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Reliability and Validity of the Hip Stability Isometric Test (HipSIT): A New Method to Assess Hip Posterolateral Muscle Strength

Studies[3,8,9,17,29] have reported that excessive hip internal rotation and adduction range of motion can be prevented by proper alignment of the lower limbs during daily activities and sports. The ability to maintain proper alignment depends on the strength and proper activation of the hip abductor, external rotator, and extensor muscles.[3,8,9] Weaknesses of these muscles in the lower limbs are found in different conditions, such as osteoarthritis,[5,12] knee arthroplasty,[23] patellofemoral pain (PFP),[25,31] anterior cruciate ligament injury,[13] iliotibial band syndrome,[21] femoroacetabular impingement,[20] ankle sprain,[11] and low back pain,[7] among others.

Hip abductor, external rotator, and extensor muscle strengths are evaluated separately.[25,31] However, the movements of the human body are 3-D, and this method of evaluation does not reproduce the functional demands of the hip stabilizer muscles. Furthermore, proper implementation of isolated hip muscle strength testing requires repetitive training, testing, rest periods, and positioning adjustments for the tests.[12,23,25] Clinically, these tests provide valuable information, but they are tiring for the patient and time consuming to execute. The Hip Stability Isometric Test (HipSIT) was developed to allow a 3-D evaluation of gluteal muscle strength that would be more functional than a uniplanar assessment of the hip muscles.

STUDY DESIGN: Cross-sectional study.

BACKGROUND: The Hip Stability Isometric Test (HipSIT) evaluates the strength of the hip posterolateral stabilizers in a position that favors greater activation of the gluteus maximus and gluteus medius and lower activation of the tensor fascia lata.

OBJECTIVES: To check the validity and reliability of the HipSIT and to evaluate the HipSIT in women with patellofemoral pain (PFP).

METHODS: The HipSIT was evaluated with a handheld dynamometer. During testing, the participants were sidelying, with their legs positioned at 45° of hip flexion and 90° of knee flexion. Participants were instructed to raise the knee of the upper leg while keeping the upper and lower heels in contact. To establish reliability and validity, 49 women were tested with the HipSIT by 2 different evaluators on day 1, and then again 7 days later. The strength of the hip extensors, abductors, and external rotators was also evaluated. Twenty women with unilateral PFP were also evaluated.

RESULTS: The HipSIT has excellent intrarater and interrater reliability. The standard error of measurement was 0.01 kgf/kg, and the minimal detectable change was 0.036 kgf/kg. The HipSIT showed good validity in isolated hip abduction, external rotation, and extension ($P<.01$). Women with PFP showed a 10% deficit in the HipSIT results for the symptomatic limb ($P = .01$).

CONCLUSION: The HipSIT showed excellent interrater and intrarater reliability, moderate to good validity in women, and was able to identify strength deficits in women with PFP. *J Orthop Sports Phys Ther 2017;47(12):906-913. Epub 9 Oct 2017. doi:10.2519/jospt.2017.7274*

KEY WORDS: *hip, muscle strength dynamometer, reproducibility of results, validation studies*

Selkowitz et al[27] evaluated the electromyographic activity of the gluteus maximus (Gmax), gluteus medius (Gmed), and tensor fascia lata (TFL) in 11 exercises. The authors found that the clam exercise produced the greatest electromyographic activation of the gluteus complex in relation to the TFL. This exercise is performed with the participant in sidelying and the lower limbs in 45° of hip flexion and 90° of knee flexion. The individual is instructed to separate the knees while maintaining contact between the heels, moving the superior hip into abduction, external rotation, and extension.[27,33] The HipSIT was

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developed based on the positioning during performance of the clam exercise.[27,33]

A functional, reliable, valid, and quick test to assess the strength of the hip abductors, external rotators, and extensors could help clinicians and researchers in clinical decision making. The HipSIT offers a unique assessment of the strength of the entire posterolateral hip musculature without the need to evaluate each muscle alone. Thus, the objectives of this study were (1) to assess the intrarater and interrater reliability of the HipSIT and to evaluate its validity by comparing it with isolated strength tests of the hip abductors, extensors, and external rotators; and (2) to assess the ability of the HipSIT to detect hip strength asymmetries in young, female athletes with PFP.

