Interrater Reliability of Performing a Step-by-Step Procedure for Selected Pain Provocation Tests for Hamstrings and Special Tests for Other Lower Extremity Musculoskeletal Injuries

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ABSTRACT

Objective Our study aims to establish interrater reliability in performing the step-by-step procedure of selected pain provocation tests for hamstrings and special tests for lower extremity musculoskeletal injuries.
Study Design An interrater reliability study

Setting University of Santo Tomas - Sports Science Laboratory
Participants Ten healthy adults (five females, five males; age = 22.2 ± 0.42) from the university community.
Main Outcome Measures Interrater reliability of performing step-by-step procedures for selected pain provocation tests for hamstrings (painful resisted knee flexion 90°, painful resisted knee flexion 30°, active slump test, Puranen-Orava Test, bent knee stretch) and special tests for lower extremity musculoskeletal injuries (Lachman's test, McMurray's test, posterior drawer test, valgus, and varus stress test).
Results Fleiss kappa showed perfect agreement (κ = 1.00) for all test procedures except for Lachman's test procedure 1 (κ = -0.11 [95% CI, -0.36 to 0.14]), active slump test procedure 4 (κ = -0.03 [95% CI, -0.28 to 0.23]), active slump test procedure 5 (κ = -0.11 [95% CI, -0.28 to 0.23]), and active slump test procedure 6 (κ = -0.05 [95% CI, -0.31 to 0.20]), which resulted in negative agreements.

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Conclusions The researcher developed protocols for each special and provocative test were consistent in measuring the intended procedures, and the raters were generally consistent with their ability to measure these tests.

Keywords Interrater reliability, special tests, pain provocation tests, lower extremity injuries

INTRODUCTION

The lower extremities have the highest injury rates in sports.[1,2] In the United States of America, lower extremity strains and sprains were the most frequent injuries accounting for 42% of injuries[3] between 2011 and 2014. Within the European Union, ankle ligament injuries constitute the most prevalent type, accounting for 15% of all documented sports-related injuries. Following this, knee injuries are the second most frequent, encompassing 3% of all reported sports injuries.[4–6]

Hamstring strain injury (HSI) is one of the most frequently occurring conditions in athletic competitions.[7,8] HSI is a muscle injury that does not involve physical contact and mostly happens during sports events or among athletes engaged in running-related activities.[9] It has a high recurrence rate[7]; one-third of reinjuries usually happen within the year and are more severe.[10–13] HSI, in particular, negatively impacts the injured athletes' quality of life[14] as well as the athlete's and team's performance.[15] Most HSIs are self-limiting, with athletes suffering from persistent symptoms and a protracted recovery phase. Injury can result in extended time off, ranging from 17 to 90 days, necessitating extensive rehabilitation and treatments.[10]

Anterior cruciate ligament (ACL) injury is considered one of the most severe injuries because it requires a lengthy rehabilitation period, increases the likelihood of the injury happening again, and restricts the athlete's ability to participate in sports.[1,16,17] Decelerating, changing direction, and making initial ground contact without colliding with another player are some ways ACL injuries can occur.[18,19] Furthermore, suffering an ACL injury is among the most severe injuries that a team sport athlete can encounter. This is due to the extended rehabilitation period, increased risk of the injury happening again, and restricted participation in sports activities.[16,17,20]

Ankle injuries commonly occur when an athlete lands, steps on another athlete's foot, runs with a heel strike, or experiences stress on a fixed foot. Ankle injuries can occur when these movements involve ankle inversion, plantarflexion, and internal rotation.[21] Ankle sprains are frequently insufficiently treated, leading to persistent discomfort, diminished muscular strength, and recurrent instability.[22] Ankle sprains contribute to the absence of professional athletes from competitive engagements and impose considerable financial burdens associated with rehabilitation on their respective sports organizations.[21] In summary, injuries affecting the lower extremities represent a substantial concern requiring thorough and thoughtful attention.[1]

Injuries can range from mild neuromuscular damage to complete tissue tears, and their prognosis and recovery time vary accordingly.[23,24] While professional athletes may emphasize accurate diagnostic assessments, sports-related injuries, including those sustained by amateur and recreational athletes, can significantly impact a broad range of individuals.[25–27] Assessing the condition of the musculotendinous unit in the lower limb is crucial and imaging plays a vital role in this evaluation.[28] However, given that these imaging tools are considered the criterion-referenced standards for assessing injuries, they are not practical alternatives due to the cost associated with these tests. Therefore, before imaging, a thorough physical examination using pain provocation and special tests with robust sensitivity and specificity should be performed.

