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Original Article

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Diagnostic Accuracy of Clinical Test for Anterior Cruciate Ligament Injury: Systematic Review

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Purpose: The aim of this study was to conduct a systematic review of randomized controlled studies from 2012 to present that explore the diagnostic accuracy of clinical tests used for diagnosing anterior cruciate ligament (ACL) injury.
Methods: Study design: Systematic review. Literature search of the PubMed and Scholar databases was conducted using keywords related to diagnostic accuracy of clinical tests for ACL injury. The PRISMA Guidelines were followed to conduct this study. The Cochrane Risk of Bias Tool was utilized to assess the quality of each included study.
Results: As a result, 8 studies were included, and 6 clinical tests used in ACL tears were evaluated for diagnostic accuracy. The pivot shift test was reported as having the highest +LR (29.5) value with a sensitivity of 59% and a specificity of 98%. However, the test with the lowest -LR value was the lever test, and the values were as follows: -LR (0.08), +LR (4.7), specificity (80%), sensitivity (94%).
Conclusion: In this study, it was concluded that a single clinical test is not sufficient to determine the presence of ACL injury. Test combinations have a higher diagnostic accuracy than a single test. In this study, the accuracy of the clinical tests was examined without considering the amount of ACL rupture and acute-chronic condition. Further research is required to examine the impact of these two factors on diagnostic accuracy of clinical test.

Keywords: Anterior cruciate ligament injury, Diagnostic test accuracy, Sensitivity, Lachman, Anterior drawer test

INTRODUCTION

The anterior cruciate ligament (ACL) is an important ligament of the knee joint that originates from the femur and attaches to the intercondylar region of the tibia.[1,2] The fact that it contains collagen fibers and connective tissue make the ACL an anatomically strong ligament.[3] The ACL is momentous in stabilizing the knee joint by resisting anterior tibial translation.[2,4-7] When the knee is in extension the ACL provided 75% of the resistance to the forward movement of the tibia and 85% of the resistance at 30-90 degrees of flexion.[8]

The incidence of ACL rupture has been noticed as 3 per 100.00 sedentary person and in professional athletes has been reported as 3.7 per 100.[2,9] Considering the function of the ACL and high incidence of injury, the diagnosis of ACL injuries should be made early and accurately.[10] In the present study, a combination of history and physical examination findings was used to confirm the presence of ACL injury. Patients with ACL rupture typically exhibit positive clinical test results, pain, swelling, and limitation of activity, in addition to reporting hearing a popping sound during the injury.[11]

Many clinical tests are available to diagnose an ACL injury, however magnetic resonance imaging (MRI) and arthroscopy are the gold standards for confirming the pathology.[3] In their study, Zhao et al.[12] found that the sensitivity of MRI was 95.45% to diagnose ACL injury. However clinical tests are commonly used in the clinic because they are cheaper and more accessible than MRI.[13] Although the anterior drawer test, pivot shift test, and Lachman's test are often used to assess the ACL tears in the clinic, new tests including Lever sign, modified anterior drawer test and forced active buckling test have been used recently. On the other hand the diagnostic accuracy of these clinic tests is currently uncertain. Several factors can affect

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the diagnostic accuracy of clinical tests, including the non-heterogeneity of the study population and the ability of physician. For this reason, among these clinical tests used today, there are studies comparing the tests to investigate which test has the highest diagnostic accuracy.[14]

The purpose of this systematic review was to synthesize studies of the accuracy of clinical tests used to evaluate anterior cruciate ligament tears.

METHODS

1. Search strategy

The preferred reporting items for systematic review and meta-analysis guidelines (PRISMA) were used to supervise this systematic review. A systematic literature search was performed on the PubMed and Google Scholar databases, covering the period from 2012 to 2022. The search strategy involved the utilization of both Medical Subject Headings (MeSH) terms and relevant free words to identify articles addressing the diagnostic accuracy of clinical tests for ACL. Keywords used to literature search for this systematic review included: "physical examination" OR "clinical examination" OR "diagnostic tests" OR "diagnosis" AND "knee" OR "knee pain" OR "anterior ligament rupture" OR "anterior ligament tear" OR "Anterior ligament" AND "sensitivity and specificity" OR "sensitivity" AND "specificity".