TABLE 1 CHARACTERISTICS OF THE PARTICIPANTS (N = 49)*

Measure	Value
Age, y	21.38 ± 3.4
Weight, kg	58.19 ± 9.18
Height, m	1.63 ± 0.05
Body mass index, kg/m^2	21.74 ± 2.75
LEFS (0-80)	74.39 ± 3.8
Dominance (right), %	91.8
Abduction, kgf/kg	0.31 ± 0.07
Extension, kgf/kg	0.19 ± 0.06
Lateral rotation, kgf/kg	0.14 ± 0.03
Posterolateral muscle strength, kgf/kg	0.21 ± 0.04
HipSIT, kgf/kg	0.27 ± 0.07

Abbreviations: HipSIT, Hip Stability Isometric Test; LEFS, Lower Extremity Functional Scale.
**Values are mean ± SD unless otherwise indicated.*

METHODS

Participants

This study conducted a cross-sectional analysis of 49 physically active women (**TABLE 1**). Recreational physical activity was defined as any physical activity in which a participant was engaged for at least 30 minutes per day or for at least 150 minutes per week.[22] This group was selected to evaluate intrarater and interrater reliability and the validity of the HipSIT. Data were reported according to the Guidelines for Reporting Reliability and Agreement Studies.[14] In addition, the HipSIT was applied to 20 young, female athletes with unilateral PFP. The inclusion criteria for the group with PFP were pain specifically located around the patellofemoral joint; pain reproduced or reported in at least 2 of the following conditions of going up or down stairs, squatting, kneeling, sitting for prolonged periods, isometric contraction of the quadriceps, jumping, running, and on palpation of the lateral and/or medial facet of the patella; pain reported to be of insidious onset and lasting at least 3 months; a reported pain intensity in the last week of at least 3 on the visual analog scale[1]; and a maximum score of 86 points on the Anterior Knee Pain Scale (AKPS). The AKPS value was used to exclude patients with PFP without clinically relevant reduction of functional capacity; the minimal detectable change (MDC) for the scale is 13 (maximum, 100 points).[32] In both study groups, participants who experienced trauma to or had surgery of the lower limbs and lower back, pain during testing, or a neurological disorder that could compromise the test results were excluded.

Participants were 18 to 30 years of age and available for testing at the Human Movement Analysis Laboratory, Federal University of Ceará. Prior to participation, the objectives, procedures, and risks of the study were explained to each participant. This study was approved by the Ethics Committee at the Federal University of Ceará (protocol number 1.000.404). All of the participants provided written informed consent before participating in the study.

Instruments

Participants reported anthropometric and clinical features, sporting activities, and injury history on an evaluation form. The Lower Extremity Functional Scale[19] was applied to the participants without PFP, and the AKPS[10,19] was applied to the participants with PFP, to assess the functional status of the lower limbs of the participants. The strength of the hip muscles was evaluated using a handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Instrument Company, Lafayette, IN).

The Lower Extremity Functional Scale was developed based on the model suggested by the World Health Organization. There are 5 possible responses (0-4) for each of the 20 questions, with possible scores from 0 (worst) to 80 (best). This scale was culturally adapted to Brazilian Portuguese, with excellent reliability and validity for knee injury patients.[19]

The AKPS assesses pain and symptoms in patients with PFP. This scale was translated and culturally adapted to the Brazilian Portuguese language,[10] and the score ranges from 0 (worst) to 100 (best).

