Musculoskeletal Predictors of Movement Quality for the Forward Step-down Test in Asymptomatic Women

Visual observation of lower extremity movement patterns during various tasks is a common way to assess dynamic function and alignment in the clinical setting. Functional movements, such as the lunge, step-up, step-down, single-leg press, bilateral squat, and balance and reach, are frequently used to assess movement quality of the lower extremities. Authors of previous studies have reported moderate to good interrater reliability for visual assessment of movement quality during the FSD test in 26 asymptomatic women (mean age, 22.7 years). Hip muscle strength and lower extremity joint range of motion and muscle flexibility were measured in sidelying (iliotibial band/tensor fascia latae flexibility) and prone (quadriceps flexibility), and less hip adduction range of motion measured in prone (quadriceps flexibility), and less hip adduction range of motion measured in sidelying (iliotibial band/tensor fascia latae flexibility) compared to those with good movement quality.

**STUDY DESIGN:** Cross-sectional.

**OBJECTIVE:** To investigate the interrater reliability of movement-quality ratings for the forward step-down (FSD) test and to compare hip muscle strength and lower extremity joint range of motion and muscle flexibility among asymptomatic women with different levels of movement quality.

**BACKGROUND:** The interrater reliability of the FSD test has not yet been investigated. Additionally, it is not known whether differences in musculoskeletal measures exist among individuals with different levels of movement quality during the FSD test.

**METHODS:** Two physical therapists assessed movement quality during the FSD test in 26 asymptomatic women (mean ± SD age, 22.7 ± 0.9 years). Hip muscle strength and lower extremity joint range of motion and muscle flexibility were also assessed. The interrater reliability of the FSD test was estimated by using the kappa coefficient and percent agreement. Differences in musculoskeletal measures based on movement quality were assessed by independent t tests.

**RESULTS:** The kappa coefficient and percent agreement for rating the quality of movement on the FSD test were 0.80 (95% confidence interval: 0.57, 1.00) and 85%, respectively. The subjects with moderate movement quality had significantly less strength of the hip abductors, less knee flexion range of motion measured in prone (quadriceps flexibility), and less hip adduction range of motion measured in sidelying (iliotibial band/tensor fascia latae flexibility) compared to those with good movement quality.

**CONCLUSION:** There was good agreement for the rating of movement quality during the FSD test, and there were physical attributes that distinguished those with moderate from those with good quality of movement. J Orthop Sports Phys Ther 2013;43(7):504-510. Epub 11 June 2013. doi:10.2519/jospt.2013.4073

**KEY WORDS:** abductors, hip, knee, reliability, strength

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lize the pelvis in the frontal plane and to control motion of the femur in the frontal and transverse planes.\textsuperscript{16,24} Weakness of these muscles can lead to excessive hip adduction and hip internal rotation during weight-bearing activities\textsuperscript{12} and, consequently, to excessive knee valgus alignment.\textsuperscript{13,24}

Other potential factors can also lead to poor lower extremity function during weight-bearing tasks. Limited quadriceps flexibility may limit knee flexion and result in greater ipsilateral hip adduction, whereas limited iliotibial band/tensor fascia latae (ITB/TFL) flexibility may lead to ipsilateral pelvic rotation in the transverse plane, along with hip internal rotation\textsuperscript{15,21} and tibial external rotation, inducing knee valgus alignment.\textsuperscript{17} Decreased hamstring and gastrocnemius muscle flexibility may contribute to abduction and external rotation of the tibia, also facilitating dynamic knee valgus alignment.\textsuperscript{13,17}

The aims of this study were (1) to investigate the interrater reliability of the movement-quality ratings for the FSD test and (2) to compare hip muscle strength and lower extremity joint range of motion and muscle flexibility among asymptomatic women with different levels of movement quality on the FSD test. We hypothesized that (1) interrater reliability of the movement-quality ratings for the FSD would be high and (2) women with lower levels of movement quality would have less hip abductor and external rotator muscle strength, greater hip internal rotation range of motion, and decreased flexibility of the ITB/TFL. Women were selected for the study based on a higher incidence of patellofemoral joint pain in this population.\textsuperscript{14}

METHODS

Subjects

TWENTY-SIX ASYMPTOMATIC FEMALE subjects were recruited from the Department of Physical Therapy at Yonsei University. All subjects had not participated in regular strength training or in a stretching program for at least 3 months prior to the study. The average ± SD age, height, and body mass of the subjects were 22.7 ± 0.9 years, 161.5 ± 4.2 cm, and 54.0 ± 3.9 kg, respectively. Subjects were included if they were pain free and had no musculoskeletal or neurological injuries in the lower extremities or lumbar spine within the 6 months prior to the study. Subjects were excluded if they had undergone surgery for the lower extremities or lumbar spine during the 6 months preceding the study, had any balance impairments secondary to a vestibular or neurological disorder, or used medications that could cause dizziness or loss of balance. All subjects read and signed an informed-consent form prior to participation. The protocol for the study was approved by the Yonsei University Wonju Campus Human Studies Committee.

