to 3% or more depending on the kind of sport.[13] High-risk sports include basketball, soccer, handball, and skiing[13] mainly because of the characteristics of these sports.[2] After an ACL rupture, athletes generally need 9 to 12 months to return to play.[22] Moreover, for high-intensity sports, surgical reconstruction of the ACL is a necessity. An early and accurate diagnosis of an ACL rupture by an expert such as an orthopaedic/trauma surgeon, sports physician, or (sports) physical therapist is considered crucial to start the appropriate treatment, and it may prevent further complications.[11,23]

As with many diagnoses, the clinical practice for detecting an ACL rupture remains an issue of debate. There are 3 physical examination tests commonly used by surgeons and physical therapists to evaluate ACL status: (1) the anterior drawer test, (2) the Lachman test, and (3) the pivot-shift test. Although the anterior drawer test is suggested to be appropriate for diagnosing chronic injuries, it may not be sensitive enough to use for acute ACL ruptures[1] (overall sensitivity of 38%-92% and specificity of 67%-91%).[1,16,18,21] The Lachman test is suggested to be the most valid test because of its high sensitivity (81%-86%) and specificity

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(81%-94%).[1,16,18,21] The pivot-shift test has been shown to be highly specific (81%-99%) but not that sensitive (18%-48%) for ACL ruptures.[1,16,21] Generally, these tests are combined to improve both the specificity and sensitivity to diagnose ACL ruptures more accurately.[18] However, some limitations have been acknowledged when conducting these commonly used physical examination tests.[10] First, the diagnosis of partial tears of the ACL is difficult.[4] Second, swelling in the knee, guarding of the knee, or the development of pain resistance may preclude anterior translation of the tibia, which is essential for a positive result on the ACL tests.[1,21] Finally, it has been found that the Lachman test and anterior drawer test are more difficult to carry out by examiners with smaller hands or on patients with large, muscular thighs.[14]

In 2005, another physical examination test, the lever sign or Lelli test, was proposed to overcome these limitations. The test is reported to be easy to perform, even in the acute setting with joint swelling and pain resistance, and it is equally determinative for partial as well as complete tears.[10] Studies concerning the diagnostic validity of the lever sign test using magnetic resonance imaging (MRI) or arthroscopic surgery as the gold standard show good results (sensitivity of 63%-100% and specificity of 90%-91%).[4,5,10,20] These studies claim that the lever sign test might be more accurate than the other manual tests. However, the lever sign test lacks a comprehensive evaluation of its measurement properties, including interrater reliability across disciplines. Moreover, it is unknown whether combining the lever sign test with other ACL tests has added value for diagnosing an ACL rupture. Consequently, this study aimed to (1) determine the interrater reliability of the lever sign test between orthopaedic/trauma surgeons and physical therapists, (2) determine the diagnostic properties of the lever sign test regarding ACL ruptures, and (3) investigate the diagnostic value of adding the lever sign test to a cluster of ACL tests.

METHODS

Design

The design of this study was 3-fold. First, a test-retest design was used to investigate the interrater reliability of the lever sign test with a maximum time interval of 1 week. All included patients were examined by an orthopaedic or trauma surgeon during the initial test. In 2 of the included hospitals, patients were re-examined by a physical therapist. In the Netherlands, surgeons and physical therapists often work together in clinical practice when diagnosing patients who are suspected of suffering from an ACL rupture. Second, the diagnostic value (ie, criterion validity) of the lever sign test was evaluated using arthroscopic surgery as the "gold standard." Finally, the lever sign test was added to a cluster of parallel and serial tests to evaluate its additional value. Only the data of the initial test collected by the surgeon were used to address the latter 2 issues.

Patients

Patients were recruited from the orthopaedic or trauma surgery outpatient departments of 3 hospitals in the Netherlands from November 2014 to July 2016. Inclusion criteria were (1) a minimum age of 16 years, (2) trauma to the knee, and (3) an indication for knee arthroscopic surgery. Patients with malignancies, systemic diseases, central neurological disorders, locking complaints of the knee, and previous (partial) ruptures of the ACL were excluded. Inclusion and exclusion criteria were checked for each patient by the orthopaedic or trauma surgeon during the first consultation. Written informed consent was obtained before testing. This study and informed consent procedures were approved by the medical ethical review committee of the VU University Medical Center Amsterdam (MTC/2015.327) in full compliance with the Declaration of Helsinki.

