Diagnostic Accuracy of Clinical Tests for Assessment of Hamstring Injury: A Systematic Review

Hamstring injuries are one of the most common soft tissue injuries in athletes. Treatment and management of hamstring injuries, as well as injury prevention and return to sport, have received significant research effort in the past 10 years. Examination of athletes with hamstring injury has traditionally relied on combinations of pain with palpation of the injured area, traditional manual muscle testing, passive straight leg raise testing, magnetic resonance imaging (MRI), and isokinetic testing. However, the studies on diagnostic accuracy of palpation, traditional manual muscle testing, and leg raise testing have not provided sufficient information to quantify the clinical ability of these tests to differentiate between those with and without confirmed hamstring injury. In addition, some of these tests have been described only for assessment of readiness for return to sport.

MRI and ultrasonography (US) are considered the criterion reference standards for diagnosis of hamstring injuries. However, both MRI and US are not practical alternatives for diagnosis of hamstring injury due to the high incidence of this injury and the costs associated with these diagnostic tests. Therefore, clinical tests with strong psychometric properties for use in diagnosing this condition are needed. The purpose of this study was to conduct a systematic review of the literature reporting on the diagnostic accuracy of clinical tests that have been proposed to be helpful in the diagnosis of hamstring injury. The studies included had cohort, case-control, and/or cross-sectional designs.

*STUDY DESIGN:* Systematic literature review.

*BACKGROUND:* The diagnosis of a hamstring injury has traditionally relied on various clinical measures (eg, palpation, swelling, manual resistance), as well as the use of diagnostic imaging. But a few studies have suggested the use of specific clinical tests that may be helpful for the diagnostic process.

*OBJECTIVE:* To summarize the current literature on the diagnostic accuracy of orthopaedic special tests for hamstring injuries and to determine their clinical utility.

*METHODS:* A computer-assisted literature search of the MEDLINE, CINAHL, and Embase databases (along with a manual search of grey literature) was conducted using key words related to diagnostic accuracy of hamstring injuries. To be considered for inclusion in the review, the study required (1) patients with hamstring or posterior thigh pain; (2) a cohort, case-control, or cross-sectional design; (3) inclusion of at least 1 clinical examination test used to evaluate hamstring pathology; (4) comparison against an acceptable reference standard; (5) reporting of diagnostic accuracy of the measures (sensitivity [SN], specificity [SP], or likelihood ratios); and (6) publication in English. SN, SP, and positive and negative likelihood ratios were calculated for each diagnostic test.

*RESULTS:* The search strategy identified 602 potential articles, of which only 3 articles met the inclusion criteria, with only 1 of these 3 articles being of high quality. Two of the studies investigated a single special test, whereas the third article examined a composite clinical assessment employing various special tests. The SN values ranged from 0.55 (95% confidence interval [CI]: 0.46, 0.69) for the active range-of-motion test to 1.00 (95% CI: 0.97, 1.00) for the taking-off-the-shoe test. The SP values ranged from 0.03 (95% CI: 0.00, 0.22) for the composite clinical assessment to 1.00 (95% CI: 0.97, 1.00) for the taking-off-the-shoe test, active range-of-motion test, passive range-of-motion test, and resisted range-of-motion test. The use of a single special test demonstrated stronger SP than SN properties, whereas the composite clinical assessment demonstrated stronger SN than SP properties.

*CONCLUSION:* Very few studies have investigated the utilization of clinical special tests for the diagnosis of hamstring injuries. Further studies of higher quality design are suggested prior to advocating independent clinical utilization of these special tests.


*KEY WORDS:* diagnosis, sensitivity, specificity, strain
that enabled comparison of the diagnostic accuracy of clinical tests to their appropriate criterion reference standards.

**METHODS**

The PRISMA guidelines were utilized during the search-and-reporting phase of this review. The PRISMA statement includes a 27-item checklist designed to be used as a basis for reporting systematic reviews of randomized trials, but can also be applied to multiple forms of research methodologies.