The number of subjects in the study was determined by calculating the effect size, based on previously published data\textsuperscript{22} on the difference in ankle dorsiflexion range of motion measured with knee extension between subjects with different levels of movement quality during the lateral step-down test. With an effect size of 1.26, power analysis indicated that a total sample size of 18 participants was required to achieve a significance level of .05 and a power of 0.8.

Procedures

Two examiners participated in data collection. One examiner had 2 years of clinical experience in the field of applied kinesiology and musculoskeletal physical therapy. The other examiner had more than 6 years of clinical experience in musculoskeletal physical therapy. Before data collection, the 2 examiners had a 5-hour training session on the methods to be used in the study. For reliability examination of the FSD test, the examiners discussed the operational definition and practiced scoring and classifying subjects in 3 categories (good, moderate, and poor), based on movement quality. For musculoskeletal measurements (hip muscle strength and lower extremity joint range of motion and muscle flexibility), the 2 examiners determined the testing position and methods to detect end range of movement, and standardized all procedures. Following this training session, pilot testing was performed on 5 healthy volunteers and final modifications of the testing procedures were made.

The 2 examiners assessed the movement quality of the FSD test simultaneously on each subject to establish interrater reliability. Following the FSD test, each examiner completed the musculoskeletal measurements of the subjects. The average value of the 2 examiners was used for statistical analysis. The data-collection session lasted approximately 40 minutes for each subject. The order of musculoskeletal measurements was randomly determined by drawing a sealed envelope from a box, to account for any potential effects of measurement order. All testing was performed on the dominant limb of each subject, defined as the limb used to kick a ball.\textsuperscript{10}

FSD Test

The FSD test used in this study was a modification of the test used by Piva et al\textsuperscript{22} (FIGURE). Prior to performing the test, the tibial tuberosity of the tested limb and the vertical front edge of the step, just under the second toe of the tested limb, were marked with a 1-cm red sticker to facilitate visualization. Next, the height of the step was adjusted so that each participant achieved 60° of knee flexion during the test. If the heel of the nontested limb did not contact the floor when the knee of the tested limb was bent to 60°, wood blocks were placed on the step to ensure that the knee of the tested limb reached 60° of flexion when the heel of the non-tested limb touched the floor.

For testing, the subject stood on a 20-cm step, with the foot of the tested limb close to the edge of the step and the non-tested limb positioned in front of the step, with the knee straight and the ankle at maximum dorsiflexion. Subjects were asked to keep their trunk straight, hands...
on their waist, and to bend the knee on the tested side until the heel of the non-tested limb touched the floor. The subjects were asked not to apply any weight on the heel of the non-tested limb once it reached the floor and to immediately re-extend the knee of the tested limb to return to the starting position. The subjects performed 5 consecutive FSD movements after 3 minutes of familiarization. After the 5 consecutive trials were completed, each examiner rated the performance of the subject across all 5 repetitions of the FSD. Standing 3 m directly in front of the subject across all 5 repetitions of the test. The raters' scores of the FSD test were used for the calculation of inter-rater reliability.

Immediately after testing, the 2 examiners compared their ratings to determine if they agreed on the good, moderate, or poor classification. Consensus was required to assign each subject to a single category for the analysis comparing musculoskeletal measurements between groups of different movement quality. If consensus was not present between the 2 raters, the subjects were asked to repeat 5 additional FSD movements to finalize the classification. Only 4 of 26 subjects were rated differently between the 2 examiners and needed to repeat the test.

### Strength Testing

Strength testing of the hip abductors and external rotators was performed with a handheld dynamometer (Lafayette Manual Muscle Testing System; Lafayette Instrument Company, Lafayette, IN), as described by Piva et al., who reported intraclass correlation coefficients of 0.85 and 0.79, respectively, for inter-rater reliability. Muscle strength was recorded in kilograms and normalized by dividing the raw score by the participant’s body mass. Each trial was performed for 3 seconds, with 1 minute of rest between trials. Each subject was allowed 2 repetitions for practice, and the results of the 3 subsequent repetitions were averaged and recorded.

#### Hip Abduction Strength

Hip abduction muscle strength was measured in the sidelying position, with the subject lying on the non-tested side. The subject’s tested hip was in approximately 30° of abduction and 5° of extension, and the iliac crest of the tested side was manually stabilized by the examiner. The subject performed isometric hip abduction against the resistance of the handheld dynamometer, which was placed just proximal to the lateral malleolus.

