

## Is There a Role of Weight-Bearing Tests to Diagnose Meniscal Tears?

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Received date: May 09, 2017; Accepted date: August 11, 2017; Published date: August 28, 2017

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### Abstract

**Introduction:** Non weight-bearing tests are routinely performed to diagnose meniscal tears, recently it has been suggested that tests performed in weight-bearing can produce higher diagnostic values as they effectively imitate the mechanism of injury to the meniscus by increasing axial load. We prospectively evaluated two non-weight bearing meniscal tests (McMurrays and Joint Line Tenderness), with two weight-bearing tests (Thessalys and Eges). The accuracy, sensitivity and specificity values of these tests were then calculated by correlating with arthroscopy findings.

**Methods:** The four clinical tests were performed on 89 subjects pre-operatively. A positive or negative result was recorded following each clinical test and later compared against the arthroscopy findings post operatively.

**Results:** The weight-bearing tests were overall shown to have a better diagnostic value than non-weight bearing tests. For the medial meniscus, joint line tenderness was the most sensitive test; Eges the most specific, Thessalys had the highest PPV and NPV and was the most accurate. For the lateral meniscus, joint line tenderness was the most sensitive; McMurrays the most specific, Thessalys had the highest PPV and NPV and was the most accurate. All four tests were more accurate for medial meniscus compared to lateral. Other pathologies found within the knee were shown to have negative effect on the clinical efficacy of the tests and the highest number of misdiagnoses for meniscal tears occurred with the JLT.

**Conclusion:** This study suggests that the overall clinical ability of the weight-bearing tests to determine the true presence or absence of a Meniscus tear is higher than non-weight-bearing tests.

**Keywords** Weight-bearing tests; Arthroscopy; Meniscus tear

### Introduction

Arthroscopy of the knee is referred to as the 'gold standard' for diagnosing internal derangement of the knee and is used to help confirm a diagnosis made following clinical testing. However involves high costs, is invasive and has the complications associated with surgery. There have been two relatively new weight-bearing tests devised (Eges and Thessalys) and each have been researched once and have been advised by their investigators to be used in the diagnosis of meniscal tears. We thus compare these two tests with the two most commonly used non weight-bearing tests (Joint Line Tenderness and McMurrays) to determine whether they have a higher diagnostic value.

### Pathology of the meniscus

Meniscal tears occur as a result of injury or degeneration of the substance of the meniscus.

### Trauma

With a traumatic injury most patients report an acute onset of sharp pain following a high energy twisting injury with the knee flexed and foot planted on the ground [1]. If the knee is maintained in internal or external rotation then the freedom of movement of the menisci as described above is greatly reduced and tension in affected cartilage is considerably increased. This tension can be at the meniscus

attachments to the head of the tibia or the inner free margin and the meniscus substance itself. As the femur internally rotate with subsequent tibial external rotation the middle of the attached margin of the medial meniscus cartilage is pulled back and while the anterior attachment is pulled forward and out. As the medial meniscus slides further into the joint the inner portion is gripped between the femur and tibia and the continuation of rotation of the knee causes rupture at one of the points of tension [2,3]. The reverse occurs with external rotation of the femur and subsequent internal rotation of the tibia (McMurray). The lesions to the meniscus cannot occur when the knee is fully extended as rotation of the knee is not possible (McMurray). With early stages of knee flexion the anterior horn of the meniscus is more likely to be affected whereas with due to the meniscus being forced posteriorly with increasing knee flexion the tension moves to the posterior horn [4].

### Degenerative meniscal tears

Meniscus tears are often presumed to be associated with a traumatic event, but they can also occur as a result of the cartilage degenerative process in osteoarthritis (OA) of the knee. Degenerative menisci only require a low impact trauma to become symptomatic [1]. Locking is more common in younger patients with meniscal tears whereas older patients are more likely to have degenerative meniscal tears with less mechanical symptoms and an insidious onset of symptoms [4]. Prevalance of such tears increases with age [5-7] and the severity of osteoarthritis [5]. Patients older than 40 years have been shown by Meisha et al. [8] to have decreased intrinsic and peri-meniscal

cellularity in the torn meniscus compared with patients less than 40 years. As the tissue degenerates it can delaminate which may account for inferior mechanical quality of this tissue making it more susceptible to splitting from shear stress [9]. Once present meniscal tears are associated with an accelerated progression of cartilage degeneration in knee osteoarthritis presumably secondary to crucial role of meniscus within knee joint distributing joint forces, load bearing and enhancing joint stability [10].

## Types of meniscal tear

There are a number of types of tear that can occur including longitudinal, bucket handle, flap, radial, degenerate, horizontal and complex.

A bucket handle tear is an extended longitudinal tear at or near the periphery which may run vertically, obliquely or in a complex way through the meniscal substance. The widely held view is that it commences posteriorly and then extends anteriorly allowing the bucket handle to prolapse into the intercondylar notch. With a bucket handle tear the unstable meniscus fragment cannot always move back into an anatomic position which can result in locking of the knee in a flexed position. Due to its increased mobility the lateral meniscus is less likely associated with locking when torn [4]. Shakesphere and Rigby demonstrated in 1983 [11], that 36% of the patients with lateral meniscus bucket handle tears had no locking symptoms compared to 18% patients with medial meniscus bucket handle tears.

The radial tear tends to localise in the posterior horn para-central to the meniscal root. Its effect can be to disrupt the hoop strain within the circumferential collagen fibers and permit extrusion of the meniscal body [12].

Flap injuries involve a split in the cartilage which extends into the meniscal substance from the peripheral border. When the flaps are small locking of the joint is impossible but there can be a feeling of instability if nipping occurs of partially separated mass. If the flap is larger than locking of the joint can occur if the segment becomes wedged in the anterior compartment of the joint [2].

## Pathological characteristics following a torn human meniscus

Unlike other connective tissue such as the medial collateral ligament the human meniscus often fails to heal spontaneously in tears more

than 1cm in length or tears involving the inner 2/3 of the meniscus [8,13] studied the histologic and pathological characteristics of the torn meniscus. They found the human meniscus to undergo three histological phases after rupture: a reactive phase, perimeniscal proliferation phase and a remodeling phase. Meisha et al. study [8] found a lack of tissue in the gap within the meniscus tear sites and minimal intrinsic fibroblasts therefore a fibrin clot does not form in the intra-articular milieu possibly because of fibrinolytic enzymes in synovial fluid. In peripheral tears healing occurs by migration of synovial cells over the surface of the meniscus. One of the primary reasons the inner zone of the meniscus does not heal after injury is that it is incapable of mounting a reparative response due to a lack of neovascularisation which was confirmed in observations in animal models [14]. This failure to heal is similar to other cartilage tissues such as articular cartilage which also do not exhibit proliferative fibroblast or an angiogenic response to injury.