ACL Tests

Four tests were used to assess for discontinuity of the ACL: the lever sign test, the anterior drawer test, the Lachman test, and the pivot-shift test. Table 1 shows an overview of the published measurement properties of these ACL tests in the recent literature.

Lever Sign Test. The aim of the lever sign test is to check for discontinuity of the ACL. The patient is placed in a supine position with the knees fully extended. The examiner stands at the side of the injured knee and places a closed fist under the calf at a proximal distance of one-third of the lower leg to keep the knee joint in a slightly flexed position. With the other hand, the examiner applies moderate downward force to the distal third part of the patient's femur. Figure 1 and the Supplemental Video show the lever sign test being performed. The test is conducted only once. The test finding is positive if the knee joint does not extend and the heel stays on the table.[10] A negative test result is indicated if the knee joint moves into full extension and the patient's heel rises up from the examination table.

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TABLE 1
Measurement Properties of the Anterior Cruciate Ligament Tests Assessed

	Sensitivity, %	Specificity, %	Positive Likelihood Ratio	Negative Likelihood Ratio
Lever sign test	86-100[4,10,20]	91[20]	—	—
Lachman test	81-86[1,16,18,21]	81-94[1,16,21]	25.0[18]	0.1[18]
Anterior drawer test	38-92[1,16,18,21]	67-91[1,16,18,21]	3.8[18]	0.3[18]
Pivot-shift test	18-48[16]	81-99[1,16,21]	—	—

Figure 1. Performance of the lever sign test (starting position).

Anterior Drawer Test. The anterior drawer test is carried out with the patient in a supine position with the hip and knee flexed at 45° and 90°, respectively. The tibia is pulled in a ventral direction during the test, while the foot is stabilized by means of the dorsum of the thighs of the examiner. The test finding is considered positive if there is an absence of an end feel or a perception of more anterior translation on the injured side as compared with the uninvolved side. All other cases indicate a negative result.[6,12,14]

Lachman Test. The Lachman test is performed with the patient in a supine position with the knee joint at 20° to 30° of flexion. During the test, the examiner stabilizes the patient's femur with one hand while translating the tibia in an anterior direction with the other hand. The test finding is considered positive if there is an absence of an end feel or a perception of more anterior translation on the injured side as compared with the uninvolved side. All other cases indicate a negative result.[6,12,14]

Pivot-Shift Test. For the pivot-shift test, the patient is lying in a supine position with the hip joint at 40° of flexion and slight hip adduction. The examiner starts with a submaximal extended knee and applies valgus torque, internal rotation, and axial pressure on the knee. Then, the knee is slowly passively flexed by the examiner while retaining valgus, rotation, and axial pressure. If there is an anterior subluxation of the lateral tibial plateau that reduces spontaneously beyond 30° of knee flexion, this represents a positive test finding.[6]

Arthroscopic Surgery (Gold Standard)

During arthroscopic surgery, the surgeon judged the ACL as intact, partially ruptured, or completely ruptured. The test finding was positive if the ligament was partially (≥50%) or completely ruptured. An intact ligament was noted as a negative result.

Procedure

The patient was screened by a trauma surgeon or orthopaedic surgeon at the outpatient clinic. The surgeon examined the patient's knee in a predetermined order: (1) the lever sign test, (2) the anterior drawer test, (3) the Lachman test, and (4) the pivot-shift test. The results of the 4 ACL tests were documented as positive or negative. When possible, this complete testing procedure, including all 4 tests, was repeated by a physical therapist within 1 week. The physical therapist was blinded to the test results of the surgeon. The results of the arthroscopic surgery were collected after surgery.

Statistical Analysis

SPSS Statistics 24 (IBM Corp) was used for statistical analyses. The interrater reliability of the lever sign test and other ACL tests was calculated by using the Cohen kappa. A value of >0.80 was interpreted as almost perfect agreement, 0.61 to 0.80 as substantial agreement, 0.41 to 0.60 as moderate agreement, 0.21 to 0.40 as fair agreement, and <0.21 as slight or poor agreement.[7] The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV), and accuracy[17] (diagnostic effectiveness) were calculated using the initial test results to determine the diagnostic value of the lever sign test. In addition, the lever sign test was added to a cluster of parallel and serial tests. A parallel test cluster finding was considered positive if 1 or more separate test outcomes were positive. A serial test result was considered positive if all separate test outcomes were positive. The sequence of the serial tests was chosen based on the (highest) sensitivity values.