#### Hip External Rotation Strength

Hip external rotation muscle strength was tested with the subject prone on the table, the tested knee flexed to 90°, and the hip in neutral. The non-tested limb was positioned with the hip in the neutral position, and the hip external rotation muscle strength was tested by resisting the movement of the hip external rotators against the handheld dynamometer.
central position and full knee extension. The examiner manually fixed the subject’s pelvis with 1 hand. The subject exerted an isometric action of the hip external rotators against the resistance of the handheld dynamometer, positioned just proximal to the medial malleolus of the tested limb.

Range-of-Motion Testing

Hip external and internal rotation, abduction, flexion, as well as knee flexion range of motion were measured with a fluid-filled inclinometer (MIE Medical Research Ltd, Leeds, UK). Ankle dorsiflexion range of motion was measured with a universal goniometer in 1° increments. Intraclass correlation coefficients for interrater reliability of these range-of-motion measurements have been reported to be higher than 0.82. For this study, 1 examiner performed the measurements while the other examiner read and recorded the values. The inclinometer was first zeroed on a fixed vertical reference prior to the measurements. Two practice repetitions were performed to ensure that the subject was relaxed and comfortable. Data are the average of 3 measurements, taken with 5 seconds between trials.

Hip External Rotation

Hip external rotation was measured with the subject in a prone position. The knee of the tested limb was flexed to 90°, and the non-tested hip was abducted about 30°, so that the hip motion on the tested side would not be obstructed. The starting position for measuring hip rotation was determined by positioning the tested tibia perpendicular to the support surface. The inclinometer was positioned on the distal third of the fibula. The examiner manually fixed the subject’s pelvis at neutral with 1 hand, then moved the tested limb through passive hip external rotation. End range of motion was defined as the point at which the lower shank could no longer be moved without pelvic rotation.

Hip Internal Rotation

Hip internal rotation was determined in the same way as the measurement of hip external rotation, except that the tested hip was internally rotated.

Knee Flexion in Prone (Quadriceps Flexibility)

The examiner manually fixed the subject’s pelvis in neutral with 1 hand to avoid anterior tilting of the pelvis or extension of the lumbar spine. The inclinometer was placed over the distal half of the anterior border of the tibia. The knee on the tested side was then passively flexed to end range of motion. The measurement was taken when the lumbar spine or pelvis first began to move or when the end range of motion was achieved. The opposite limb remained flat on the table.

Hip Adduction in the Sidelying Position (ITB/TFL Flexibility)

Hip adduction was examined using the Ober test. The subject was positioned lying on the side, with the tested limb in the superior position and the knee flexed at 90°. The non-tested limb was slightly flexed at the hip and knee to maintain stability on the table. The examiner manually fixed the subject’s pelvis in neutral with 1 hand and grasped just below the knee of the tested side with the other hand. The inclinometer was placed over the distal portion of the tested thigh. The examiner moved the tested thigh first in flexion, then through abduction combined with extension, until the hip was positioned in midrange hip abduction with neutral flexion/extension. From this position, the thigh was allowed to drop toward the table until the thigh stopped, at which point the inclinometer value was recorded.

Hip Flexion in the Supine Position (Hamstring Flexibility)

The subject was placed in the supine position with the knee of the tested limb in full extension. The non-tested limb remained flat on the table to avoid posterior pelvic tilt. The examiner lifted the tested limb in hip flexion, while maintaining the knee in full extension. The inclinometer was placed on the distal half of the anterior border of the tibia. The measurement was taken when no further motion occurred or when the examiner noted any change in the position of the pelvis.

Ankle Dorsiflexion With the Knee Extended (Gastrocnemius Flexibility)

The subject was positioned in the prone position, feet over the edge of the table. The foot of the tested ankle was maintained in subtalar joint neutral, with the examiner palpating the medial and lateral aspects of the head of the talus. Dorsiflexion was measured as the angle formed by the line from the head of the fibula to the tip of the lateral malleolus and the lateral midline of the foot, using the border of the rearfoot/calcaneus.

Statistical Analysis

Kappa coefficients and percent agreement between examiners were used as estimates of interrater reliability for the rating of the quality of movement on the FSD test. Kappa values of 0.20 or less were considered poor, 0.21 to 0.40 fair, 0.41 to 0.60 moderate, and greater than 0.60 good. All of the continuous variables were found to approximate a normal distribution (Kolmogorov-Smirnov Z test, P>.05). Independent t tests were used to identify differences in demographic variables (age, height, and body mass), as well as in the musculoskeletal measurements between subjects with good and moderate movement quality on the FSD test. The alpha level was set at .05. All statistical analyses were performed using PASW Statistics 18 (SPSS Inc, Chicago, IL).