In the study of Cacchio, et al. (2012), they examined three pain provocation tests for hamstring muscles; the Puranen-Orava (PO) test was the functional examination whereas the bent-knee stretch (BK) and modified bent-knee stretch (MBK) were the two passive assessments.[29] These assessments have good agreement between raters ranging from ICC = 0.82 to 0.88[29] and good sensitivity (SN) and specificity (SP) values as follows: PO = 76% (SN), 82% (SP); BK = 84% (SN), 87% (SP); MBK = 89% (SN), 91% (SP).[29] On the other hand, special tests are performed to ascertain if a specific illness, medical condition, or harm exists.[30] Several special tests have shown promising results in accurately detecting and evaluating musculoskeletal injuries in the lower extremities. These tests have demonstrated good SN and SP, indicating their ability to identify positive and negative cases correctly.

Additionally, they have exhibited excellent reliability values among different raters and even within the same rater, indicating consistent and dependable results.[30] While positive results from these tests provide strong indications of a particular medical condition, negative results do not necessarily eliminate the possibility of the disease or condition. The accuracy of diagnosis will be influenced by both SN and SP of each test, as well as proficiency and expertise of the medical professional.[30] We hypothesize that the combination of pain provocation tests for HSI and special tests for lower extremity musculoskeletal injuries with MRI and ultrasound can assist medical practitioners in precisely diagnosing particular injuries of the lower extremities. Nevertheless, research has yet to evaluate the consistency of results among different raters in performing the step-by-step procedures in selected pain provocation tests for HSI and special tests for lower extremity musculoskeletal injuries. Therefore, our study aims to establish interrater reliability in performing the step-by-step procedure of selected pain provocation tests for HSI and special tests for lower extremity musculoskeletal injuries. This study is a component of a broader project to evaluate the alterations in kinematics, kinetics, and sonographic characteristics observed among running-related athletes who have experienced recurrent HSIs.

METHODS

Study Design: An interrater reliability study
Setting: University's Sports Science laboratory.
Ethical approval: The University of Santo Tomas, Faculty of Pharmacy Research Ethics Committee approved the study.

The researchers adhered to the guidelines set forth by the Guidelines for Reporting Reliability and Agreement Studies to ensure the validity of our methods[31] (see supplemental section 2).

Participants and examiners

The sample size was computed based on the recommendations of Walter, et al. (1998) and Bonett (2002). We assumed a minimum acceptable interrater ICC = 0.80 set an $\alpha = 0.05$, a power of 80% for four raters performing three repetitions per lower extremity. The results suggest a minimum of n=20 sampled lower extremities for testing, which was achieved in this study by bilaterally testing 10 participants across the testing protocol. Exclusion criteria included lower extremity pain and a history of injury or surgery of any part of the lower extremity within six months before the study. Before participating, all volunteers were given detailed information about the study and provided written consent.

Research suggests that evaluating the interrater reliability of lower extremity injury assessment can be achieved by involving a minimum of two to three assessors for pain provocation tests for hamstrings and special tests for musculoskeletal injuries in the lower extremities.[29,34–37] The examiners who were involved in the study consisted of four individuals, including three licensed physical therapists and one sports scientist. The assessors will be part of the main project, including 72 participants as its sample size. The examiners had varying levels of experience performing pain provocation tests for hamstrings and special tests for lower extremity musculoskeletal injuries, ranging from 3 to 15 years. Additionally, they received training on these specific tests.

An additional physical therapist, who has gained extensive experience as a clinician for two decades, was designated to evaluate the assessors. He holds a master's degree in physical therapy and is also an academic staff of the physical therapy department at a university.