**Search Strategy**

A systematic, computerized search of the literature in the MEDLINE, CINAHL, and Embase databases was conducted in February 2012. The MeSH search string in MEDLINE was (((hamstring[ti] OR semitendinosus[ti] OR semimembranosus[ti] OR “posterior thigh”[ti] OR “biceps femoris”[ti])) AND (strain) OR strained OR (tear) OR tears OR (injury) OR injuries AND “evaluation” OR “physical examination” OR “orthopedic clinical examination” OR diagnosis OR diagnose)) NOT (“cruciate ligament”[ti] OR “ACL”[ti] OR “PCL”[ti]), with limits for English language and humans. Two authors (M.P.R. and J.K.L.) independently performed the search. Because computerized search results for diagnostic accuracy data frequently omit relevant articles, the reference lists of all selected publications were checked to retrieve relevant publications that were not identified in the computerized search. The grey literature, which included publications, posters, abstracts, or conference proceedings, was hand searched. The reference lists and grey literature were searched by 1 author (M.P.R.). To identify relevant articles, titles and abstracts of all identified citations were independently screened by both authors. Full-text articles were retrieved if the abstract provided insufficient information to establish eligibility or if the article passed the first eligibility screening.

**Selection Criteria**

Articles examining clinical tests for hamstring injuries were eligible if they met all of the following criteria: (1) patients presented with hamstring or posterior thigh pain; (2) a cohort, case-control, or cross-sectional design was used; (3) the study included at least 1 clinical examination test to evaluate hamstring pathology; (4) the results of the clinical test were compared against an acceptable reference standard (MRI or US); (5) the study reported diagnostic accuracy of the measures (sensitivity [SN], specificity [SP], positive likelihood ratio [+LR], and negative likelihood ratio [–LR]); and (6) the study was published in English.

An article was excluded if (1) the reported pathology was associated with a condition located elsewhere (eg, lumbar spine) that referred pain to the hamstring/posterior thigh, (2) the study did not provide either SN or SP data, (3) the clinical examination test was performed under any form of anesthesia or on cadavers, (4) the study used specialized instrumentation not readily available to all clinicians, and (5) the study was performed on infants/toddlers.

All criteria were independently applied by both reviewers to the full text of the articles that passed the first eligibility screening. Disagreements among the reviewers were discussed and resolved during a consensus meeting.

**Quality Assessment**

The Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool was used to determine the quality of the studies. The QUADAS consists of 14 items (Table 1), each with response categories of yes, no, or unclear. A yes score indicates sufficient information, with bias considered unlikely; a no score indicates sufficient information, but with potential bias from inadequate design or conduct; and an unclear score indicates that the article

**TABLE 1**

<table>
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<tr>
<th>Article</th>
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<tr>
<td></td>
<td>1</td>
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<tr>
<td>Cacchio et al [25]</td>
<td>N/U</td>
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<tr>
<td>Schneider-Kolsky et al [27]</td>
<td>Y</td>
</tr>
<tr>
<td>Zeren and Oztekin [26]</td>
<td>N/U</td>
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Abbreviations: N, no; U, unclear; Y, yes.