Muscle strength was evaluated using the handheld dynamometer. This instrument has been widely used to measure muscle strength because of its ease of use. Studies have shown that this equipment has excellent intrarater and interrater reliability and validity compared with the gold standard isokinetic dynamometer.[18,28] This method has good to excellent intrarater and interrater reliability for measurement of hip strength.[2,26] The positioning of the handheld dynamometer in this study was based on parameters established in the literature.[2] Muscle strength (kilogram-force) data were normalized by the body mass (kilograms) of each participant (strength/body mass).

Procedures

The women participated in 2 sessions of data collection. In the first session, they completed the evaluation form and the specific questionnaires, and conducted the HipSIT and isolated hip abductor, external rotator, and extensor muscle strength assessments. The HipSIT was evaluated by 2 blinded evaluators. In the first session, the sequence of evaluation of the hip muscles was randomized using Random Allocation Software (Version 1.0.0; M. Saghaei, MD, Department of Anesthesia, Isfahan University of Medical Sciences, Isfahan, Iran). Participants were again evaluated with the HipSIT by only 1 evaluator after a week.

To mitigate the influence of the rater, a strap was used for all tests. Participants were instructed to push the dynamometer as hard as they could for 5 seconds. They performed 1 practice trial, rested for 30 seconds, and then performed the measured trials. Two tests were performed, with a 30-second rest between trials. Mean values were calculated for each participant. Participants rested for 1 minute before changing the muscle group. When compensation was identified, values were discarded and a new evaluation was done after 20 seconds.[2]

The 2 researchers had 3 years of experience in measuring muscle strength of the lower limbs with the handheld dynamometer. Before starting the data collections, the researchers held meetings to standardize verbal stimuli and positioning. The evaluators were blinded to the results of the HipSIT between themselves (interrater reliability) and between the first and second evaluations (intrarater reliability). For HipSIT evaluation of patients with PFP, the evaluator was blinded in relation to the symptomatic and asymptomatic limbs.

The HipSIT was performed with the participant in sidelying, with both legs positioned at 45° of hip flexion and 90° of knee flexion, with the limb to be tested superior to the opposing limb (**FIGURE 1**). The participant was instructed to lift the knee of the superior leg while keeping the heels in contact, such that the hip was in 20° of abduction. The center of the dynamometer was laterally positioned 5 cm above the knee joint interline. After positioning, the proper performance of the test was demonstrated, and the participant was asked to perform the movement with the greatest possible force by separating the knees without the feet losing contact.

Isometric hip abductor force was measured with participants in sidelying, with the lower hip and knee positioned at 45° of flexion. The tested hip was abducted (20°) and extended (10°), and, with neutral rotation (absence of internal or external rotation), the knee was extended. The dynamometer was positioned 5 cm proximal to the lateral malleolus midpoint.

Isometric hip extensor force was measured with subjects in a prone position. The limb not being assessed was fully extended, while the assessed limb was in 10° of hip extension, 10° of hip external rotation, and 90° of knee flexion. The dynamometer was positioned over the posterior thigh, 5 cm proximal to the popliteal crease.

Isometric hip external rotator force was tested with participants in the sitting position, with the hip and knees flexed to 90°. The dynamometer was positioned over the distal medial tibia, 5 cm proximal to the medial malleolus midpoint. Straps were used to prevent subjects from adducting the hip.

The isometric hip posterolateral complex force consisted of the sum of the force values of the 3 hip stabilizer muscles, divided by 3: (abductors + extensors + external rotators)/3.[2,16]

Statistical Analysis

The normality of distribution of the data was determined by using the Shapiro-Wilk test. Descriptive statistics (mean ± SD) were used to describe the anthropometric and clinical characteristics and the outcome variables. The first step of the analysis was to calculate intrarater and interrater reliability, which was expressed as the degree of consistency in an intraclass correlation coefficient ($ICC_{2,1}$). Analysis of variance was used to compare the means found in the 3 evaluations of the HipSIT to which each subject was submitted (1A, 1B, and 2).