2. Study selection

In this systematic review, all studies had to meet the following inclusion criteria. 1) Population: patient with suspected ACL injury, 2) Study design: randomized controlled studies, clinical trial (publication 2012 to present, 3) Evaluation type: clinic examination test for the ACL, 4) Measurement value: sensitivity, specificity. The title and abstract of all relevant articles were reviewed for relevance by 5 authors. After reading full text article, inappropriate studies were excluded. Eight studies were approved for study eligibility by all 5 review authors. The exclusion criteria were as follows. 1) Studies written in languages other than English, 2) Studies without specificity or sensitivity value, 3) Studies with less than 30 subjects, 4) Studies involving subjects who had recently undergone knee surgery.

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Table 1. Likelihood ratios and clinical values

+LR Value range	-LR Value range	Probability
>10	<0.1	Large, often conclusive
5-10	0.1-0.2	Moderate, but usually important
2-5	0.2-0.5	Small, sometimes important
1-2	0.5-1	Very small, rarely important

+LR: Positive likelihood ratio, -LR: Negative likelihood ratio.

3. Quality assessment

The Cochrane risk of bias (RoB) score tool was used to determine the risk of bias in each article in this systematic review and the RoB 2 Excel Marco Form Manual (Beta Version 7) was used to analyze data. The RoB score tool consist of 7 domains. The author's judgment for each item can be answered as high risk (x), low risk (+), and unclear risk (-).

4. Data analysis

In this study, the Likelihood Ratio (LR) value of each test was calculated to evaluate the diagnostic accuracy of clinical test used for the ACL injury in the clinic. The LR value is a strong indicator of the accuracy of a diagnostic test.[15] The LR is calculated using sensitivity and specificity values. Sensitivity is a value that indicates the power of clinical tests to find patients among the true patients according to gold standard. Specificity value indicates the power to find non-patients among the true non-patient according to gold standard.[12] The positive Likelihood Ratio (+LR) is the rate of accuracy in diagnosing the disease. If +LR value of clinical tests is 10 or above and the negative likelihood ratio (-LR) values 0.1 or less, the diagnostic accuracy of the test is interpreted as often conclusive. The value ranges for clinical interpretation of +LR and -LR values are presented (Table 1).

RESULTS

1. Study selection

The PRISMA flow chart that was followed to select appropriate articles for this study were presented at (Figure 1). To select the most suitable studies for our systematic review, the relevant keywords were entered into the databases as a first step. 15,320 articles were reached, and after the duplicate studies were removed, the titles and abstracts of 7,900 studies were read by 5 authors. As a final step, 23 studies were selected for full-text reading, and only 8 studies met inclusion criteria and were

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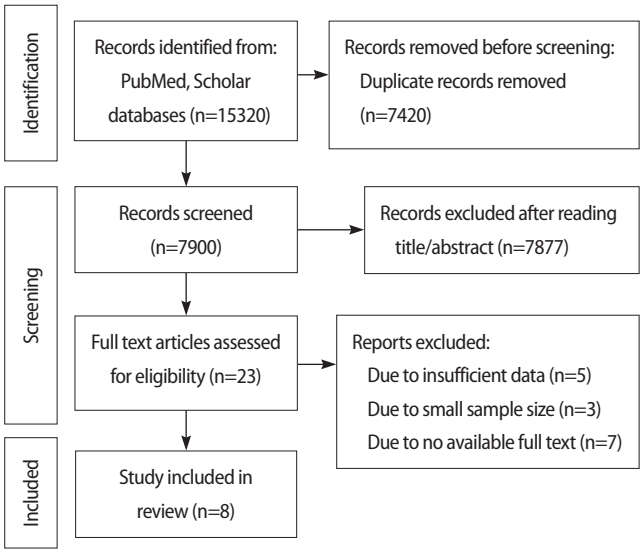


Figure 1. PRISMA flow chart for this study selection process.

accepted by all authors. 15 studies were excluded due to the lack of sufficient information to calculate likelihood ratio value.