*Item 1: was the spectrum of patients representative of those in clinical practice? Item 2: were selection criteria clearly described? Item 3: is the reference standard likely to classify the target condition correctly? Item 4: is the period of time between the reference standard and index test acceptable? Item 5: did the whole sample of patients receive verification using the reference standard? Item 6: did patients receive the same reference standard regardless of the index test result? Item 7: was the reference standard independent of the index test? Item 8: was the execution of the index test described in sufficient detail for replication? Item 9: was the execution of the reference standard described in sufficient detail for replication? Item 10: were the index test results interpreted without knowledge of the reference standard? Item 11: was the reference standard interpreted without knowledge of the results of the index test? Item 12: were the same clinical criteria available when test results were interpreted as would be in clinical practice? Item 13: were uninterpretable/intermediate test results reported? Item 14: were withdrawals from the study explained?
or methodology provided insufficient information or the methodology was unclear. The total score was a count of all of the criteria that scored yes (valued as 1, whereas no and unclear scores were valued as zero), with a maximum attainable score of 14. The methodological quality of each of the studies was independently assessed by both reviewers. Disagreements were discussed and resolved during a consensus meeting. Qualitatively, studies that exhibit higher QUADAS values are associated with less risk of design bias than those with lower values. Similar to previously published reviews, the studies were stratified as “high quality/low risk of bias” if their QUADAS score was 10 or greater or as “low quality/high risk of bias” if their QUADAS score was less than 10.23

Data Extraction

One author (M.P.R.) independently gathered data regarding study population, setting, special test performance, pathology, diagnostic reference standard, and number of true positives, false positives, false negatives, and true negatives for calculation of SN, SP, +LR, and −LR when these were not provided. The other authors (J.K.L. and A.P.G.) verified data extraction accuracy once completed. Cell counts of zero are common in diagnostic accuracy studies, and in such instances 0.5 was added to all cells, as suggested by Cox.24 SN is defined as the percentage of people who test positive for a specific disease among a group of people who have the disease. SP is the percentage of people who test negative for a specific disease among a group of people who do not have the disease/disorder. +LR is the ratio of a positive test result in people with the pathology to a positive test result in people without the pathology. A +LR identifies the strength of a test in determining the presence of a finding, and is calculated by the formula SN/(1 − SP). A −LR is the ratio of a negative test result in people with the pathology to a negative test result in people without the pathology, and is calculated by the formula (1 − SN)/SP. The higher the +LR and the lower the −LR, the greater the posttest probability is altered. Posttest probability can be altered to a minimal degree with +LRs of 0.5 to 1.0, to a moderate degree with +LRs of 1.0 to 2.0 or −LRs of 0.2 to 0.5, to a moderate degree with +LRs of 2.0 to 5.0 or −LRs of 0.1 to 0.2, and to a large and almost conclusive degree with +LRs greater than 10.0 and −LRs less than 0.1. Pretest probability is defined as the probability of the target disorder before a diagnostic test result is known. It represents the probability that a specific patient with a specific past history, presenting to a specific clinical setting with a specific symptom complex, has a specific diagnosis.25

Identification

915 abstracts identified through MEDLINE (n = 596), CINAHL (n = 143), and Embase (n = 176)

8 abstracts identified through hand search

602 titles included after duplicates removed

576 abstracts rejected because each did not reflect diagnosis

26 abstracts screened

18 articles rejected for providing quantitative numbers that did not allow measurement of sensitivity or specificity

8 full text articles screened

5 articles rejected for failing to calculate diagnostic accuracy or failing to report both sensitivity and specificity

3 studies included in the qualitative analysis

RESULTS

Selection of Studies

THE SYSTEMATIC SEARCH THROUGH MEDLINE, CINAHL, and Embase netted 915 abstracts, and 8 additional papers were identified through an extensive hand search. In total, 602 titles were initially retained after duplicates were removed. Abstract and full-text review reduced the acceptable papers to 3 (FIGURE, TABLE 2). The sample sizes of the 3 studies were 46,11 140,26 and 5817 athletes, respectively. Cacchio et al11 and Zeren and Oztekin26 investigated individual special tests, whereas Schneider-Kolsky et al17 employed a composite clinical assessment.