Reliability coefficients were interpreted as follows: 0.69 or less, poor interrater reliability; 0.70 to 0.79, fair interrater reliability; 0.80 to 0.89, good interrater reliability; and 0.90 to 1.0, excellent interrater reliability.[6] We used 3 measures of agreement: Bland-Altman plots, the standard error of measurement (SEM),

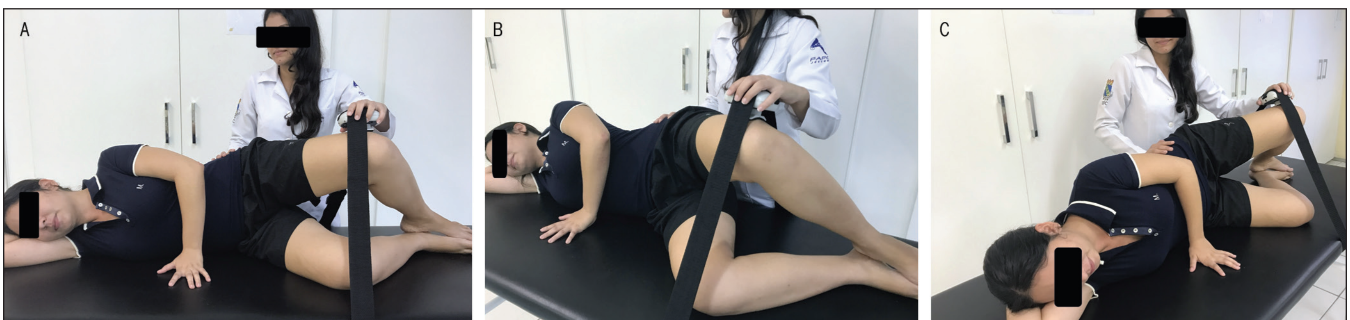

FIGURE 1. Hip Stability Isometric Test (HipSIT).

and the MDC with 95% confidence intervals (CIs). The SEM was calculated by dividing the SD of the mean differences between the 2 measurements by the square root of 2 (SD differences/√2), and the MDC was calculated as MDC = 1.96 × √2 × SEM. The SEM reflects the absolute error of the instrument, and the MDC reflects the smallest within-person change in a score that can be interpreted as a "real" change, above the measurement error of an individual.[30] Limits of agreement were calculated as the SD of the individual differences between raters multiplied by 1.96. Both the SEM and MDC were also presented as percentages by dividing the SEM and limits of agreement by the average score of HipSIT 1A and 1B (subsequent week).

Validity was analyzed using a Pearson correlation coefficient to check the strength of the relationship between the HipSIT results for the forces of the abductors, external rotators, extensors, and posterolateral complex of the hip. The coefficient values were set as less than 0.5 indicating poor validity, 0.5 to 0.75 moderate to good validity, and greater than 0.75 excellent validity. The Bland-Altman plots were designed in order to assess the agreement between the HipSIT and other measures of hip strength.

The PFP group was used to verify differences in HipSIT scores between the symptomatic and asymptomatic limbs. It was not used for comparisons between groups. The same statistical procedures were performed in patients with PFP by considering 2 assessments, in sequence, of the HipSIT. Finally, the paired *t* test was used to compare HipSIT results between limbs with PFP and limbs without PFP in young, female athletes. Significance was established at the 5% level for all statistics. Calculations were performed using SPSS Version 17.0 for Windows (IBM Corporation, Armonk, NY).

RESULTS

Reliability and Validity of the HipSIT

The anthropometric and clinical features of the 49 women evaluated to analyze the reliability and validity of the HipSIT are presented in **TABLE 1**.

The values from the HipSIT of each subject are shown in **FIGURE 2**. The HipSIT 1A data represent the values obtained for the first evaluator, HipSIT 2 shows the values obtained for the second evaluator, and HipSIT 1B represents the third evaluation (retest) performed after 1 week by the first evaluator. Forty-nine subjects performed HipSIT 1A and 2, and 46 performed HipSIT 1A and 1B. Analysis of variance did not find significant differences between the 3 evaluations ($P = .58$).