## Incidence of medial vs. lateral meniscus tears

Christoforakis et al. [5] found in 497 consecutive knee arthroscopies 65.5% medial meniscus tears and 34.4% lateral meniscus tears. There are a number of reasons for this. The medial meniscus unlike the lateral meniscus is firmly attached to the tibia and medial collateral ligament therefore is less mobile with less displacement and the inner side of the knee joint normally forms an apex of the angle between the femur and tibia causing increased strain and susceptibility of the medial meniscus to injury [3,15,16]. Another reason proposed by Last [17] and McCormack and McGrath [18] bearing in mind the meniscofemoral ligament-meniscal motion hypothesis was that the fine control exerted on the lateral meniscus by the menisco-femoral ligament and popliteus prevented the meniscus from being ground between the femur and tibia helping explain less frequent tears of the lateral meniscus.

## Misdiagnoses that can be made by clinical mensical tests

Tables 1 and 2 below outline from a few studies possible misdiagnoses of medial and lateral meniscus tears that can be made.

Possible misdiagnosis for a medial meniscus tear	Incidence	Proposed reason for the misdiagnosis
Symptomatic fibrotic plicae	12 out of 23 misdiagnoses [19] 1 out of 103 [20]	Any disorder affecting the medial plica or fat pad can mimic medial meniscal symptoms such as joint line tenderness, popping, catching and locking. This is because the medial plica is contiguous with the medial fat pad, which attaches to the retinaculum just above the MM at the junction of the mid 1/3 and anterior 1/3 capsular ligament [19]
Fat pad impingement	4 out of 23 misdiagnoses	Refer to proposal of symptomatic fibrotic plicae by Terry et al. [19]
Lateral meniscus tear	1 out of 23 misdiagnoses [19] 2 out of 103 misdiagnoses [20].	The tear believed associated with a low grade synovitis with signs of medial plica irritation. The secondary inflammation of the medial plica was thought to be responsible for the cross-over signs misinterpreted as a medial meniscus tear [19]
Chondral fractures	40% of misdiagnoses [21]	
Lateral patella subluxation		The subluxation cause medial retinacular strain, fat pad injury or plica injury that can mimic a meniscal tear [19]

Avulsion fracture of a posterior osteophyte of the medial tibial plateau	1 out of 23 misdiagnoses [19]	This patient had previously had an open partial medial meniscectomy it was thought that a posteromedial tibial osteophyte had formed as a result of a post meniscectomy adaptive bone change [19]
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**Table 1:** Misdiagnoses made as medial meniscus tears.

Possible misdiagnosis for a lateral meniscus tear	Incidence	Proposed reason for the misdiagnosis
Synovitis under lateral patellotibial ligament	6 out of 15 misdiagnoses [19]	Mechanical or inflammatory irritation of synovial reflection of the lateral aspect of the fat pad compressed by the lateral patellotibial ligament [19]
Fibrotic lateral plica	4 out of 15 misdiagnoses [19]	Attachment of lateral plica into the lateral retinaculum also communicates with the lateral fat pad [19]
Chondral fractures of the lateral compartment – 1 of tibial plateau and 1 of femoral condyle	1 out of 15 misdiagnoses [19]	Associated with secondary irritation of the synovium particularly at the popliteal hiatus opening and at the synovial reflection of the lateral fat pad giving joint line tenderness and popping [19]
	50% of misdiagnoses [21]	Absence of nerve fibers in the hyaline cartilage causing the misdiagnosis [21]

**Table 2:** Misdiagnoses made as lateral meniscus tears.

### Clinical testing for meniscal pathology

DeHaven and Collins [22] and Daniel et al. [23] stated that 75% of knee diagnoses can be accurate on history alone. Knowing the accuracy of clinical tests is harder as throughout the literature the physical examinations are not standardised and different studies are using varied modifications of various tests. The importance of tests having high accuracy allows an effective course of treatment to be developed and avoids the use of expensive diagnostic testing such as MRIs and arthroscopies. More than 20 meniscal tests have been described for diagnosing tears [20].

The clinical diagnosis of meniscal tears may be difficult for even experienced surgeons to make. The diagnostic values and reliability of several meniscal tests have been assessed by a number of authors [23-28]. It is generally accepted that all meniscal tests have their diagnostic limitations. Fowler and Lubliner [27] and Mariani et al. [3]

reported no one clinical test was predictive in diagnosis of meniscal lesions and recommended combination of tests [3].

### Diagnostic signs used as a positive interpretation of a meniscal tear

Most tests depend on the presence of a point of tenderness in the articular joint line and/or presence of an audible 'snap' or 'click'. It is said that the flexion and extension of the knee with internal or external rotation can enhance these symptoms by displacing the fragment of the meniscus [3]. The McMurray and Eges tests combine both flexion/extension with rotation whereas Thessalys only uses rotation in an already slightly flexed position. When using the JLT, Eren [20] suggests the tenderness can be enhanced by rotating the leg before palpating. Table 3 below describes the diagnostic clinical signs for a positive test as described in the original descriptions of each of the tests.

Test	Positive sign for medial meniscus pathology as described in original description	Positive sign for lateral meniscus pathology as described in the original description
Joint Line Tenderness	Tenderness to palpation along the medial articular joint line	Tenderness to palpation along the lateral articular joint line
McMurrays [2]	Pain and/or click along the medial joint line with external rotation of the tibia	Pain and/or click along the lateral joint line with internal rotation of the tibia
Thessalys [29]	Pain and feeling of locking or catching when leg externally rotated	Pain and feeling of locking or catching when leg is internally rotated
Eges [30]	Pain and/or click along medial joint line in squatting with legs in external rotation	Pain and/or click along lateral joint line in squatting with legs in internal rotation

**Table 3:** Diagnostic criteria set for a positive test as described by creators of it.

The Eges and Thessalys tests have only been studied once so variation of diagnostic criteria for a positive result between studies so far does not exist. However the diagnostic signs interpreted as a positive McMurrays test are particularly varied between studies. For example some accepted the test as positive with a painful click, [1,27,31] some with a click in the presence of absence of pain [26,32]

and some with pain in presence or absence of a click [2,30,33]. As a result confusing results appear in the literature consequently comparisons are difficult to make between different studies.