FIGURE. Flow diagram for study inclusion.
Quality Scores
The kappa value between testers for the overall score using the QUADAS was 0.68 (95% confidence interval [CI]: 0.44, 0.91), with this point estimate reflecting substantial agreement. Of the individual items of the QUADAS, items 1, 3, 5, 6, 7, 8, 12, and 14 had 100% agreement; and items 2, 4, 9, 10, 11, and 13 had 83% agreement between raters. Quality scores for each of the studies are shown in TABLE 3. Using our previously established stratification of the QUADAS, the Schneider-Kolsky et al.17 article was considered of high quality/low risk of bias, whereas the Cacchio et al.25 and the Zeren and Oztekin.45 articles had a QUADAS score of less than 10 points, suggesting low quality/high risk of bias (TABLE 3). The most poorly scored items of the QUADAS were items 1 (spectrum representative of those in clinical practice), 4 (time period between reference standard and index test), 10 (index test results interpretation without knowledge of reference standard), 11 (reference standard interpretation without knowledge of index test results), 13 (uninterpretable test results), and 14 (explanation of withdrawals).

Diagnostic Clinical Tests
Schneider-Kolsky et al.17 and Cacchio et al.25 used MRI as the reference standard, whereas Zeren and Oztekin,45 the study with the lowest score on the QUADAS, used diagnostic US. Based on recent advances in technology, diagnostic US is now considered comparable to MRI for the diagnosis of muscle injury.23,38 Seven individual special tests were investigated in the Cacchio et al.25 and Zeren and Oztekin45 studies. Schneider-Kolsky et al.17 used a composite method based on the interpretation of 3 special tests (TABLE 3, APPENDIX).

Cacchio et al.25 examined the Puranen-Orava test, 0.86 (95% CI: 0.78, 0.93) for the bent-knee stretch test, and 0.88 (95% CI: 0.82, 0.94) for the modified bent-knee stretch test. The Puranen-Orava test was determined to have an SP of 0.82 (95% CI: 0.68, 0.92) and an SN of 0.76 (95% CI: 0.61, 0.87). The bent-knee stretch test had SN and SP values of 0.84 (95% CI: 0.71, 0.93) and 0.87 (95% CI: 0.73, 0.95), respectively. The modified bent-knee stretch test had SN and SP values of 0.89 (95% CI: 0.76, 0.96) and 0.91 (95% CI: 0.79, 0.97), respectively.

Zeren and Oztekin45 examined 4 individual special tests for proximal hamstring muscle strain injury in 140 male professional soccer players: the taking-off-the-shoe test, active range-of-motion test, passive range-of-motion test, and resisted range-of-motion test. The criterion standard utilized by the authors was US. Reliability of the tests was not determined in this study. SP for all of these tests was 1.00 (95% CI: 0.97, 1.00). All 140 noninvolved legs (control side) tested negative, resulting in an SP of 1.00 (95% CI: 0.97, 1.00) for all of these tests.45 The SN for these tests ranged from 0.55 (95% CI: 0.46, 0.63) for the active range-of-motion test to 1.00 (95% CI: 0.97, 1.00) for the taking-off-the-shoe test.

Schneider-Kolsky et al.17 investigated the diagnostic accuracy of a composite clinical assessment in 58 professional footballers (rugby) with hamstring injuries, with a positive test result being the reproduction of the patient’s concordant pain/stiffness during any of the 3 individual tests. Reliability of the testing was not investigated. The composite clinical assessment had an SN of 0.95 (95% CI: 0.83, 0.99) and an SP of 0.03 (95% CI: 0.00, 0.22).

**DISCUSSION**

Our study investigated the diagnostic accuracy of selected orthopaedic special tests for hamstring injury. There were only 3 studies illustrating tests that included both SN and SP values. Our review also found limited...
The assessment of posterior thigh pain may be complex on occasion. Once red flags are ruled out (previous history of cancer, age of onset less than 20 or greater than 55 years old, saddle anesthesia, and so on), a detailed subjective history can help rule out signs and symptoms inconsistent with hamstring injury. Additionally, examination of the lumbar spine, pelvis, and related nervous system may assist in ruling out these areas as potential pain generators. Lumbar spine contribution to posterior thigh–related pain may be appropriately ruled out with claudication. Orthopaedic special tests for this same purpose would include the slump test (SN, 0.83) and straight leg raise test (SN, 0.97). Sacroiliac joint dysfunction and piriformis syndrome could be ruled out with cluster testing (SN, 0.91) and the FAIR test (SN, 0.88-0.97), respectively.