The intrarater and interrater reliability of the HipSIT showed excellent reliability indices. The intrarater $ICC_{2,1}$ was 0.981 (95% CI: 0.966, 0.990) and the interrater $ICC_{2,1}$ was 0.981 (95% CI: 0.967, 0.989). The limits of agreement ranged from −0.047 to 0.025 kgf/kg for the intrarater and interrater evaluations, as shown by the Bland-Altman plots (**FIGURE 3**). The SEM was 0.013 kgf/kg (4.7%), and the MDC was 0.036 kgf/kg (13.2%).

The validity of the HipSIT in isolated tests for abduction, external rotation, and extension of the hip was good, with Pearson correlation coefficients equal to 0.535 ($P<.01$), 0.536 ($P<.01$), and 0.514 ($P<.01$), respectively. The validity of the HipSIT for the average of the 3 muscle groups assessed was 0.65 ($P<.01$) (**FIGURE 4**). The Bland-Altman plot between the HipSIT and the other variables of hip strength presented a mean difference from 0.04 to 0.12 kgf/kg (**FIGURE 5**).

The HipSIT in Women With PFP

The anthropometric and clinical features of young, female athletes with PFP are shown in **TABLE 2**. The HipSIT showed excellent reliability indices between the first and second evaluations (ICC = 0.991; 95% CI: 0.978, 0.997) in women with PFP. The limits of agreement ranged from −0.030 to 0.039 kgf/kg. The SEM was 0.012 kgf/kg (4%), and the MDC was 0.034 kgf/kg (11.4%). Compared to the limb with no PFP, the limb with PFP showed a 10%

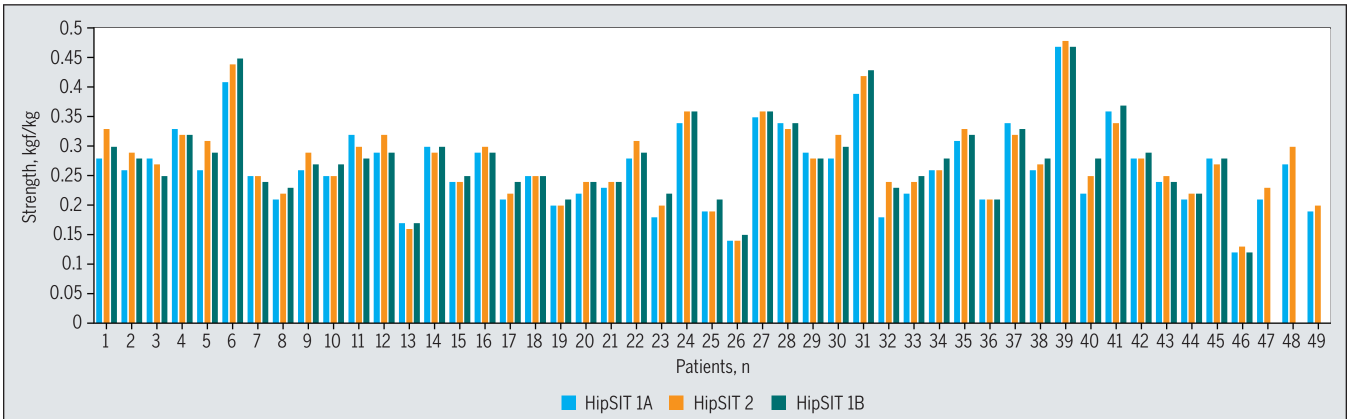

FIGURE 2. Results from the HipSIT 1A (first evaluator), HipSIT 2 (second evaluator), and HipSIT 1B (subsequent week for first evaluator). Abbreviation: HipSIT, Hip Stability Isometric Test.

deficit in the results obtained during the HipSIT (P = .01) (**TABLE 2**).