RESULTS

A total of 94 patients were included in the study, comprising 57 male and 37 female patients with a mean age of 34 ± 15 years (Table 2). According to the arthroscopic surgery, 48 of the included patients had a ruptured ACL, of which 11 were partially ruptured. Within the total

TABLE 2
Patient Characteristics

	Total Sample			Retest Sample		
	Total	Rupture[a]	Nonrupture	Total	Rupture[a]	Nonrupture
Sex, n	94	48	46	36	14	22
Male	57	30	27	28	11	17
Female	37	18	19	8	3	5
Age,[b] mean ± SD, y	34 ± 15	29 ± 13	40 ± 15	35 ± 15	30 ± 14	38 ± 14
Time since injury,[c] n						
Acute phase (<3 wk)	26	20	6	7	3	4
Subacute phase (3-11 wk)	31	18	13	14	6	8
Chronic phase (≥12 wk)	37	10	27	15	5	10
Injured side, n						
Left	48	25	23	18	8	10
Right	46	23	23	18	6	12

[a]Rupture includes patients with total and partial ruptures.
[b]Statistically significant difference ($P < .001$) for the total sample.
[c]Statistically significant difference ($P = .001$) for the total sample.

TABLE 3
Interrater Reliability[a]

	n	Kappa	Qualification	PPV, %	NPV, %	Accuracy, %
Lever sign test	35	0.82	Almost perfect	100	65	71
Anterior drawer test	36	0.80	Substantial	91	77	82
Lachman test	36	0.77	Substantial	91	88	94
Pivot-shift test	35	0.84	Almost perfect	95	71	78

[a]NPV, negative predictive value; PPV, positive predictive value.

TABLE 4
Diagnostic Value Using Arthroscopic Surgery as the Gold Standard[a]

	n	Sensitivity, %	Specificity, %	Incidence, %	PPV, %	NPV, %	Accuracy, %
Lever sign test	87	39	100	47	100	65	71
Anterior drawer test	91	71	94	50	91	77	82
Lachman test	93	87	91	51	91	88	94
Pivot-shift test	81	50	98	44	95	71	78

[a]NPV, negative predictive value; PPV, positive predictive value.

sample, 26 patients were in the acute phase, 31 in the subacute phase, and 37 in the chronic phase. Approximately half of the patients (n = 48) were injured on the left side. The variables of age and time since injury were significantly different between the patients with and without an ACL rupture ($P \leq .001$). The reliability-retested patient group included 36 patients with similar characteristics as the total group regarding age, time since injury, and injured side. The retest sample included relatively fewer female patients compared with the total sample.

Table 3 presents the interrater reliability between the orthopaedic/trauma surgeon and physical therapist. There were 2 missing values: one for the lever sign test and one for the pivot-shift test. The lever sign test and pivot-shift test had kappa values exceeding 0.80, which is considered almost perfect agreement.[7] The Lachman test and anterior drawer test had kappa values between 0.61 and 0.80, which is considered substantial agreement.

The sample size to evaluate the diagnostic value of the physical examination tests ranged from 81 to 93 patients depending on the test (Table 4). Missing values were caused by muscle defense, which prevented us from conducting a test properly. The lever sign test showed the highest specificity (100%) and the lowest sensitivity (39%) compared with the other 3 tests. With an incidence of 47% ACL ruptures in this population, the lever sign showed a PPV of 100%, an NPV of 65%, and an accuracy of 71%.

In Table 5, the lever sign test has been included and excluded in a cluster of parallel tests with the anterior

TABLE 5
Clusters of Parallel Testing[a]

	n	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Cluster 1 (anterior drawer, Lachman, and pivot-shift tests)	78	88	91	88	91	90
Cluster 2 (lever sign, anterior drawer, Lachman, and pivot-shift tests)	78	91	91	88	93	91

[a]NPV, negative predictive value; PPV, positive predictive value.