Although Zeren and Oztekin commendingly investigated a fairly large sample of 140 male soccer players (using the noninvolved limb as a control), the study scored the lowest (6/14) of the 3 studies on the QUADAS. Despite the fact that the taking-off-the-shoe test demonstrated 1.00 (95% CI: 0.97, 1.00) SN and SP, as well as the fact that the +LR and –LR values for this test were suggestive of increasing and decreasing, respectively, posttest probability of a hamstring injury diagnosis almost conclusively, the zero cell counts for false positive and false negative resulted in substantially large CIs for both likelihood ratio values. The other tests from this study demonstrated –LR values in the 0.4-to-0.5 range. Pretest-to-posttest probability shifts of ruling out a diagnosis of hamstring injury for these other tests would, therefore, be small and of questionable clinical utility. In contrast, the QUADAS scores for the Cacchio et al study and Schneider-Kolsky et al study were higher, potentially resulting in a lower risk of bias. However, the sample sizes and diagnostic accuracy values in these studies were smaller than those in Zeren and Oztekin.

As previously mentioned, the time frame from injury onset to examination was variable in all 3 studies. The Schroeder-Kolsky et al and Zeren and Oztekin studies examined the more acutely injured athlete, compared to the Cacchio et al study. Therefore, the acuteness of the injury, like the type of injury, as previously discussed, could be a confounding factor in the diagnosis of hamstring injury.

The quality of these studies. The diagnostic accuracy of the tests investigated in this study was quite variable, with SN values ranging from 0.55 (95% CI: 0.46, 0.63) to 1.00 (95% CI: 0.97, 1.00) and SP values ranging from 0.03 (95% CI: 0.00, 0.22) to 1.00 (95% CI: 0.97, 1.00). The paucity of studies precluded meta-analysis.

The study by Schneider-Kolsky et al, the only investigation that utilized composite clinical testing, had less potential for bias (as demonstrated by a higher QUADAS score) than the Cacchio et al and Zeren and Oztekin studies. Although this study had the highest quality and least potential for bias of the 3 studies in this review, it had the weakest ability to determine a diagnosis. Although this study had a high SN value of 0.95 (95% CI: 0.83, 0.99), it only altered the posttest probability of a diagnosis to a degree less than minimal, with a +LR of 0.97 and a –LR of 1.9. The subjects in this study were examined more acutely than those in the Cacchio et al and Zeren and Oztekin studies (within 3 days of onset), and the sample size was moderate compared to the other 2 studies.

Sample sizes in the Cacchio et al and Schneider-Kolsky et al studies were much smaller than that in the Zeren and Oztekin study. Although Zeren and Oztekin commendably investigated a fairly large sample of 140 male soccer players (using the noninvolved limb as a control), the study scored the lowest (6/14) of the 3 studies on the QUADAS. Despite the fact that the taking-off-the-shoe test demonstrated 1.00 (95% CI: 0.97, 1.00) SN and SP, as well as the fact that the +LR and –LR values for this test were suggestive of increasing and decreasing, respectively, posttest probability of a hamstring injury diagnosis almost conclusively, the zero cell counts for false positive and false negative resulted in substantially large CIs for both likelihood ratio values. The other tests from this study demonstrated –LR values in the 0.4-to-0.5 range. Pretest-to-posttest probability shifts of ruling out a diagnosis of hamstring injury for these other tests would, therefore, be small and of questionable clinical utility. In contrast, the QUADAS scores for the Cacchio et al and Schneider-Kolsky et al studies were higher, potentially resulting in a lower risk of bias. However, the sample sizes and diagnostic accuracy values in these studies were smaller than those in Zeren and Oztekin.