DISCUSSION

The results from this study support the HipSIT as a valid test for evaluating the muscle strength of the posterolateral hip stabilizers and show excellent intrarater and interrater reliability, as well as moderate to good validity in measurements of isolated muscle strength. The differences found between the HipSIT and the isolated hip strength tests are within clinically acceptable values, as demonstrated by the Bland-Altman plots.

The handheld dynamometer is commonly used in scientific research and clinical practice to measure strength because it is easy to handle and portable, and has good reliability and validity compared with the isokinetic dynamometer, which is considered the gold standard for evaluations of strength.[28] Studies[15,18] have shown that the handheld dynamometer has good to excellent reliability for assessing the strength of the lower-limb muscles, especially the hip muscles. The HipSIT also provides excellent levels of intrarater and interrater reliability to assess the strength of the hip muscles. The SEM and MDC presented similar values for the populations with and without PFP. These parameters help in the evaluation, interpretation, and monitoring of the evolution when using the HipSIT as a measure of outcome.

The physical position adopted in the HipSIT was based on the clam exercise and is suitable to evaluate the function of the Gmax and Gmed as hip stabilizers, decreasing the influence of the TFL,[4,27,33] which is an important internal rotator muscle of the hip.[27] In this position, there is high electromyographic activity of the Gmax and Gmed muscles, with low electromyographic activity of the TFL.[27] Willcox and Burden[33] evaluated the electromyographic activity of the Gmax, Gmed, and TFL using the clam exercise at 0°, 30°, and 60° of flexion.

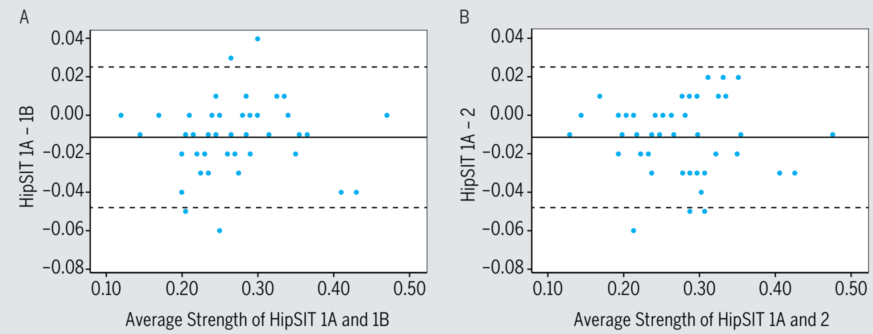

FIGURE 3. Intraexaminer (A) and interexaminer (B) Bland-Altman plots. Results from the HipSIT 1A (first evaluator), HipSIT 2 (second evaluator), and HipSIT 1B (subsequent week for first evaluator). Abbreviation: HipSIT, Hip Stability Isometric Test.