TABLE 6
Clusters of Serial Testing[a]

	n	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Cluster 1 (Lachman and anterior drawer tests)	79	68	93	89	79	82
Cluster 2 (Lachman, anterior drawer, and pivot-shift tests)	78	39	98	93	69	73
Cluster 3 (Lachman, anterior drawer, pivot-shift, and lever sign tests)	78	21	100	100	63	67

[a]NPV, negative predictive value; PPV, positive predictive value.

drawer test, Lachman test, and pivot-shift test. The specificity and PPV of cluster 2 (the lever sign test with the other ACL tests) slightly decreased compared with the separate lever sign test analysis, but the outcomes on the sensitivity and NPV increased. The traditional cluster of the anterior drawer test, Lachman test, and pivot-shift test showed similar outcomes.

Table 6 presents the results of serial testing in the same group of patients. The more the tests were executed in a serial sequence, the more the sensitivity figures dropped (from 68% to 21%), while specificity increased (toward 100%). As a result of these changes in sensitivity and specificity, predictive values also altered. The complete cluster eventually had a PPV of 100%, and the NPV dropped to 63%.

DISCUSSION

This study investigated the interrater reliability and diagnostic value of the lever sign test in comparison with the usual diagnostic ACL tests. The results indicate that the lever sign test is reliable. The other tests showed similar reliability values. Further, the lever sign test appeared to have a very high specificity but a rather poor sensitivity. The Lachman test was deemed the most sensitive and accurate test. When the lever sign test was included in a cluster of parallel tests, the accuracy for diagnosing ACL ruptures only increased by 1%, which is not considered clinically relevant. The addition of the lever sign test to a serial cluster (ie, the Lachman test, anterior drawer test, and pivot-shift test) increased the specificity (+2%) and PPV (+7%) but decreased the cluster's sensitivity (–18%). Therefore, these results show that the lever sign test seems to be able to detect partial or total ruptures by itself or in a serial cluster in secondary health care settings. Because of the low sensitivity, the examiner should not rely on the lever sign test alone if the test result is negative.

Deveci et al[4] evaluated the interrater reliability of the lever sign test with the intraclass correlation coefficient (ICC). The test was applied to both the injured and uninjured sides. Only patients undergoing ACL reconstruction were included in the study. The influence of the different examiners and recruitment of the patient population on interrater reliability is unknown. The ICC of the lever sign test in the study by Deveci et al[4] was considered as good and reliable, and the outcome was comparable with that of this study. Two recent systematic reviews reported the interrater reliability of the Lachman test, anterior drawer test, and pivot-shift test.[3,8] The interrater reliability, calculated with the Cohen kappa, or the ICC of the Lachman test varied from slight to almost perfect (0.19-0.93). The interrater reliability of the anterior drawer test and pivot-shift test was inconclusive, as no sufficient data were available.

Only 4 studies have thus far been published on the diagnostic accuracy of the lever sign test.[4,5,10,20] Our results are in contrast with the outcomes of the lever sign test and the MRI findings reported by Lelli et al.[10] In that study, the sensitivity was much higher (100%). The discrepancy may be because of various aspects. In the study by Lelli et al,[10] all patients had an ACL tear (acute or chronic). In addition, Lelli, the inventor of the lever sign test, was the only examiner in the study, which might lead to an inventor's bias. Test experience may have further contributed to this discrepancy. Because of the difference in the patient population, the current study seems to be closer to daily practice. Deveci et al[4] compared the lever sign test with knee arthroscopic surgery as the gold standard in the diagnosis of ACL tears. However, their study results show large differences in sensitivity compared with our results: 94% versus 39% in the current study. This could be because of differences between the examiners and in patient recruitment. Only chronic cases were included in the Deveci et al[4] study. Further, the decision for surgical intervention was made by a combined evaluation of a physical examination, MRI, and the patient's claims of instability. Therefore, the probability of an ACL rupture was much higher as well as the sensitivity value.