PROCEDURES

The procedures for pain provocation tests for hamstrings and special tests for selected lower extremity injuries were adapted from the study of Cacchio, et al. (2012), Heiderscheit, et al. (2010), and the book of Magee (2014). Cacchio, et al.'s (2012) study utilized the bent knee stretch for proximal hamstrings and the PO test as diagnostic measures for proximal hamstring tendinopathy. On the other hand, the resisted range of motion (ROM) test, as conducted by Heiderscheit, et al. (2010), evaluated isometric strength and pain response of hamstrings. Additionally, the active slump test, developed by E. K. Johnson & Chiarello (1997), is frequently used to assess tension in neural tissues and is the most prevalent neurological assessment for the lower extremity.[30] The special tests incorporated into this study evaluated whether a deformity or injury was present in the lower extremities. These tests have been shown to hold clinical value through examiner experience and statistical analysis, helping to identify underlying issues.[30] Table 2 details the specific deformities or injuries each of these special tests assess.

An initial discussion was held among assessors to standardize assessment procedures of each test. Before the actual reliability testing session, orientation was held, and test procedures were then pilot-tested. The study evaluated ten tests, including five special tests for selected lower extremity musculoskeletal injuries and five pain provocation tests for hamstrings (see Tables 1 and 2). The detailed researcher-developed protocol, which includes the procedures, SP, SN, and other measures for pain provocation tests for hamstrings and special tests for lower extremity musculoskeletal injuries can be seen in Tables 1 and 2, respectively.

The protocol developed by the researchers is presented in Tables 3 and 4 (see Tables 3 and 4). The various pain provocation tests for hamstrings and special tests for selected lower extremity injuries are listed in these tables. The research team incorporated crucial procedures, which were identified and agreed upon in the initial discussion, to guarantee the reliability of each test. Each of these tests has a distinct number of procedures, all listed in these tables. A score of “1” was given for procedures executed accurately. Conversely, a score of “0” was assigned if the evaluator could not perform the procedure correctly.

Each volunteer was subjected to bilateral testing by the four examiners who worked independently and were blinded to each other’s test results. Two sessions were allotted for reliability testing, with five volunteers assessed in each session. Four raters were independently assessed on their ability to carry out each procedure across 10 participants using the researcher-developed protocols for each special and provocative test.

Statistical analysis

All data were encoded in an Excel worksheet. Means and standard deviation were used for descriptive data. Given the dichotomous nature of the scale used, the Fleiss multi-rater kappa test (κ) was used to determine interrater reliability.[39,40] The interpretation of the Kappa result is as follows: values of 0 or lower indicate lack of agreement, values from 0.01 to 0.20 suggest minimal agreement, values from 0.21 to 0.40 indicate reasonable agreement, values from 0.41 to 0.60 signify moderate agreement, values from 0.61 to 0.80 imply substantial agreement and values from 0.81 to 1.00 denote near-perfect agreement.[41]

RESULTS

The demographic characteristics of the volunteers are summarized in Table 5 (see table 5). Ten asymptomatic adults volunteered for the study (five females, five males) with a mean age of 22.2 ± 0.42 years [range = 22-23 years], mean height of 168.54 ± 8.57 cm, and mean weight of 73.19 ± 12.52 kg.

Fleiss kappa showed perfect agreement ($\kappa = 1.00$) for all test procedures except for Lachman’s test procedure 1, ($\kappa = -0.11$ [95% CI, -0.36 to 0.14]), active slump test procedure 4 ($\kappa = -0.03$ [95% CI, -0.28 to 0.23]), active slump test procedure 5 ($\kappa = -0.11$ [95% CI, -0.28 to 0.23]), and active slump test procedure 6 ($\kappa = -0.05$ [95% CI, -0.31 to 0.20]), which resulted in negative agreements (see table 6).

DISCUSSION

The research examined the interrater reliability of hamstring muscle group assessment using five pain provocation tests and selected lower extremity musculoskeletal injury assessment using five special tests. Our study showed perfect agreement for all test procedures except for Lachman’s test procedure 1, active slump test procedure 4, active slump test procedure 5, and active slump test procedure 6, which resulted in negative agreements. Establishing a correct diagnosis is crucial for effectively managing hamstring injuries and other lower extremity musculoskeletal injuries.[42] In clinical practice and research, evaluating reliability of pain provocation and special tests is essential to properly document and assess a condition’s outcome. To our knowledge, this is the first study investigating reliability of the step-by-step procedure of performing these tests, particularly concerning injuries such as HSI and other lower extremity musculoskeletal injuries.