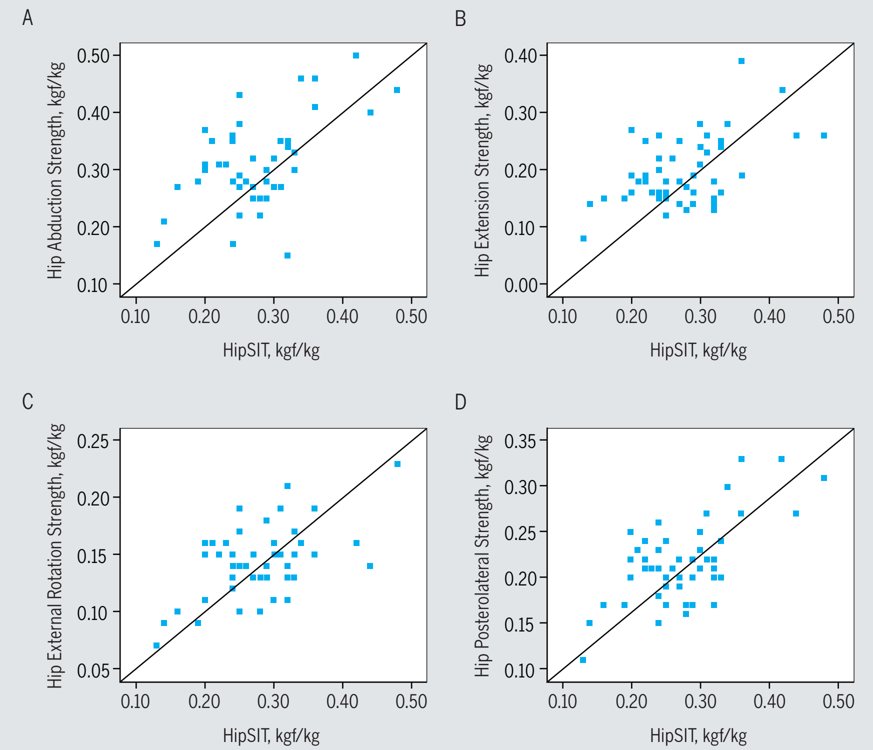

FIGURE 4. Correlation between the HipSIT and (A) the hip abductor isometric test (r = 0.535, P<.01), (B) the hip extensor isometric test (r = 0.514, P<.01), (C) the hip external rotation isometric test (r = 0.536, P<.01), and (D) the hip posterolateral isometric test (r = 0.65, P<.01). Abbreviation: HipSIT, Hip Stability Isometric Test.

They found that, in all 3 positions, the electromyographic activity of the Gmax and Gmed was higher than that of the TFL. Moreover, Berry et al[4] compared the Gmax, Gmed, and TFL in subjects performing side stepping with a resistive band around the ankle while maintaining a standing position and in squatting. In the squatting position, the activation of the Gmax and Gmed was superior to that of the TFL. Therefore, the literature supports the use of the position adopted in our study.

The HipSIT is more practical for assessing the strength of the stabilizing muscles, because it considers muscular action as 3-D. Besides being a reliable test, it proved to be a valid test when