The presence of tenderness is easier to palpate than a click. Absence of tenderness should not be contraindication to diagnosis when there

is solely a click felt as although usually tenderness is present after injury it tends to diminish and in many cases disappears after a few weeks even though underlying cartilage may be torn or displaced [2].

The sense of locking as reported in the Thessalys sign can only be produced by the interposition of tissue between the articular surfaces of the tibia and femur and in front of the mid-plane of the joint. Locking can only occur in those rare injuries where tear has occurred in anterior section of cartilage or in other large group where split in cartilage extends through its length as a bucket handle tear.

### Non-weight bearing clinical tests for the meniscus

The most widely used tests are McMurrays and Joint Line Tenderness (JLT) which are the non-weight bearing tests used in this study. Descriptions of the tests are in appendix.

Despite the wide use of McMurrays and JLT their sensitivity and specificity respectively are low. Also many reports describing them in the literature are old and of poor quality and very few of the tests have been studied to determine their diagnostic accuracy compared with arthroscopy and MRI [20,26,27,31,34-39].

Scholten et al. performed a literature search between 1966 and 1999 of the physical diagnostic tests for assessing meniscal lesions of the knee. Only 13 out of 402 studies addressed accuracy of at least one physical diagnostic test and used arthroscopy or MRI as the gold standard. The accuracy of McMurray was determined in 11 studies and the accuracy of JLT in 10. They found the sensitivities of various meniscal tests to be overestimated therefore an accurate conclusion of accuracy cannot be reached. Most of the diagnostic errors in the studies on McMurrays [26,28] were associated with the lateral meniscus.

The accuracy of McMurray varies widely in previous reports [23,26,27,31,36] which may be due to two possible factors including patient selection and differences in applying the test and interpretation of the results. Evans et al. [26] examined accuracy and inter-examiner reliability of the McMurray test for diagnosis of meniscal tears and concluded test could not be relied upon. Even McMurray cautioned when he devised the test that 'the method of examination is not easy to master, the rotation requires a considerable amount of practice and the whole procedure must be carried out systematically if success is to be obtained'.

There also seems to be a wide variation in the reported sensitivities (16-58%) of the McMurray test for detecting meniscal tests [23,26,27,31] and the number of studies testing McMurrays in consecutive patients seems to be quite low. So the test is good, but only in conjunction with other tests. However although its sensitivity is low, the specificity is high, which helps the test to rule out the meniscal lesions when it is negative [40,41].

Accuracy of assessment of JLT in the diagnosis of the meniscus tear has only been determined in 9 studies that meet the selection criteria. Eren's study [20] was the first study to address only joint line tenderness in identifying meniscal tears in stable knees and he concluded that it can only be safely used for detection of lateral meniscus tears.

### Weight bearing tests for the meniscus

The axial shear forces across the menisci are increased during weight bearing flexion (Tovin) compared to non-weight-bearing as in

the McMurray test. The philosophy of the weight bearing tests are that they mimic the activities precipitating the symptoms of a torn meniscus more accurately and more specifically than the tests performed by the physician under non-weight bearing conditions.

In the studies involving weight bearing tests Eges and Thessalys [30,31] acute injuries under 6 weeks history are not included for several reasons including that an arthroscopy in cases of acute trauma is not performed unless the knee is locked, squatting is already a painful act no matter what the cause might be and it may lead to a high number of false positive results in acute cases which is also true for other clinical meniscus tests.

The Thessaly test was first reported in the literature by Karachalios et al. [29]. The test involves monopodal weight bearing and was developed to reproduce the exact dynamic mechanisms that cause meniscal injuries in humans. It can be inferred that the dynamic internal and external rotation of the knee at 20 degrees of flexion squeezes apart the fragments of the meniscus and causes pain arising from the outer part of the meniscal substance which is innervated. They believe that because the meniscal load is increased substantially with this test that even small tears can be detected. The test was examined with JLT and McMurrays against both arthroscopy and MRI and demonstrated high sensitivity and specificity rates and a diagnostic accuracy of 94% for tears of the medial meniscus and 96% for tears of the lateral meniscus which are comparable with the accuracy rates reported for MRI [40,41]. JLT and McMurrays showed low accuracy results and the same manouver at 5 degrees did not show equivalent accuracy rates. They concluded the Thessaly test at 20 degrees can be used safely as a first-line screening test for diagnosis of both lateral and medial meniscal tears.

Eges Test was first described by Akseki et al. [30]. The test was also compared with McMurrays and JLT. In Eges test like McMurrays the knees are also forced into internal rotation and external rotation as the patient squats. The study results showed Eges to be more specific and accurate than McMurrays and JLT in detecting medial and lateral meniscus tears. They concluded the accuracy of traditional meniscus tests may be improved by including Eges test in clinical examination as the test reflects the symptoms of a torn meniscus more accurately than the tests performed with the patient supine because it is performed in a functional position.

### Limitations of previous studies on meniscal tests

Having reviewed a wide range of studies on testing for the meniscus, there are several limitations in these studies that are apparent and are listed in the Table 4 below.

Limitation
Variation in experience of examiners
Variation in precise method used for conducting the physical examination
Chronicity of injuries used not stated
Definitions of an 'abnormal' or 'positive' physical exam varied between studies and not always clearly stated
Reproducibility of physical exam unclear and rarely reported
Non-consecutive patients studied

Diagnostic accuracy not compared with the 'gold standard' arthroscopy or MRI
Inter-examiner reliability if more than one examiner
Inter-observer and intra-observer agreement among examiners
Performance of many tests within one study can be unreliable
Single sex groups or varying age groups
Varied patient criteria between studies and in some cases no inclusion/exclusion criteria stated
Observation of MRI result prior to performing the test if gold standard used being arthroscopy creating bias
Some studies only used patients suspected of having meniscal tears creating bias

**Table 4:** Limitations in meniscal tear studies.

### Why compare the clinical diagnostic tests with arthroscopy?

Arthroscopy is considered the 'gold standard' in the assessment of internal derangement of the knee. Although some studies have stressed the high diagnostic value of MRI [1,42,43] others have reported MRI is not superior to physical exam in the diagnosis of meniscal tears [37,44]. Cetite [45] stated that there are some difficulties with MRI while diagnosing bucket handle tears such as the normal appearance of reduced tears on MRI. A study by Thomas et al. [46] on 138 patients compared MRI results with arthroscopy and found an overall accuracy of 63% for medial meniscus and 86% for lateral meniscus indicating a lower accuracy of MRI in detecting pathology especially of the medial meniscus.