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potential contributors to posterior thigh pain. Orthopaedic special tests for those patients with suspicion of a hamstring injury would, therefore, be valuable in identifying those patients with a hamstring injury.

Hence, the clinical utility of the various orthopaedic special tests investigated in this review requires careful consideration. Future studies should concentrate on investigating a set of tests with good diagnostic accuracy to either rule in or rule out hamstring injury as a potential cause of posterior thigh pain. Such tests, singly or in a cluster, could then complement other tests that have been shown to be useful to identify posterior thigh pain due to the lumbar spine, sacroiliac joint, and piriformis syndrome, as previously mentioned. The diagnostic accuracy of these hamstring injury orthopaedic special tests would better be determined by future investigations with less bias. Future studies controlling for injury acute-ness assessment, blinding the results of diagnostic imaging, and reporting the reasons for study participant withdrawal would help limit this bias.

Limitations
A limitation of the present study is its use of stratified QUADAS scores to assess study quality. Although previous studies have used QUADAS summary scores, others have cautioned against the use of a dedicated quality score. The 1 study ranked as high quality could have potentially been inflated, as the QUADAS does not qualitatively score for sample size or a case-control design. The use of different reference standards may be a limitation in this review, although diagnostic US has been suggested to be as useful as, and more cost-effective than, MRI as a reference standard. Additional limitations include limiting the studies to publication in English and having only 1 author search the grey literature and pull data points, which increases the risk of potential error. However, the other authors did verify the data points.

CONCLUSION
There are a limited number of studies and, therefore, tests that investigate the diagnostic accuracy of orthopaedic special tests for hamstring injury in the athletic population. The diagnostic accuracy of these orthopaedic special tests is quite variable. The Puranen-Orava, bent-knee stretch, and modified bent-knee stretch tests were found to alter posttest probability of a diagnosis to a small to moderate degree. The taking-off-the-shoe test was found to alter posttest probability to an almost conclusive degree, although the study investigating this test demonstrated the potential for significant bias. The use of a composite clinical assessment, although demonstrating high SN, only alters post-test probability to a degree less than minimal. Caution should be used when utilizing orthopaedic special tests for the diagnosis of hamstring injury, as diagnostic accuracy of these tests is not well established. A comprehensive clinical examination for diagnosis of posterior thigh pain attributable to hamstring injury that excludes other potential pain generators, versus reliance on these tests alone for decisive diagnostic clinical practice, is suggested.

KEY POINTS
FINDINGS: The findings from the few studies that have looked at clinical diagnosis of hamstring injury suggest that single clinical examination orthopaedic special tests demonstrate stronger diagnostic than screening capability.

IMPLICATIONS: Due to a dearth of, and potential bias in, the current literature, it is apparent that there is a need for high-quality diagnostic accuracy studies of clinical orthopaedic special tests for diagnosis of hamstring injury.

ACKNOWLEDGEMENTS: We would like to thank Carly Reiman for serving as a model; Holly R. Thompson, BA for her review; and Leila Ledbetter, MLIS for assisting with the literature search for this study.

REFERENCES
10. Brooks JH, Fuller CW, Kemp SP, Reddin DB.