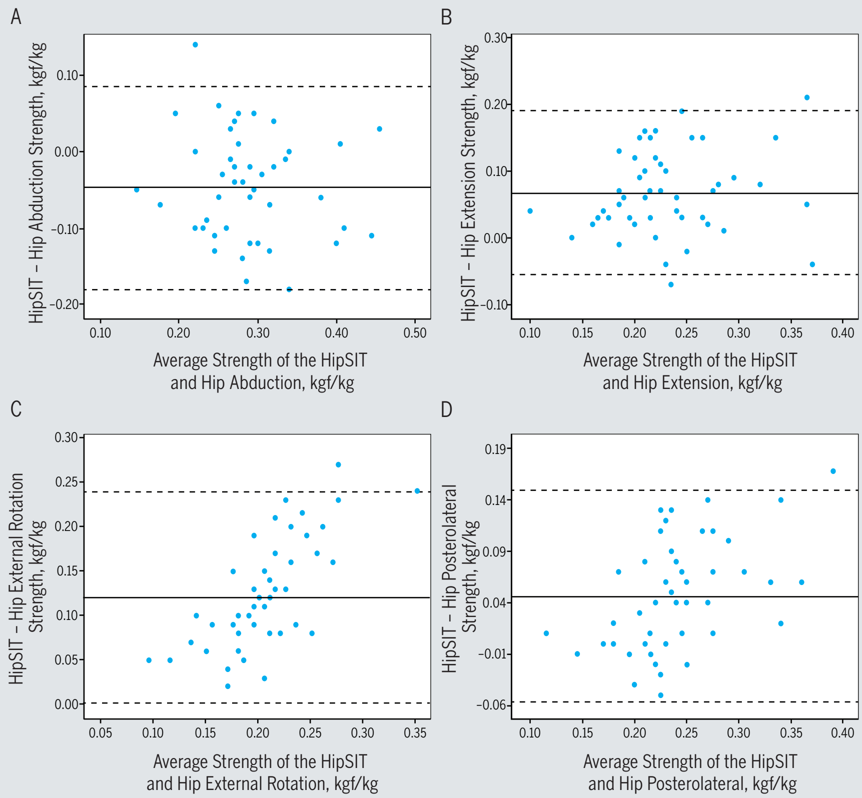

FIGURE 5. Bland-Altman plots representing comparisons between strength (kilogram-force per kilogram) of the HipSIT and that of hip (A) abduction, (B) extension, (C) external rotation, and (D) posterolateral complex. Abbreviation: HipSIT, Hip Stability Isometric Test.

TABLE 2 Characteristics of the Women With Patellofemoral Pain (n = 20)*

Measure	Value
Age, y	22.09 ± 3.02
Weight, kg	70.9 ± 11.7
Height, m	1.72 ± 0.13
Body mass index, kg/m²	23.5 ± 3.3
Pain VAS (0-10)	4.63 ± 1.5
AKPS (0-100)	74.36 ± 8.4
HipSIT, kg/kg	
Limb with PFP	0.27 ± 0.08
Limb without PFP	0.30 ± 0.09

Abbreviations: AKPS, Anterior Knee Pain Scale; HipSIT, Hip Stability Isometric Test; PFP, patellofemoral pain; VAS, visual analog scale.
**Values are mean ± SD.*

compared with isolated measures of the extension, abduction, and external rotation of the hip and with the average of these 3 evaluations. However, the HipSIT evaluates 3 hip muscle groups concomitantly; therefore, a deficit in only 1 muscle group may not be detectable because of the overlap of strength of the other muscle groups. For example, if the patient has weakness of the hip abductors and has adequate or superior strength of the external rotators and extensors, then the HipSIT presents symmetrical data between the limbs. The differences found between the HipSIT and the isolated hip tests may be due to the changes in the patient's position during the isolated tests, because this influences the activation and the lever arm of the muscles.

Weakness of the hip muscles has been associated with PFP.[25] We found a strength deficit of 10% in the HipSIT results for the limb with PFP compared to the limb without PFP. This is similar to findings in previous studies,[16,24] in which deficits ranged from 12% to 27% in abductors, 7% to 52% in extensors, and 5% to 36% in external rotator muscles.

The limitations of this study may serve to inform future studies. Although evaluators were blinded to the symptomatic and asymptomatic limbs in patients with PFP, just knowing who has PFP can be considered a bias. Another limitation is that it was only evaluated in women, so it is unknown whether the same results would be observed in men. Prospective cohort studies need to elucidate the HipSIT relationship with the development of lower-limb injuries, especially PFP and injuries to the anterior cruciate ligament. The relationship of the HipSIT with biomechanical changes of the lower limb has not yet been evaluated. Such information may guide preventive and therapeutic approaches to lower-limb injuries.

CONCLUSION

The HipSIT was found to have excellent intrarater and interrater reliability in assessments of hip muscle strength in women. The test showed good validity for measures of strength in the extensors, external rotators, and abductors of the hip, and was able to identify strength deficits in women with PFP. The HipSIT, therefore, may be recommended as a quick and reliable method for evaluating hip strength in both clinical practice and research. ◉

KEY POINTS

FINDINGS: The Hip Stability Isometric Test (HipSIT) was found to be a method with excellent reproducibility and good validity for measuring the strength of the extensors, external rotators, abductors, and posterolateral hip complex.

IMPLICATIONS: The HipSIT is a more functional way of evaluating the strength of the hip-stabilizing muscles and is faster than assessing these muscles in 3 isolated planes of motion.

CAUTION: This study was not designed to establish a cause-and-effect relationship between the HipSIT and injury or biomechanical abnormalities of the lower limbs.

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