### Methodology

The most commonly used techniques to aid diagnosis of meniscal tears such as McMurrays and Joint Line Tenderness (JLT) are performed in non-weight bearing. It has recently been suggested that tests performed in weight bearing such as Eges and Thessalys would be of a higher diagnostic value when testing for meniscal pathology.

The purpose of this research is to study patients undergoing a knee arthroscopy and compare the diagnostic value of two commonly used non-weight bearing tests McMurrays and JLT with two recently proposed weight-bearing tests Eges and Thessalys. This may provide information to any clinician assessing the knee as to which tests are the more effective in diagnosing meniscal tears.

### Null hypothesis

Weight-bearing meniscal tests do not have a higher diagnostic value over non-weight bearing meniscal tests in the diagnosis of meniscal lesions.

### Ethical aspects

The study was approved by the Royal Marsden Ethics Committee and Guys and St Thomas NHS Trust COREC. All of the participants in the study were provided with information about the study and signed a consent form prior to the tests being performed.

### Subjects

Following informed consent, 89 participants aged between 17 and 75 (average age 43) took part in the study. The 89 participants were booked to have an arthroscopy on their knee between the dates of March 26th 2007 and 19th July 2007 by one of four orthopaedic surgeons working under Guys and St Thomas NHS Trust. 47 of the participants were male and 42 were female. The 89 participants met the inclusion and exclusion criteria noted below in Table 5.

### Screening

To identify the participants to be included to undergo the four clinical tests, all referrals for a knee arthroscopy to be performed by one of the four consultants were screened. The participants included met the inclusion and exclusion criteria described below. Data of the patients identified as suitable was entered into the table.

An information letter was then sent to each of the participants to explain the nature of the study and invite them to take part. A follow up phone call was made to ensure they had received the letter and answer any questions they may have, confirm whether they would like to take part and to further screen for any exclusion criteria.

Inclusion Criteria
Booked for a knee arthroscopy performed by one of the four consultants at Guys Hospital between March 26th 2007 and July 31st 2007.
Able to weight bear on symptomatic side
Able to perform a small squat
Exclusion Criteria
Unable to weight bear on symptomatic side
Unable to perform a small squat
Suspected or confirmed serious pathology of the knee (fracture, metastatic, inflammatory, or infective diseases)
Other lower limb injury on the symptomatic side, i.e., Hip, ankle, foot
Unable to speak English

**Table 5:** Inclusion and exclusion criteria.

### Experience of practitioners involved in the investigation

Investigator performing the tests – 5 years qualified Senior Physiotherapist and four Orthopedic surgeons.

### Interventions

The participants were all seen at Guys Hospital Day Surgery Clinic while they were waiting for their knee arthroscopy. The location they were tested was the Recovery Room in Day Clinic. Prior to the clinical tests being performed they were provided with a consent form. The four clinical tests performed on each participant including McMurrays, Joint Line Tenderness, Eges and Thessalys. Each of the tests was repeated three times.



### Criteria used as a positive result for each of the tests

The primary outcome measures for each of the tests were those described in the original descriptions of the tests as shown in Table 6 below.

Clinical Test	Criteria for a positive test
Joint Line Tenderness	Tenderness along the joint line
McMurray	Pain and/or click
Eges	Pain and / or click going into or coming out of squat
Thessalys	Sense of locking / catching or discomfort

**Table 6:** Criteria used for a positive result for each test.

### Information derived from the arthroscopy results

The primary information sought from the patients notes following their arthroscopy included:

- Positive or negative result for meniscal injury.
- Type of meniscal tear and location of tear.
- Other pathologies mentioned.

### Controlling bias

**Prior to the investigation:** The McMurray Test has been stated as a difficult test to perform therefore inter-observer reliability was assessed performing the test by two knee physiotherapy clinical specialists prior to the investigation.

All four tests were practiced on 20 non symptomatic people prior to the investigation beginning.

**During the investigation:** The chief investigator was blinded to any diagnoses made from any clinical examination prior to the operation and to any previous MRI results.

The tests were each performed on the healthy knee first which helps the patient to trust the examiner and allows greater relaxation.

The order of the four tests was alternated between participants.

### Statistical analysis

The results of the tests were compared with the arthroscopy results and true positive, true negative, false positive and false negative results were determined as follows. When a medial meniscal tear was suspected with one of the tests and found on arthroscopy then this result was classed as a true positive result for medial meniscus pathology. If a medial meniscus tear was not suspected with one of the tests and not found on arthroscopy this result was classed as a true negative result. If a medial meniscus tear was suspected with a clinical test but not found on arthroscopy then this was classed as a false positive result. Finally if a medial meniscus tear was not suspected but is found on arthroscopy then this was classed as a false negative result. The same statistical analysis as above was conducted for the lateral meniscus. Once this data had been formulated and inserted into a table, the five statistical parameters accuracy, sensitivity, specificity, positive and predictive values were then calculated using the formulas in Table 7 below.

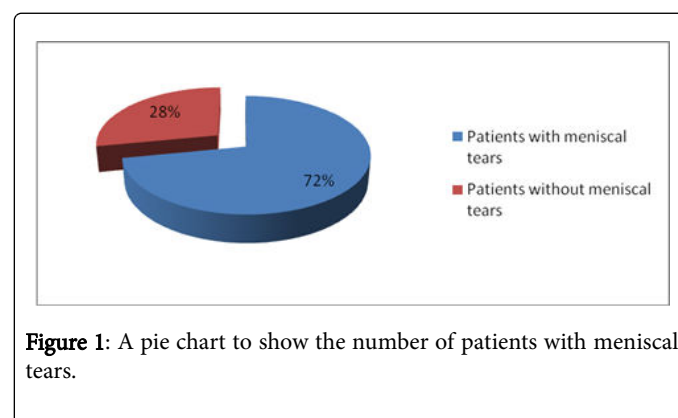
Term	Definition	Formula
Accuracy	Reflects the overall clinical ability to determine the true presence or absence of a particular disorder	$\frac{\text{True Positives} + \text{True Negatives}}{\text{Total}}$
Sensitivity	Reflects the clinical ability to positively correlate a final pathological diagnosis with the initial clinical diagnosis	$\frac{\text{True Positives}}{\text{True Positives} + \text{True Negatives}}$
Specificity	Reflects the clinical ability to correctly determine the absence of pathological condition	$\frac{\text{True Negatives}}{\text{True Negatives} + \text{False Positives}}$
Positive predictive value (PPV)	The frequency with which a positive initial diagnosis actually signifies the diagnosis confirmed postoperatively	$\frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$
Negative predictive value (NPV)	The frequency with which a negative initial diagnosis identifies disorders that were not confirmed postoperatively	$\frac{\text{True Negatives}}{\text{True Negatives} + \text{False Negatives}}$

**Table 7:** Definitions and formulas for the diagnostic values used.

## Results

### Arthroscopic findings

The findings from the arthroscopies showed 64 (72%) patients out of the 89 to have meniscal tears as displayed in the pie chart below. 74 tears altogether were diagnosed from the 64 patients. Medial meniscus lesions alone were found in 41 patients and lateral meniscus tears alone were found in 13 patients. 10 patients had bilateral meniscal tears (Figure 1).