Table 1. Pain Provocation Tests for Hamstrings

Pain Provocation Tests for Hamstrings				
TEST	**PROCEDURE**	**SPECIFICITY**	**SENSITIVITY**	**OTHER MEASURES**
Bent knee stretch for proximal hamstrings [29]	• **Position** : Supine with the test leg's hip and knee fully flexed • Examiner slowly straightens the knee	84%	87%	Positive likelihood ratio = 6.5; negative likelihood ratio = 0.18 [30]; ICC (involved side) = 0.86; ICC (uninvolved side) = 0.82
Resisted range of motion test [8,30]	• **Position**: prone with feet dangling at the edge of the table • Subject will be asked to actively bend the knee at different angles while the examiner performs the isometric tests in different positions of the ROM • Resistance is placed behind the heel cord, while other hand is placed over the hamstrings tendon	97%	84%	Positive likelihood ratio = 26.86; negative likelihood ratio = 0.17
Painful resisted knee flexion at 90 degrees [8,30]	• **Position**: prone with feet dangling at the edge of the table • Patient is asked to bend their knee at 90 degrees flexion • Examiner will stand at the side of the test leg and apply resistance • Resistance is placed behind the heel cord, while the other hand is placed over the hamstrings tendon	97%	84%	Positive likelihood ratio = 26.86; negative likelihood ratio = 0.17
Painful resisted knee flexion at 30 degrees [8,30]	• **Position**: prone with feet dangling at the edge of the table • Patient is asked to bend their knee at 30 degrees flexion • Examiner will stand at the side of the test leg and apply resistance • Resistance is placed behind the heel cord, while the other hand is placed over the hamstrings tendon	97%	84%	Positive likelihood ratio = 26.86; negative likelihood ratio = 0.17
Active slump test [30]	• **Position**: seated with legs supported at the edge of the table (hips should be in neutral position) • Ask patient to forward flex the thoracic and lumbar area (neck should be in neutral position) • Maintain thoracolumbar flexion by applying overpressure across the shoulder using one arm • Patient is then asked to actively flex the cervical spine up to end range • Examiner holds the patient's foot in maximum dorsiflexion • Patient is asked to actively straighten their knee as much as they can • If patient cannot extend their knee, patient is asked to actively extend the neck as the examiner releases the pressure placed on the cervical spine	70%	91%	Positive likelihood ratio = 3.03; negative likelihood ratio = 0.13; Interrater reliability *k* = 0.89; Positive predictive value = 0.77; negative predictive value = 0.88
Puranen-Orava test [29]	• **Position**: Standing position • Test leg of the hip will actively flex ~90 degrees and knee fully extended on a foot stool	82%	76%	Positive likelihood ratio = 4.4; negative likelihood ratio = 0.29[30]; ICC (involved side) = 0.84; ICC (uninvolved side) = 0.82

Table 2. Special Tests for Lower Extremity Musculoskeletal Injuries

Special Tests for Lower Extremity Musculoskeletal Injuries				
TEST	**PROCEDURE**	**SPECIFICITY**	**SENSITIVITY**	**OTHER MEASURES**
Valgus stress test (for medial collateral ligament tear) [30]	• **Position 1**: Supine with knee in extension • Examiner pushes the knee laterally while stabilizing the ankle for slight lateral rotation • **Position 2**: Supine with knee in 20° to 30° of flexion • Examiner pushes the knee laterally while stabilizing the ankle for slight lateral rotation		**86 – 96%**	Interrater measure in Kappa and percent of agreement (motion k = 0.16 PA = 56%, pain k = 0.33 PA = 60%, end feel k = 0.38 PA = 80%); Interexaminer in extension 68%, interexaminer in 30° flexion 56%
Varus stress test (for lateral collateral ligament tear) [30]	• **Position 1**: Supine with knee in extension • Examiner pushes the knee laterally while stabilizing the ankle • **Position 2**: Supine with knee in 20° to 30° of flexion • Examiner pushes the knee laterally while stabilizing the ankle		**25%**	
Lachman's test (for anterior cruciate ligament tear) [30]	• **Position**: Supine with knee flexed in 20° • One hand (the "outside") hand to stabilize the femur while pulling the proximal aspect of the tibia anteriorly with the other hand ("inner")	**93%**		Positive likelihood ratio = 15; negative likelihood ratio = 0.26; Interrater reliability *k* = 0.19; intrarater *k* = 0.51; Positive predictive value = 47%; negative predictive value = 64%
Posterior drawer's test (for posterior cruciate ligament tear) [30]	• **Position**: supine with hip flexed to 45° and knee at 90° (feet flat on the table) • Examiner then holds the patient's leg with both hands and applies firm push backward	**99%**	**90%**	
McMurray test (for meniscal tear) [30]	• **Position**: Supine with knee completely flexed • Examiner medially rotates the tibia while extending the knee • Examiner then laterally rotates the tibia while extending the knee	**93.4%**	**51.6%**	Positive likelihood ratio = 8.86; negative likelihood ratio = 0.44; Interrater reliability *k* = 0.35