**APPENDIX**

### DESCRIPTION OF THE ORTHOPAEDIC SPECIAL TESTS

<table>
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<tr>
<th>Test</th>
<th>Description</th>
<th>Positive Finding</th>
<th>Illustration</th>
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<tbody>
<tr>
<td>Puranen-Orava test</td>
<td>• This test entails actively stretching the hamstring muscles in the standing position with the hip flexed at about 90°, the knee fully extended, and the foot on a solid support surface.</td>
<td>Exacerbation of the patient’s symptoms.</td>
<td><img src="image1.png" alt="Puranen-Orava test" /></td>
</tr>
<tr>
<td>Bent-knee stretch test</td>
<td>• The patient is supine. The hip and knee of the symptomatic limb are maximally flexed, and the clinician slowly straightens the knee while keeping the hip flexed.</td>
<td>Exacerbation of the patient’s symptoms.</td>
<td><img src="image2.png" alt="Bent-knee stretch test" /></td>
</tr>
<tr>
<td>Modified bent-knee stretch test</td>
<td>• The patient lies in the supine position with the lower extremities fully extended. The clinician grasps the symptomatic limb behind the heel with one hand and at the knee with the other. The clinician maximally flexes the hip and knee, and then rapidly straightens the knee.</td>
<td>Exacerbation of the patient’s symptoms.</td>
<td><img src="image3.png" alt="Modified bent-knee stretch test" /></td>
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</table>
## Test Description

### Taking-off-the-shoe test
- In standing, the patient is asked to take off the shoe on the affected side with the help of his/her other shoe. While performing this maneuver, the affected leg hindfoot must press the longitudinal arch of the noninvolved foot. The affected leg during the maneuver is in approximately 90° of external rotation at the hip and 20° to 25° of flexion at the knee.

### Active range-of-motion test
- Hip extension: in prone, the patient is asked to actively extend the hip with an extended knee. 
- Knee flexion: in prone, the patient is asked to flex the knee as far as he/she can.

### Passive range-of-motion test
- Passive hip flexion: the patient is supine, with the pelvis stabilized by grasping the iliac crest. As the hip is flexed, the knee is allowed to flex from the tension placed on the hamstrings and gravity. With pressure applied proximal to the knee joint, the normal end feel for hip flexion is soft owing to the approximation of the quadriceps with the abdomen.
- Passive knee extension: the patient is supine with the hip flexed to 90°, with the knee flexed in a relaxed position. The lower leg (below the knee) is passively extended to a firm muscle tension end point.

### Resisted range-of-motion test
- Hip extension with an extended knee: the patient is prone, with the knee extended and the pelvis stabilized with pressure on the iliac crest. An isometric break test is performed at end-range hip extension, with resistance applied to the popliteal fossa.

### Illustration

Taking-off-the-shoe test: posterior view.

- The feeling of a sharp pain over the injured biceps femoris.
- Reproduction of patient’s concordant pain with either test.
### APPENDIX

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<th>Illustration</th>
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<tr>
<td>Resisted range-of-motion test (continued)</td>
<td>• Knee flexion: the patient is prone with the knee extended. An isometric break test is performed with the knee flexed to 10°, 45°, and 90° unless contraindicated. Clinician provides resistance over the Achilles tendon.</td>
<td>Reproduction of patient’s concordant pain/stiffness during any 1 of the 3 tests.</td>
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| Composite clinical assessment | • Passive straight leg raise: with the patient’s lower extremity completely relaxed, the clinician lifts the lower extremity off the plinth with the knee fully extended. The degree of hip flexion is measured with a bubble goniometer.  
• Active knee extension: the patient’s thigh is vertical with the posterior distal aspect of the thigh, resting lightly against a frame to keep the thigh perpendicular to the plinth. With the ankle relaxed in plantar flexion, the patient is asked to actively extend the knee while maintaining light contact with the horizontal part of the frame. A temporary myoclonus of alternating contraction and relaxation of the quadriceps and hamstring muscle groups tends to occur at the maximum angle of active knee extension. At this point, the patient is instructed not to force the leg past the point of initial mild resistance. The patient is then asked to slightly flex the knee until myoclonus ceases. At the first point at which the shaking ceases, the angle between the vertical and the tibia is recorded using an inclinometer.  
• Manual muscle testing: manual muscle testing in the prone position is performed by asking the patient to lift his/her heel by bending his/her knee to the point at which the toe is off the couch. The patient is asked to hold that position while a gentle, steadily increasing resistance is applied to the heel (about 15° of knee flexion). | |                                  |

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