**Figure 1:** A pie chart to show the number of patients with meniscal tears.

### Types of meniscal tear

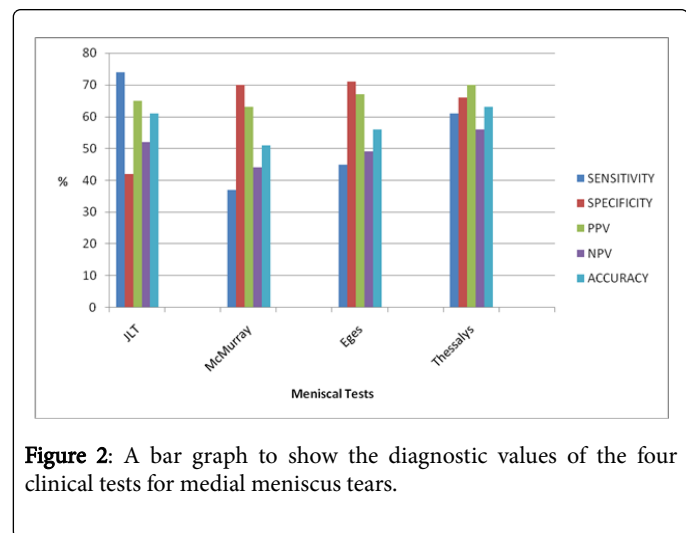
Out of the 74 meniscal tears identified on arthroscopy 28 were degenerative and 6 were bucket handle tears. With regards to the location of the tears 15 were to the posterior horn, 3 were to the anterior horn and the remainder was in the main meniscal body. Table 8 below shows which tests picked up which type of tears.

Type of tear	Number shown by arthroscopy	Number picked up by each test
Degenerative	28	JLT – 21 McMurrays – 10 Ege – 14 Thessalys - 15
Bucket handle	6	JLT – 3 McMurrays – 3 Eges – 3 Thessalys – 4
Anterior horn	5	JLT – 3 McMurray – 1 Eges – 8 Thessalys – 9
Posterior horn	13	JLT – 3 McMurray – 1 Eges – 2 Thessalys - 3

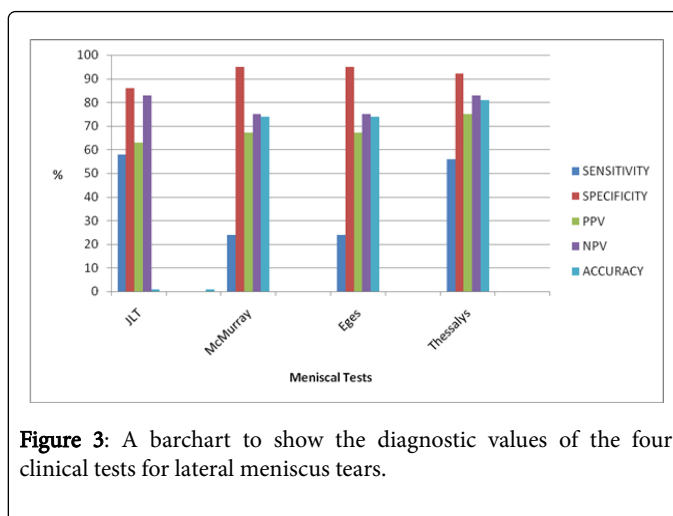
**Table 8:** Number of degenerative, bucket handle, anterior horn and posterior horn tears picked up by each clinical test.

### Results of the clinical diagnostic tests

Having compared the tests against the arthroscopy, the results are shown below of the true positive, true negative, false positive and false negative results for each test. Below are two barcharts to display an overall picture of the diagnostic values of each test for medial meniscus tears (Figure 2) and lateral meniscus tears (Figure 3).



**Figure 2:** A bar graph to show the diagnostic values of the four clinical tests for medial meniscus tears.



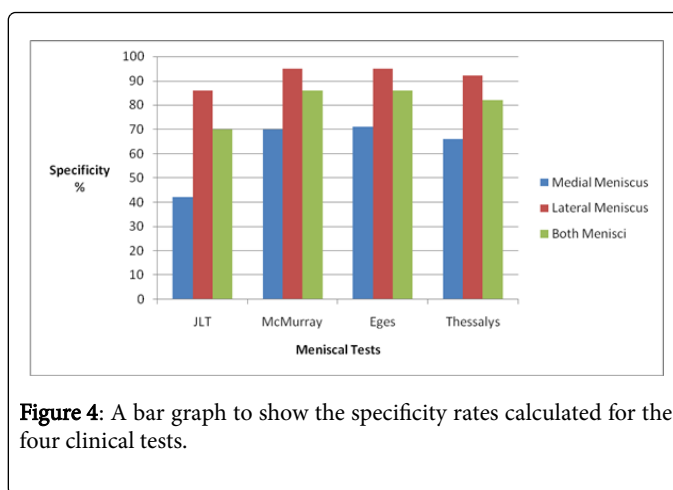
**Figure 3:** A barchart to show the diagnostic values of the four clinical tests for lateral meniscus tears.

### Sensitivity and specificity rates

The JLT test had the highest sensitivity for both medial meniscus (74%) and lateral meniscus (58%) out of the four tests. Thessalys was the second most sensitive test for both medial meniscus (61%) and lateral meniscus (56%). McMurrays and Eges both had very low sensitivity rates for both menisci.

Figure 4 illustrates the specificity rates for each clinical tests. With regards to specificity the reverse occurs to sensitivity. With both Eges having the highest specificity for a medial meniscus tear (71%) and McMurrays following close behind with 70%. Eges and McMurrays produced equally high specificity results for the lateral meniscus at 95%. Thessalys was close behind MCMurrays and JLT test with specificity rates being 66% and 92% for medial and lateral meniscus lesions respectively. The JLT test had the lowest specificity for both menisci with 42% and 86% respectively for medial and lateral menisci.