In general, our results suggest that employing these pain provocation tests for hamstrings and special tests for selected lower extremity musculoskeletal injuries can aid physicians and physiotherapists in establishing a clinical diagnosis. Furthermore, when a physician or physiotherapist suspects lower extremity injuries in an individual under time constraints, any of these tests can be selected as the screening test. However, during the Lachman's and active slump test, one of the assessors needed more consistency and accuracy when it came to procedures 1 for Lachman and 4, 5, and 6 for the active slump test.

Procedure 1 for Lachman's test involved positioning the participant in a supine position with knees flexed at 20 degrees. According to different studies,[43–45] the Lachman's test is widely regarded as the most dependable technique for identifying ACL injuries

Table 3. Researcher-developed Protocol for Pain Provocation Tests for Hamstrings

Score	Pain Provocation Tests and Procedures
/2	1. **Bent knee stretch for proximal hamstrings (2)** • **Position**: Supine with the test leg's hip and knee fully flexed • Examiner slowly straightens the knee
/3	2. **Resisted range of motion test (3)** • **Position**: prone with feet dangling at the edge of the table • Subject will be asked to actively bend the knee at different angles while the examiner performs the isometric tests in different positions of the ROM • Resistance is placed behind the heel cord, while the other hand is placed over the hamstrings tendon
/4	3. **Painful resisted knee flexion at 90 degrees (4)** • **Position**: prone with feet dangling at the edge of the table • Patient is asked to bend their knee at 90 degrees flexion • Examiner will stand at the side of the test leg and apply resistance • Resistance is placed behind the heel cord, while the other hand is placed over the hamstrings tendon
/4	4. **Painful resisted knee flexion at 30 degrees (4)** • **Position**: prone with feet dangling at the edge of the table • Patient is asked to bend their knee at 30 degrees flexion • Examiner will stand at the side of the test leg and apply resistance • Resistance is placed behind the heel cord, while the other hand is placed over the hamstrings tendon
/7	5. **Active slump test (7)** • **Position**: seated with legs supported at the edge of the table (hips should be in neutral position) • Ask the patient to forward flex the thoracic and lumbar area (neck should be in neutral position) • Maintain thoracolumbar flexion by applying overpressure across the shoulder using one arm • Patient is then asked to actively flex the cervical spine up to end range • Examiner holds the patient's foot in maximum dorsiflexion • Patient is asked to actively straighten their knee as much as they can • If patient cannot extend their knee, patient is asked to actively extend the neck as the examiner releases the pressure placed on the cervical spine
/2	6. **Puranen-Orava test (2)** • **Position**: Standing position • Test leg of the hip will actively flex ~90 degrees and knee fully extended on a foot stool

due to its notable accuracy in clinical settings. This procedure involves evaluating the patient's knee while they assume a supine position with the knee flexed at an angle ranging from 20 to 30 degrees. Based on combined findings from various meta-analyses,[43,45,46] the Lachman's test conducted in a supine position demonstrated a SN ranging from 0.85 to 0.87 and a specificity ranging from 0.91 to 0.94. It is worth noting that the accurate positioning of the patient during the assessment can significantly influence test results and, therefore, must be meticulously adhered to.