2. Study description

The total number of subjects in 8 studies was 968, of which 305 were female. While there were 21 female and 22 male subjects in the study of Decary et al.[16], the number of male subjects was higher in other studies. According to a cumulative analysis of five independent studies, it was observed that the left side was affected in 387 cases, while the right side was affected in 347 cases among the subjects under investigation. The study design of all included studies was a randomized controlled study or clinical trial. MRI or arthroscopy was used as a gold standard to find sensitivity and specificity values of clinical tests used in each of the studies. The characteristics of the participants are summarized in (Table 3). In 7 studies, the the accuracy values of the test were reported separately depending on amount of partial and complete tears.[16] Additionally, one study examined the changes in sensitivity and specificity values clinical tests of pre-anesthesia and post-anesthesia physical assessment tests.[17]

3. Quality assessment

The RoB score information for each study included in this study is shown in (Figure 2). Among the 8 studies, the study with the lowest risk of bias was the study of Fabian et al. and only random sequence generation domain was considered high risk.[18] For Jarbo et al.'s study[19], 3 domains were considered as high risk and approved by 5 authors. The incomplete outcome data domain was assessed as low risk for all 8 studies. There was no disagreement between the authors in quality assessment.

Table 2. General characteristics of subjects

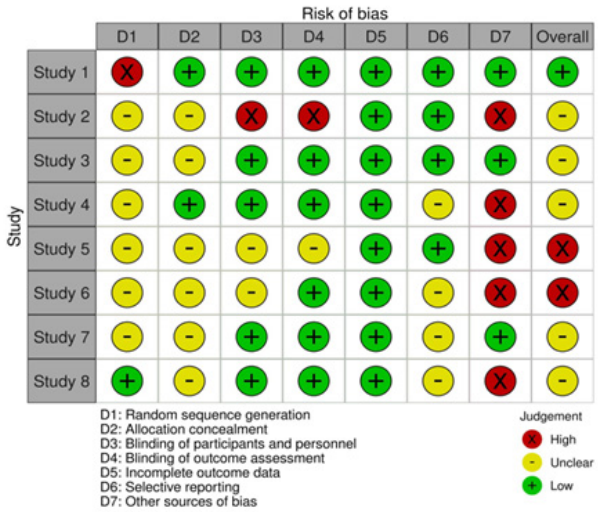
Study's author	Male	Female	Side (L/R)	Mean age	Gold standard
Blanke[18]	62	38		35.9	MRI+Arthroscopy
Jarbo[19]	58	44	50/52	23 (15-66)	MRI
Mulligan[22]	38	22	35/25	42.0±13.4 (18-65)	Arthroscopy
Massey[20]	61	30		28.0±7.0 (16-60)	MRI
Zhao[21]	296	104	218/182	28.7±7.0	Arthroscopy
Decary[16]	22	21		38.6±12.9	MRI
Lichtenberg[13]	57	37	48/46	34.0±15.0	Arthroscopy
Gürpınar[17]	69	9	36/42	25.0(17-44)	MRI

MRI: Magnetic resonance imaging.

Table 3. Summary of results

Test	Author	Sensitivity 95% CI	Specificity 95% CI	LR+	LR-
ADT	Jarbo (2017)[19]	62	88	5.17	0.43
	Zhao (2021)[21]	64	93	9.14	0.39
	Massey (2019)[20]	82	80	4.1	0.23
	Gürpınar (2019)[17]	77.4	68.8	2.48	0.33
	Lichtenberg (2018)[13]	71	94	11.83	0.31
LACHMAN	Blanke (2018)[18]	74	83	4.35	0.31
	Jarbo (2017)[19]	86	91	9.56	0.15
	Zhao (2021)[21]	79	89	7.18	0.24
	Massey (2019)[20]	89	85	5.93	0.13
	Decary (2018)[16] par.	81	98	40.5	0.19
	Decary (2018)[16] comp.	82	91	9.11	0.2
	Gürpınar (2019)[17]	80.6	62.5	2.19	0.3
	Lichtenberg (2018)[13]	87	91	9.67	0.14
	Mulligan (2017)[22]	83	89	7.55	0.19
LEVER	Jarbo (2017)[19]	63	90	6.3	0.41
	Massey (2019)[20]	94	80	4.7	0.08
	Tahsin (2019)[17]	91.9	93.8	14.82	0.09
	Lichtenberg (2018)[13]	39	100	-	0.61
	Mulligan (2017)[22]	38	72	1.36	0.86
FAB	Blanke (2018)[18]	78	95	15.6	0.23
PST	Blanke (2018)[18]	46	96	11.5	0.56
	Jarbo (2017)[19]	59	98	29.5	0.41
	Zhao (2021)[21]	61	97	20.33	0.39
	Massey (2019)[20]	66	94	11	0.36
	Decary (2018)[16] par.	77	98	38.5	0.23
	Decary (2018)[16] comp.	80	92	10	0.22
	Gürpınar (2019)[17]	51.6	93.8	8.32	0.52
	Lichtenberg (2018)[13]	50	98	25	0.51
MADT	Zhao (2021)[21]	89	94	14.83	0.12