Overall all 4 tests had a higher sensitivity for medial meniscus lesions compared with the lateral meniscus lesions but the reverse occurred with the specificity rates.



**Figure 4:** A bar graph to show the specificity rates calculated for the four clinical tests.

### Positive and negative predictive values

The PPVs and NPVs calculated for the four clinical tests. The positive predictive values (PPV) and negative predictive values (NPV)

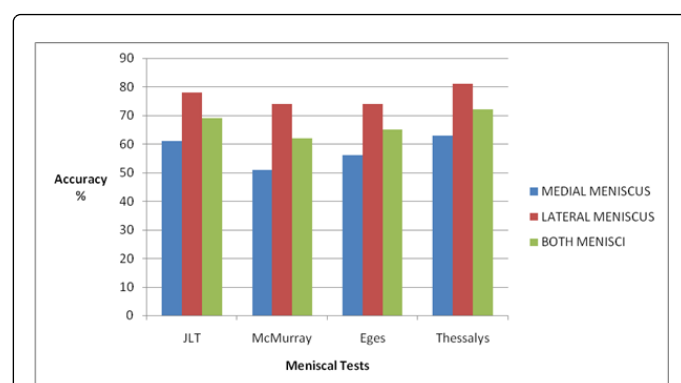
on all 4 tests for the medial meniscus tests were quite similar ranging between 63% to 70% and 44% to 56% respectively. McMurray had both the lowest PPV and NPV for the medial meniscus and Thessalys the highest.

McMurrays and Eges produced the same PPV (67%) and the same NPV (75%) for the lateral meniscus. The JLT test produced the lowest PPV (63%) for the lateral meniscus and Thessalys the highest (75%) and both JLT and Thessalys equally gave the highest NPVs (83%) for the lateral meniscus.

## Accuracy

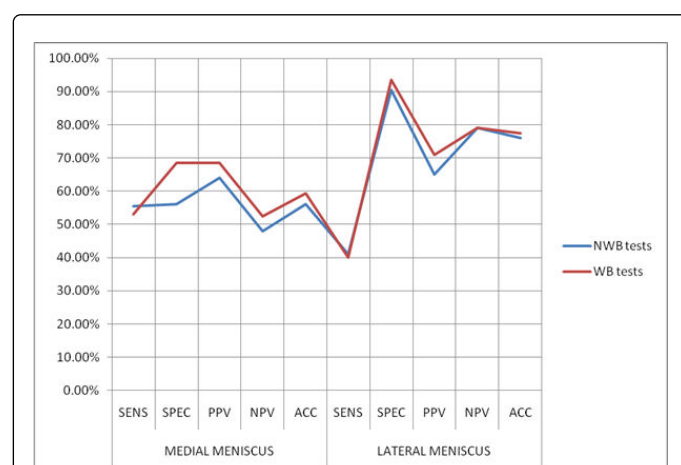
The accuracy of each test is shown in Figure 5. The accuracy rates of all 4 tests for the medial meniscus were moderate ranging between 51% and 63% with McMurrays having the lowest rate and Thessalys the highest.

The accuracy rates for all 4 tests for the lateral meniscus were higher ranging between 74 and 81% with both McMurrays and Eges having the lowest and Thessalys again the highest.



**Figure 5:** A barchart to show the accuracy rates of the four clinical tests.

## Weight bearing vs. non-weight bearing tests



**Figure 6:** A linechart to show a comparison between the diagnostic values of the non-weight bearing tests with the weight-bearing tests.

The results of the two non-weight bearing tests McMurrays and JLT were compared with the results of the two weight-bearing tests Eges and Thessalys and are depicted as a line chart in Figure 6. It can be seen that the results for all diagnostic values were quite similar between the two categories of tests. However the two weight bearing tests were found to have higher specificity, accuracy and PPV rates for both menisci over the non-weight bearing tests and the reverse for sensitivity with the non-weight bearing tests having higher sensitivity for meniscal lesions over the weight-bearing tests. The weight bearing tests were found to have a higher NPV for medial meniscal lesions and an equal NPV for lateral meniscus lesions with the non-weight bearing tests.

## Combined meniscal/other pathologies

Out of the 89 patients 5 were found to have Anterior Cruciate Ligament tears and all of these patients had associated meniscal tears. 14 of the 74 tears (30%) were found to be combined with chondral lesions and 2 (0.03%) of the tears were combined with plica pathology.

## Discussion

This study to the best of our knowledge is the first to compare the two recently proposed weight-bearing tests with each other as well as with the two most commonly used non-weight bearing tests. The following sections will first compare the results of each individual test with findings of other studies and then compare the four tests with each other. The influence of other present pathologies on the validity of the tests and the different types of tears encountered will also be discussed.

## Diagnostic effectiveness of the four clinical tests

**The joint line tenderness test:** Out of 74 tears 54 diagnoses were made correctly with the Joint Line Tenderness Test (JLT) and 30 misdiagnoses were made. From the studies analysed, four studies on JLT [20,29,30,47] specify separate results for lateral and medial menisci and showed high sensitivity rates for JLT for the medial meniscus to range between 78 and 92% and one study showed a low sensitivity rate of 44.9% [48]. However the study's sensitivity rate of JLT for lateral meniscus tears (58%) was relatively low identical to Shelbourne et al. [42] unlike the studies by [20,29,30,44] which produced sensitivity rates ranging between 67 and 95%. When making comparisons with Shelbourne et al. [42] study it needs to be remembered that their study population included patients with acute ACL ruptures and it has been shown by numerous authors that the presence of ACL tears can render the clinical exam less effective in the diagnosis of a meniscal tear [27,29].

The specificity of JLT for the medial meniscus varies between studies with high rates of 90% [29] and low rates in studies by Shelbourne et al. [42] who produced 34.5% and Akseki et al. [30] who produced 44% which is the same as this study (44%). However for the lateral meniscus the trend in recent studies is although lower than the other tests towards a high specificity with 97% [20], 80% [30] 90% [29] and 93% [44]. This study supports these results having produced a specificity rate of 86% for the lateral meniscus which is more than double the rate for the medial meniscus.

Three studies [20,30,44] calculated PPVs and NPVs for the JLT and distinguished between the lateral and medial menisci. This study produced similar PPVs for both menisci. In comparison this study showed the PPV of JLT (65%) for the medial meniscus to be similar to



the other three studies and the PPV for the LM (63%) was similar to Akseki et al. [30] and Eren [20] but differed from Rose [44] who found 86%. The NPV for all three studies and this study was higher for the lateral meniscus than the medial meniscus.