On the other hand, the slump test, a neurodynamic assessment, was employed to examine the mechanical mobility of neurological tissues and assess their SN to mechanical strain. Numerous studies have investigated the reactions observed during slump testing in young, healthy individuals.[47] Our study's active slump test procedures 4, 5, and 6 involved the position of the cervical spine, knee, and ankle. Various studies[38,48] have reported that the interplay among the three segments (cervical spine, knee, and ankle) has an influence on one another, particularly regarding the outcome of the ROM in terminal knee extension, the discomfort experienced in the posterior region of the thigh, and the degree of tension exhibited by the hamstring muscle. The study of E. Johnson & Chiarello (1997) suggests that it is a common experience to have restricted ROM of terminal knee extension when performing slump test with cervical flexion, ankle dorsiflexion, and medial hip rotation in young, healthy adult males. This finding expands upon the previously reported outcomes by Maitland (1980), wherein it was observed that limitations in the ROM for knee extension and ankle dorsiflexion occurring in conjunction with cervical spine flexion could be effectively alleviated by extending the cervical spine during the slump testing procedure.[49] Additionally, it was found that the assumed position

Table 4. Special Tests for Selected Lower Extremity Injuries

Score	Special Tests and Procedures
/4	1. **Valgus stress test (4)** • **Position 1**: Supine with knee in extension • Examiner pushes the knee laterally while stabilizing the ankle for slight lateral rotation • **Position 2**: Supine with knee in 20° to 30° of flexion • Examiner pushes the knee laterally while stabilizing the ankle for slight lateral rotation
/4	2. **Varus stress test (4)** • **Position 1**: Supine with knee in extension • Examiner pushes the knee laterally while stabilizing the ankle • **Position 2**: Supine with knee in 20° to 30° of flexion • Examiner pushes the knee laterally while stabilizing the ankle
/2	3. **Lachman's test (2)** • **Position**: Supine with knee flexed in 20 degrees • One hand (the "outside") hand to stabilize the femur while pulling the proximal aspect of the tibia anteriorly with the other hand ("inner")
/2	4. **Posterior drawer's test (2)** • **Position**: supine with hip flexed to 45° and knee at 90° (feet flat on the table) • Examiner then holds the patient's leg with both hands and applies firm push backward
/3	5. **McMurray test (3)** • **Position**: Supine with knee completely flexed • Examiner medially rotates the tibia while extending the knee • Examiner then laterally rotates the tibia while extending the knee

Table 5. Demographic and anthropometric characteristics of the participants

Volunteer Characteristics	Number (SD) Range
Male	4
Female	6
Age (Years)	22.2 (0.42) 22-23 years
Height (cm)	168.54 (8.57) 154 – 183 cm
Weight (kg)	73.19 (12.52) 55 – 95 kg
BMI (kg/m^2)	25.8 (4.16) 19.41 – 31.92 kg/m^2

associated with the highest neural tension (cervical flexion, ankle dorsiflexion, and medial hip rotation) resulted in the most significant constraints on ROM for terminal knee extension.[38] While the study of E. K. Johnson & Chiarello (1997) revealed notable improvements in terminal knee extension ROM when transitioning from a flexed to an extended position of the cervical spine, the study did not report a complete restoration of the full ROM for terminal knee extension.

Similarly, the study of Lew & Briggs (1997) investigated if modifying the position of the cervical spine during the slump test had any impact on the discomfort experienced in the back of the thigh and level of tension in the hamstring muscle. The study showed that the readings of hamstring electromyography did not show any significant variations while performing cervical movements. This suggests that(1) the tension in the hamstring muscles was not affected by movement of the neck, and(2) the changes in pain experienced during cervical flexion were not caused by any changes in the hamstring muscles due to the experiment. The conclusion drawn from this observation reinforces the perspective that when the slump test induces pain in the back of the thigh that can be alleviated through cervical extension, it is likely due to neural structures and not the hamstring muscle.[48]