ADT: Anterior drawer test, FAB: Forced active buckling sign, PST: Pivot shift test, MADT: Modified anterior drawer test, +LR: positive likelihood ratio, -LR: negative likelihood ratio, par: partial rupture, comp: complete rupture.



Study 1: Blanke[18], Study 2: Jarbo[19], Study 3: Zhao[21], Study 4: Massey[20], Study 5: Decary[16], Study 6: Gürpınar[17], Study 7: Lichtenberg[13], Study 8: Mulligan[22]

Figure 2. The quality assessment with Cochrane risk of bias tool.

4. Diagnostic accuracy of clinical tests

A total of 6 physical examination tests, including anterior drawer test, pivot shift test, Lachman's test, lever sign, forced active buckling sign test, and modified anterior drawer test, were investigated. The detailed results are presented in (Table 2). Sensitivity and specificity with 95% confidence interval (CI) and forest plots for the anterior drawer test, Lachman test, pivot shift test, and lever test for 6 the included studies are shown in (Figure 3). However, the computation of CI was not possible due to the insufficient availability of data for the two studies. Five of 8 studies investigated the accuracy of the anterior drawer test in a diagnosing ACL rupture. While sensitivity, specificity values were (71%) and (94%), respectively, the highest +LR was calculated as (11.83) for this test.[13] Only in this study, the +LR value of the ADT was calculated as large, but for this study, 3 domains, including random sequence generation, allocation concealment, and selective reporting were evaluated as unclear risk using Cochrane risk of bias tool. For all other studies, the range of +LR and -LR values were calculated as (2.48-9.14) and (0.23-0.43) respectively.[13,17,19,20]

The Lachman's test was evaluated in all 8 studies to determine its accuracy in diagnosing.[12,16-22] All studies reported that Lachman's test has a small and moderate value of +LR (2.19-9.67) and -LR (0.13-0.31). In one study, the sensitivity value of the Lachman's test in the diagnosis of only partial tears was reported as (81%) and the specificity value as 98%. With these values, the +LR value was calculated as (40.5) and -LR (0.19).[16]