JLT has been reported as the most accurate test in a number of previous studies [23,24,27,31,49]. This study supports this statement in the respect that the accuracy rate of JLT was higher than that of McMurrays which was one of the tests used in the studies above. However the studies above did not analyse the weight-bearing tests Thessalys and Eges. Thessalys has been shown by Karachalios et al. [29] and this study to have a higher accuracy rate than the JLT.

Considering the lateral meniscus this study supports the claim made by Eren [20] and Rose [44] that the JLT is a more valuable diagnostic sign for lateral meniscus tears rather than medial meniscus tears as the specificity, NPV and accuracy rates are significantly higher.

**McMurray test:** The McMurray test correctly diagnosed 25 out of 74 meniscal tears and made 14 misdiagnoses in this study. There is wide variability in the results produced for the McMurray test possibly because the test is difficult to perform [2] and has been said to be reliant on the experience of examiners by some examiners although Evans et al. [26] disagrees and intra-observer/inter-observer reliability. The McMurray test has generally been thought to have moderate to high specificity but low sensitivity [24,26,27,29-31] for both menisci. This study supports this with the test producing low sensitivity values for the medial meniscus (37%) and lateral meniscus (24%) and moderate specificity (70%) for the medial meniscus and high specificity for the lateral meniscus (95%).

There does seem to be however variation between studies with the specificity of McMurray for lateral meniscus vs. medial meniscus. The higher specificity for lateral meniscus produced in this study is supported by Akseki et al. [30] but not by Karachalios et al. [29] who found a higher specificity for medial meniscus and Evans et al. [26] and Corea et al. [24] who found equal specificity for both menisci.

Both studies by Evans [26] and Akseki [30] showed the PPV of the McMurray test to be higher for the medial meniscus than the lateral and vice versa with the NPV. Whereas this study showed similar moderate values for the PPV and NPV for both menisci.

The combined accuracy of McMurrays for both menisci in the studies described ranges from 45% Kurosaka et al. [31] to 81% [29]. This study produced a moderate combined accuracy result of 62%. In the studies that differentiate between the two menisci [29,30] it is shown that the accuracy of McMurray is higher for the lateral meniscus than the medial meniscus which is also the case in this study which showed McMurray to be 74% accurate for the lateral meniscus and 51% accurate for the lateral meniscus.

Diagnostic errors of McMurrays by Evans et al. [26] and Noble and Erat [28] were associated with the lateral meniscus which is not the case in this study which found 3 false positives for the lateral meniscus compared with the medial meniscus and 33 false negatives for the medial meniscus compared with 20 found for the lateral meniscus.

The results of this study showed the McMurray test to correctly diagnose 3 out of the 6 bucket handle tears and only 8 out of the 28 degenerative tears which dispute Anderson and Lipcombs [23] claim that the McMurray test is accurate in picking up degenerative tears but inaccurate in picking up bucket handle tears.

**Thessalys test:** The only study conducted so far on the Thessalys test is by Karachalios et al. [29] which compared the test with the two non-weight bearing tests McMurrays and JLT. Their study concluded the test to be highly accurate, sensitive and specific with all the results for both menisci being 89% and above. The sensitivity rates of Thessalys in this study differed from those of Karachalios et al. [29] in the respect that the rates were much lower for both medial meniscus (61%) and lateral meniscus (56%) and were lower than that of JLT. The specificity rates also diverged from those of Karachalios et al. [29] with the Thessalys test being less specific than both the JLT and McMurray tests for both medial and lateral meniscus tears. However the Thessalys test being the most accurate test for both menisci in this study agrees with the results of Karachalios et al. [29]. A possible reasons for the rates produced being generally lower for the test in this study compared to Karachalios et al. [29] is that their study only included patients suspected of having meniscal lesions whereas this study included patients with a range of intraarticular knee pathologies. Comparisons of PPVs and NPVs between the studies cannot be made as these values were not calculated by Karachalios et al. [29].

**Eges test:** Eges test has previously been only studied by Akseki et al. [30] who compared it with JLT and McMurrays. The sensitivity results of this study for the medial meniscus are similar to Akseki et al. [30] in the respect that they are low similarly to McMurrays but with the lateral meniscus the results are rather different with this study producing a very low sensitivity rate of 24% compared to Akseki who produced 64% [30] found the Eges test to have the highest specificity out of the three tests for both menisci with the specificity for lateral meniscus only being 2% above McMurrays. This specificity results of this study correlate well with those of Akseki et al. [30] producing the highest specificity result for the medial meniscus and the equally highest specificity for lateral meniscus tears with McMurrays (95%). The PPV in this study for the medial meniscus was lower (49%) than that of Akseki (80%) for the medial meniscus and the higher for the lateral meniscus with a PPV of 67% compared to Akseki et al. [30] producing 58%. The complete reverse occurred with the NPV. In Akseki et al. study [30] the accuracy of Eges test was similar to that of JLT which was also the case in this study with JLT producing accuracy rates of 61% and 78% for medial meniscus and lateral meniscus respectively and Eges producing accuracy rates of 56% and 74% for medial meniscus and lateral meniscus tears respectively. However the accuracy rates were marginally better for Eges over JLT in Akseki et al. study [30] but the reverse occurred in this study.

In Akseki et al. study [30] although the true negative cases were better detected by Eges, the test also produced a high number of false positives whereas Eges fared better in this respect in this study with the highest number of true negatives but also the lowest number of false positives.

### Comparison of the four individual tests

The two weight-bearing tests Eges and Thessalys have been devised by Akseki et al. [30] and Karachalios et al. [29] with the belief they would be superior tests for diagnosing meniscal tears for the reason that they imitate the mechanism of injury and use higher axial loads that can be applied by the examiner during non-weight bearing manipulative tests i.e., McMurrays. The study by Karachalios et al. [29] showed the diagnostic values of sensitivity, specificity and accuracy to be significantly higher for the Thessalys test in comparison to the JLT and McMurray tests. Whereas Akseki et al. [30] showed Eges to have similar results in comparison to JLT and McMurray. The two main

possible reasons to explain this is that the study by Karachalios et al. [29] was only using participants who were suspected of having meniscal lesions and the positive for McMurray used was solely a click rather than pain and/or click.