Table 6. Summary of Fleiss' Multirater Kappa Test

Test	κ	95% CI	
		Lower	**Upper**
Special Tests			
Valgus Stress Test Procedure 1*	1.00		
Valgus Stress Test Procedure 2*	1.00		
Valgus Stress Test Procedure 3*	1.00		
Valgus Stress Test Procedure 4*	1.00		
Varus Stress Test Procedure 1*	1.00		
Varus Stress Test Procedure 2*	1.00		
Varus Stress Test Procedure 3*	1.00		
Varus Stress Test Procedure 4*	1.00		
Lachman's Test Procedure 1	-0.11	-0.36	0.14
Lachman's Test Procedure 2*	1.00		
Posterior Drawer's Test Procedure 1*	1.00		
Posterior Drawer's Test Procedure 2*	1.00		
McMurray Test Procedure 1*	1.00		
McMurray Test Procedure 2*	1.00		
McMurray Test Procedure 3*	1.00		
Provocative Tests			
Bent Knee Stretch Procedure 1*	1.00		
Bent Knee Stretch Procedure 2*	1.00		
Painful resisted knee flexion at 90 degrees Procedure 1*	1.00		
Painful resisted knee flexion at 90 degrees Procedure 2*	1.00		
Painful resisted knee flexion at 90 degrees Procedure 3*	1.00		
Painful resisted knee flexion at 90 degrees Procedure 4*	1.00		
Painful resisted knee flexion at 30 degrees Procedure 1*	1.00		
Painful resisted knee flexion at 30 degrees Procedure 2*	1.00		
Painful resisted knee flexion at 30 degrees Procedure 3*	1.00		
Painful resisted knee flexion at 30 degrees Procedure 4*	1.00		
Active Slump Test Procedure 1*	1.00		
Active Slump Test Procedure 2*	1.00		
Active Slump Test Procedure 3*	1.00		
Active Slump Test Procedure 4	-0.03	-0.28	0.23
Active Slump Test Procedure 5	-0.03	-0.28	0.23
Active Slump Test Procedure 6	-0.05	-0.31	0.20
Active Slump Test Procedure 7*	1.00		
Puranen-Orava Test Procedure 1*	1.00		
Puranen-Orava Test Procedure 2*	1.00		

*Note: *All ratings are the same*

Based on our findings, the results of an assessment for HSI using the active slump test would be significantly affected by the non-execution of procedures 4, 5, and 6 during the test. Therefore, it is reasonable to conclude that performing these procedures would substantially affect the assessment's accuracy and must be strictly performed. Since only one assessor was not able to perform these procedures, retraining must be conducted to emphasize the importance of performing these procedures to get accurate results.

Strengths and limitations

This study has certain limitations. The characteristics of our volunteers restrict the generalizability of our findings. Since the study's volunteers were solely healthy adults, it is essential to exercise caution while extrapolating the data obtained to individuals from different age groups, conditions, and those with lower extremity musculoskeletal injuries. When performing tests on a healthy population, the observation and experiences may yield different results compared to when the same tests are applied to individuals who are likely to have injuries in the lower extremities. In addition, the researchers did not use tests to determine whether an injury was present. Instead, we only looked at how well each test was performed and whether each special and pain provocation test was applied correctly.

This study also has strengths. The assessors' extensive experience performing these tests during the study suggests that the results would be more dependable and trustworthy if the tests were to be used in clinical settings.

Recommendations

Students of Physical Therapy and Sports Sciences should also be assessed to ascertain that the procedures performed in performing the pain provocation tests for hamstrings and special tests for selected lower extremity injuries can improve the reliability of test performance even if the assessors have minimal experience.

CONCLUSIONS

In conclusion, the researcher-developed protocols for each special and provocative test were consistent in measuring the intended procedures, and the raters were generally consistent with their ability to measure these tests in the healthy, young adult population. Future research about this topic must also consider the analysis of other groups, such as athletes, older adults, and individuals with injuries.

Disclosure Statement

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Authors' Contributions

1. Research Project: A. Conception, B. Organization, C. Execution;
2. Statistical Analysis: A. Design, B. Execution, C. Review and Critique;
3. Manuscript Preparation: A. Writing the First Draft, B. Review and Critique.

R.E.E: 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B
C.G.S: 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B
L.I: 1A, 2A, 2C, 3B
I.N.G: 1A, 2A, 2C, 3B
D.G.M: 1A, 1C, 2A, 2B, 3C
V.O: 1A, 1C, 2A, 2B, 3C
J.G.F: 1A, 1B, 1C, 2A, 2B, 2C, 3C
N.B: 1A, 1B, 1C, 2A, 2B, 2C, 3C

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