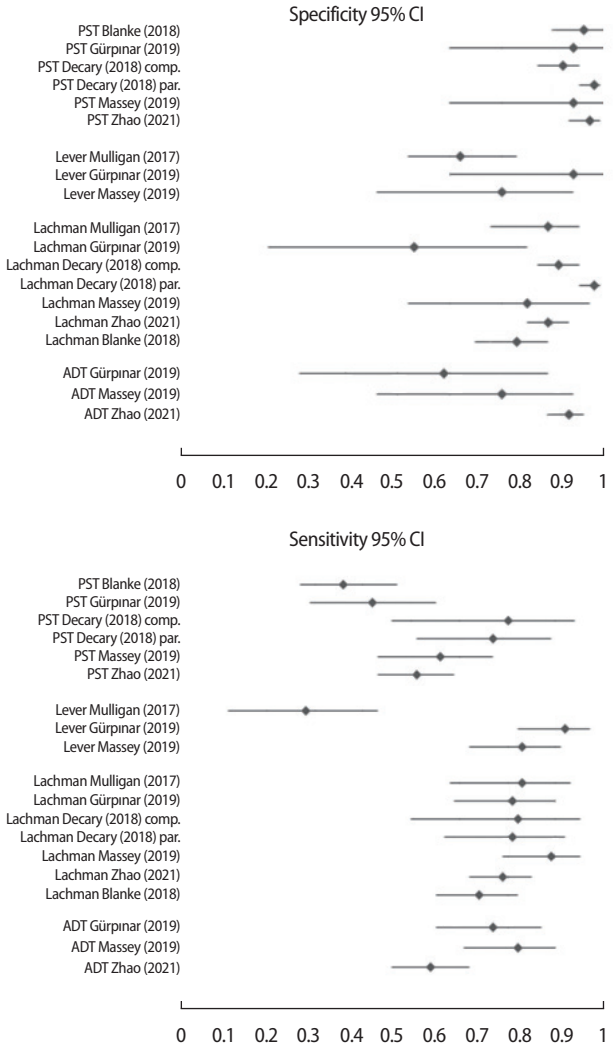


Figure 3. The forest plots of sensitivity and specificity with 95% CI for ADT, PST, Lever test and Lachman test, ADT: Anterior drawer test, PST: Pivot shift test, CI: Confidence interval.

Gürpınar et al.[17] Indicated sensitivity as (91.9%) and specificity as (93.8%) for the highest +LR (14.82) value of lever sign. In all other studies, the +LR value of this test was determined to be between (1.36-6.30).[13,19,20,22] Furthermore, lever sign test had the lowest -LR value which equals (0.09).[17]

Only one study assessed the diagnostic accuracy of the FAB test, +LR (15.6) and -LR (0.23) values were calculated with a sensitivity of (78%) and specificity of (95%).[18]

The sensitivity and specificity values of the pivot shift test were reported in 7 studies.[13,17-21] Based on these values, +LR value was calculated between (11-29.5) and -LR value between (0.36-0.56) in 5 studies.[13,18-21] The lowest +LR (8.32) value for pivot shift test was observed in the study of Gürpınar et al.[17] With a sensitivity of (51.6%)

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and specificity of (93.8%). However, the risk of bias assessment for this study was not considered as high quality.

Only one study, investigated diagnostic accuracy for modified anterior drawer test with a sensitivity of (89%), and specificity of (94%). With these values, we calculated +LR as (14.83), and -LR as (0.12).[21]

DISCUSSION

1. Statement of principal findings

We assessed 6 clinical tests used to diagnose ACL injuries in 8 studies using MRI or arthroscopy as the gold standard. Since the diagnostic accuracy assessment of FAB test and MAD test was performed in only one study, inter-study comparisons could not be made for these tests.[18,21] Based on the studies, these tests have been reported to have high diagnostic accuracy in the diagnosis of ACL injuries. Random sequence generation domain was assessed as high risk and unclear risk for these two studies. However, in a study investigating whether there is a significant difference between appropriate and inappropriate random sequence generation, the effect size was reported as (0.02).[23] Therefore, the diagnostic accuracy of the test does not change significantly depending on the risk of random sequence generation domain. However, as only one study reported the accuracy of these tests, we could not generalize about their diagnostic accuracy. We could not find any systematic review or meta-analysis studies investigating the accuracy of these tests in the databases.

The pivot shift test (PST) was considered as having the highest diagnostic accuracy for use in the ACL injury with +LR value range (8.23-29.50).[13,17-21] The fact that this test was reported with a high +LR value in all 6 studies was interpreted as this test is more reliable than other tests. However, the PST has been reported to have a high -LR value (0.22-0.56).[13,17-21] As a result, this test has high accuracy in diagnosing the subject with ACL injury, whereas it has poor accuracy in diagnosing the subject without ACL injury. Huang et al.[24] reported that the PST had the highest +LR value (16.00), consistent with our study. Furthermore, in the meta-analysis study of both Sokal et al.[25] and Tanaka et al.[26] the PST was reported to be test with the highest +LR value.