Thapa et al[20] performed a more comparable study to ours. All patients with knee symptoms of giving-way/

locking/pain after a sports or nonsports injury who underwent arthroscopic surgery were included. However, the sensitivity in the study by Thapa et al[20] was very high (86%) compared with that in the current study (39%). There is no clear explanation for this difference based on the study design because they are considered similar. Consequently, we can only speculate about causes such as the small difference in inclusion criteria between the 2 studies. Thapa et al[20] specifically included patients with locking and giving-way symptoms. In the current study, all patients with knee trauma and indications for knee arthroscopic surgery were included. Besides this aspect, the experience and number of examiners in the Thapa et al[20] study, which are unknown, may have been different from our study. The results of the study by Jarbo et al[5] are most similar; the overall accuracy of the lever sign test was 77% (63% sensitivity and 90% specificity). Jarbo et al[5] evaluated the sensitivity and specificity of the lever sign test by comparing the test results with MRI outcomes.

The diagnostic accuracy of the other ACL tests is well established in multiple meta-analyses and systematic reviews.[1,9,16,18,19,21] In accordance with the current study, the Lachman test appears to have the highest diagnostic accuracy overall, while the pivot-shift test has the highest specificity but low sensitivity. However, the low diagnostic accuracy of the anterior drawer test is in contrast with the high specificity in the current study. Factors such as the experience level of the examiner, muscle spasms, thigh circumference, size of the examiner's hands, timing of examination, chronicity of the lesion, and type of rupture may have influenced the outcome.[9] The included articles in the meta-analyses and systematic reviews were of low-level evidence because of different observational designs with diverse patient populations, resulting in a large interstudy heterogeneity.[16,19] A difference between the current study when compared with other studies is the recruitment of patients. The majority of studies in the literature only reported physical examination findings of patients with known ACL injuries based on MRI or an arthroscopic examination.[9] In our study, all patients with knee trauma who were eligible for arthroscopic surgery were included. The pretest probability of an ACL tear was therefore much lower and closer to reality.

The number of tests described in the literature demonstrates that there is no "one-size-fits-all" physical examination to detect ACL ruptures.[9] This study shows that clustering the tests parallel (only 1 test finding has to be positive) influences the accuracy in a positive way, although the addition of the lever sign test to the usual tests was of little extra value. A cluster of serial tests influences the accuracy negatively. The specificity of the lever sign test alone was already perfect and could only decrease by parallel testing. The sensitivity of the lever sign test was rather poor, providing little added value to the other tests.

To improve the diagnostic value, there is another way to interpret the results. Based on the current data, serial testing of the lever sign test and Lachman test may be the best way to proceed, using the strength of both tests. When starting with the lever sign test, the current data indicate that a positive outcome confirms an ACL rupture for 100%, with no need for further testing. If negative, the Lachman test can be applied; then, a positive outcome still diagnoses an ACL rupture (with a 9% false-positive chance), and a negative outcome excludes an ACL rupture (with a 13% false-negative chance).

This study has several limitations. Probably the most important point is verification bias. The reference standard of arthroscopic surgery was only applied to a select group of patients with a certain indication for arthroscopic surgery. The findings in this study are valid for specialized outpatient clinics and presumably less relevant for a primary care setting.[16] Besides this, the predetermined order of the tests might introduce bias, as the examiner knew the results of the previous tests. The presumption of an ACL tear may change because of the outcomes of the previous tests. The initial test (lever sign test) was at a disadvantage compared with the other tests performed later. In addition, repeated knee testing could have influenced pain resistance and consequently the outcome of the test.

Another limitation that may have affected the outcomes was the substantial group of patients in which the lever sign test and pivot-shift test could not be performed properly. Besides this, retesting could only be conducted in a subgroup of the included patients. However, the influence on the outcome is presumably minimal because the total sample and retested sample had similar patient characteristics. Additionally, the number of patients did not allow for further classification into several stages after trauma. Also, a separate analysis of partial lesions was not meaningful because of the numbers. Finally, the lever sign test was not executable for all patients. Patients were therefore excluded because of limited extension or locking complaints. Future studies should investigate using larger cohorts. The group can then be divided into different phases after trauma, and separate analyses of partial lesions can be conducted.

CONCLUSION

The lever sign test appeared to have high interrater reliability and is the most specific test, with a maximal PPV. Other benefits are that the test is easy to perform and can be performed by examiners with smaller hands or on patients with large, muscular thighs. However, the test has a low sensitivity, and in our study it could not be performed on 9% of the patients. The lever sign test is a useful addition to the physical examination battery of knees with suspected ACL injuries.

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