This study was the first to directly compare the two tests on the same population and this study method was similar to Akseki et al. in the respect of including patients with intra-articular knee pathology rather than just those suspected of having meniscal lesions and used the original criteria for a positive McMurray test described by McMurray being pain and/or a click. Therefore diagnostic values for the Thessaly test were rather different than those described by Karachalios et al. [29]. The accuracy rates of all four tests were quite similar ranging from 51 to 63% for the medial meniscus and 74 to 81% for the lateral meniscus. However in this study results did agree with Karachalios et al. [29] in the respect that the Thessaly test had the highest accuracy results for both menisci out of the four tests supporting their conclusion that Thessalys should be accepted as an accurate mensical test. Eges test in this study had the highest specificity for both medial and lateral menisci as with Akseki et al. [30] study except that the specificity of Eges for a lateral meniscus tear in this study was equal to that of McMurray making both Eges and McMurrays the most specific tests for diagnosing lateral meniscus tears.

The JLT has previously been thought by authors of studies on non-weight bearing tests to have the highest sensitivity. This study supports and expands on these findings as it found the JLT to have higher sensitivity results compared to McMurrays as has been proved before but also higher sensitivity results than the two new weight bearing tests.

Thessalys produced the highest PPVs' for both menisci and McMurrays gave the highest number of false negatives for the medial meniscus and as a result obtained the lowest PPV whereas for the lateral meniscus JLT obtained the lowest PPV. Thessalys also produced the highest NPV and McMurrays the lowest for the medial meniscus and for the lateral meniscus both JLT and Thessalys produced the highest NPVs and Eges and McMurrays the lowest.

In summary when the results of both menisci are combined JLT was the most sensitive test and McMurrays was the least sensitive test. McMurrays and Eges had the highest specificity rates therefore when a meniscal lesion is not present in the knee McMurrays and Eges determine it more correctly than the other two tests. JLT was the least specific test. Thessalys had the highest diagnostic accuracy and highest positive predictive values therefore the overall best.

### **Weight-bearing vs. non-weight bearing tests**

When the tests of the non-weight bearing tests were combined and the tests of the weight-bearing tests combined the results were very interesting. Neither sets of tests dramatically produced better results than the other and the specificity and accuracy were highest with the weight bearing and sensitivity highest with the non-weight bearing tests. This therefore supports the claim that not one of the tests can solely be relied upon as the most effective test in diagnosing meniscal tears and that a combination of tests is required to provide the examiner with a valid diagnosis.

### **Pain and/or click as a positive test result**

The different interpretations used as a positive test between different studies makes it difficult in some cases to compare the results. The original descriptions for all of the four tests use pain or tenderness as a positive result for meniscal pathology and Eges and McMurray also use click as a positive sign. All of the true positive results of the tests used in this study produced pain alone or pain with a click. The literature review identified the possible reasons that pain can be caused by a meniscal injury therefore it would seem appropriate to accept pain or tenderness as a positive sign with or without a click as opposed to only classing a click as a positive diagnosis as used by Karachalios et al. [29].

### **Other pathology**

In most of the previous reports the study participants were those suspected of meniscal injury and those with ligament injuries or arthrosis were excluded. This study included all patients with intra-articular pathology and no previous examinations or investigations were seen prior to carrying out the tests with the belief that this would produce a more realistic study. However when analysing the results therefore it needs to be acknowledged that the reliability of the tests has been found to be negatively affected by accompanied intraarticular lesions [20,27,30]. This study found the percentage of correct diagnoses to decrease as the number of intra-articular lesions increased which is supported by other studies [20,30].

### **Validity of this study**

This study filled the criteria for level I evidence identified by Solomon et al. [4], as it included more than 50 participants, the examiner was blind to any previous examinations or investigations of the patient, the patients were recruited consecutively and the reference standard used was arthroscopy which is labeled the 'gold standard' for internal derangements of the knee therefore accuracy, sensitivity, specificity and positive and negative predictive values for all four tests were based on arthroscopic findings.

A possible explanation why in general the results of this study are lower than that of a number of studies as the study population had a range of internal knee derangements. The majority of the studies looking at the diagnostic value of meniscal tests study patients who are suspected of having a meniscal tear following full subjective with main concern being the history of injury and physical examination. This study tested all patients with knee symptoms and the examiner was blinded to previous subjective or physical examination results of patients and also to any diagnostic investigations e.g. Radiographs or MRI prior to carrying out the tests to eliminate bias. The possible advantages of performing an examination on all patients with knee symptoms is that the results are more realistic and that the patients that present to clinicians with meniscal tears have not necessarily sustained a high force traumatic injury but may have developed insidious symptoms over which arise from tears forming in degenerative menisci. It is just as important to be able to diagnose these degenerative tears as well as traumatic tears so that the most effective treatment plan can be formulated.

This study included a population of patients that were being treated under Guys and St Thomas NHS Trust with a broad age range and both males and females. Out of the 12 studies described, six studies did not look at patients above the age of 50 and two did not state an age range. All of the studies included a significantly higher number of males in comparison to females.

## Conclusion

The results of this study cannot be relied upon for diagnosis of acute meniscus tears less than 6 weeks history as all of the participants had over 6 weeks history of knee symptoms. However the weight bearing tests of Eges and Thessalys are not recommended to be performed on acute patients and also it is believed performance of clinical tests in the acute knees leads to a higher number of false positives.

The examiners in all of these studies were orthopaedic surgeons however in many of the studies the experience of the surgeon was not stated. A limitation of this study may be that the examiner was a senior musculoskeletal physiotherapist who even though had undergone training in performing the techniques by knee specialists and practiced on non-symptomatic subjects would not have as much experience as an orthopaedic surgeon. However Evans et al. [26] reported that experience of the examiner has little effect on the accuracy of the McMurray test which is more difficult to perform than the JLT. It can be said however that the results are therefore more realistic for the general population of practitioners who are not specialists of the knee.

Inter-examiner reliability was eliminated in this study as the tests were all performed by the same person in this study. However this did mean we were not blind to the results and performed the statistical analysis ourselves which could be potentially seen as a limitation.

Some studies did not specify the exact physical examination they used or failed to describe the exact method they used for each test. This study aimed to address this possible limitation by clearly stating the tests that would be compared and following the original descriptions of the test which were described. Following on from this the author also used the original criteria representing a positive diagnosis from when the tests were first devised and stated this clearly.

Karachalios et al. [29] devised the Thessaly Test and Akseki et al. [30] devised the Eges Test. Therefore they may be biased towards the clinical effectiveness of those tests. The main advantage of this study over theirs is that the authors were not aiming for one particular test to show higher diagnostic value and also did not devise any of the tests being studied therefore any bias that could have arisen in this respect was eliminated.

## Conflict of Interest

None declared.

## Funding

No funding declared.

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