The anterior drawer test is one of the three most used physical examination tests to strengthen the diagnosis of ACL rupture.[13] Contrary to the frequent use of this test, its diagnostic accuracy was not found to be large in 4 studies.[17,19-21] We concluded that the ADT is less reliable than the PST in identifying true patients with ACL rupture. To use the ADT, which is used in the diagnosing of ACL injury, the subjects must be able to flex the knee joint to 90 degrees. However, in patients with ligament tears, range of motion may be limited due to pain and swelling in the knee, and therefore this test may be difficult to use.[27] Sokal et al.[25] reported the pooled +LR value of this test as (6.34), which is consistent with our study. In the study of Huang et al.[27] the pooled +LR value of the ADT was evaluated as equal to (3.57).

The -LR value indicates the accuracy of a clinical tests in finding true non-patients.[28] While -LR value for lever sign test was calculated as (0.09) in study of Gürpınar et al.[17] it was calculated as 0.86 in another study.[22] Therefore, in our systematic review, no generalization could be made about the -LR value of lever sign test. However, Kristin et al. reported the pooled -LR value of the lever test as 0.22, and Pawel et al. reported as 0.15 in their study.[10,25] These results are consistent with the results of 2 studies included in our study. In the study of Huang. et al.[27] the test with the lowest -LR value was reported as the lever sign test, and in the study of Abruscato et al.[10] -LR value of lever sign test was equal to (0.22). In our study, the -LR value of Lachman's test was calculated in the range of (0.13-0.31).[13,16-22] The -LR value of Lachman's test was more stable and lower than other clinic tests.

Although the diagnostic accuracy of the same test was evaluated, +LR and -LR values were quite different when comparing inter-studies. In this systematic review, the highest and lowest +LR values for Lachman's test were calculated as (40.5) and (2.19) respectively.[16,17] The sensitivity and specificity values of clinical test may vary depending on several factors. In some studies, it was observed that the amount of rupture affects the diagnostic accuracy of clinical test. When testing patients with complete tears, there is no ligament strength to resist movement, so the test was expected to have higher diagnostic accuracy. However, in the study of Decary et al.[16] contradicting this view, the +LR value was reported as (38.5) for partial ACL rupture and (10) for complete rupture. Since there was only one study investigating the diagnostic accuracy of clinical test in partial and complete ruptures separately, an inter-study comparison could not be made. In a study investigating the diagnostic accuracy of the lever sign, it was reported that the diagnostic accuracy of the test changed according to the acute chronic condition of the injury.[13]

Diagnosis of patients with acute ACL injury is more difficult due to injury-related effusion, pain, and muscle guarding.[16] In addition, 68.49% of the subjects included in our systematic review were male. The sensitivity and specificity values of the physical examination tests may change due to the differences between men and women. Because a heavier leg requires more force during testing.[10] Medial meniscus and medial collateral ligament tears are lesions that often accompany an ACL tear. This unhappy triad lesion may cause more severe pain, swelling, and tenderness in the knee than just ACL injury and therefore may affect the accuracy of clinic tests.[29] Another reason that will affect the accuracy of the tests is that the accuracy of MRI, which is used as the gold standard, is not 100%. To evaluate the clinic tests more accurately, more detailed inclusion criteria should be created by taking these factors into consideration.

2. Study limitations and future research directions

Subjects of the studies included in our systematic review were patients with a general suspicion of ACL injury. The accuracy of physical examination tests was not evaluated according to the characteristics of subjects, such as acute-chronic condition or severity of injury. Because of this limitation, the accuracy of the tests may have varied significantly in inter-study comparison. Further research is required to better understand the impact of subject characteristic on the accuracy of physical examination tests. Another limitation of our systematic review was the inability to generalize about the accuracy of MADT and FAB tests in diagnosing ACL injuries. In the future, more studies are required to investigate the sensitivity and specificity values of MADT and FAB tests.

CONCLUSION

To sum up briefly, no single clinical test has sufficient accuracy to examine the presence of ACL injuries. None of the tests had a +LR value greater than 10 and a -LR value less than 0.01 at the same time. In this regard, test combinations have higher diagnostic accuracy than a single test. In our study, it was decided that the PST and the Lachman's test would be a good combination. Further research is required to better understand the impacts of the factors that influencing the diagnostic accuracy of the clinical tests.

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