RESULTS

The examiners rated the movement quality on the FSD test as good for 11 subjects, moderate for 14 subjects, and poor for 1 subject. The kappa coefficient (95% confidence interval) and percent agreement for the interrater reliability of rating the quality of movement for the FSD test were 0.80 (0.57, 1.00) and 85%, respectively. The results of the independent t tests (excluding the subjects with the poor rating) assessing the differences in demographics and musculoskeletal measurements between the good and moderate groups are sum-
The purposes of this study were to investigate the interrater reliability of assessing movement quality of the lower extremity during the FSD test and to compare the musculoskeletal characteristics between asymptomatic women with different levels of movement quality. The primary findings were that the kappa coefficient and percent agreement of the FSD test were high, and that the subjects with moderate movement quality had significantly less hip abductor strength and quadriceps and ITB/TFL flexibility compared to those with good movement quality.

The interrater reliability of the classification system for rating movement quality during the FSD test in our investigation ($\kappa = 0.80$; agreement, 85%) was similar to that previously reported by Piva et al. ($\kappa = 0.67$; agreement, 80%), who used the same classification system during a lateral step-down test in patients with patellofemoral pain syndrome. In contrast, previous studies reported better interrater reliability for movement quality assessed during functional tasks. Ageberg et al. reported high interrater reliability ($\kappa \approx |0.90|$; agreement, 96%) for the visual assessment of mediolateral knee motion during a single-limb mini-squat. Similarly, Ekegren et al. reported high intrarater reliability ($\kappa = 0.75-0.85$; agreement, 88%-90%) for visual ratings of dynamic knee valgus during a drop jump performed by healthy participants. These differences in interrater reliability can be partially explained by the classification criteria. These authors used a classification system solely based on the frontal plane position of the knee relative to the foot. In contrast, the classification system used in this study is more comprehensive and requires the simultaneous evaluation of arm strategy, trunk, pelvis, knee alignment, and balance. This greater number of scoring criteria might have increased the probability of disagreement between raters.

In this study, the examiners rated the movement quality on the FSD test as good for 11 subjects and moderate for 14 subjects. In addition, 1 subject (3.8%) was considered to have poor movement quality during the FSD. Chmielewski et al. reported that 11.5% of uninjured subjects who performed a lateral step-down task had a poor movement rating. It is possible that the greater the number of deviations during the FSD, the greater the potential risk of limited performance and injury.

Previous studies have established an association between hip abductor weakness and altered movement pattern during dynamic activities. Our findings are consistent with these studies, as we found that subjects with a moderate movement quality during the FSD showed relatively lower hip abduction strength than those with good movement quality. Hip abduction musculature provides pelvis and stance limb

### TABLE 1

<table>
<thead>
<tr>
<th>Subject Characteristics for Groups Based on Quality of Movement*</th>
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<tr>
<td>Good (n = 11)</td>
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<td>---------------</td>
</tr>
<tr>
<td>Age, y</td>
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<tr>
<td>Height, cm</td>
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<tr>
<td>Body mass, kg</td>
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<tr>
<td>Hip abduction strength, % body mass</td>
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<td>Hip external rotation strength, % body mass</td>
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<td>Hip external rotation ROM, deg</td>
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<td>Hip internal rotation ROM, deg</td>
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<td>Knee flexion ROM, deg</td>
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<td>Hip adduction ROM, deg</td>
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<td>Hip flexion ROM, deg</td>
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<td>Ankle dorsiflexion ROM, deg</td>
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Abbreviation: ROM, range of motion.
*Values are mean ± SD.
†Significantly different between good and moderate groups (P < .05), independent t test.

### TABLE 2

<table>
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<th>Frequency of Movement Deviation for Groups Based on Quality of Movement</th>
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<td>Arm Strategy</td>
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<tr>
<td>Rater 1</td>
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<tr>
<td>Good (n = 11)</td>
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<tr>
<td>Moderate (n = 14)</td>
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<tr>
<td>Poor (n = 1)</td>
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<tr>
<td>Rater 2</td>
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<tr>
<td>Good (n = 11)</td>
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<tr>
<td>Moderate (n = 14)</td>
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<td>Poor (n = 1)</td>
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stability by eccentric control during weight-bearing activities. Weakness of the hip abductors can lead to excessive femoral adduction, a contralateral pelvic drop, or both during weight-bearing activities. This, in turn, can alter hip and knee joint mechanics. The 2 movement alterations more likely to occur as a result of weaker hip abductors are changes in trunk alignment and pelvic plane motion, which were the most frequent movement deviations noted in our sample (Table 2). Leaning the trunk laterally over the stance leg shifts the center of mass over the hip joint center, thereby reducing the internal abduction moment demand on the weak muscles. In addition, elevating the contralateral pelvis is a common compensation strategy for reducing the demand on the hip abductors, as it moves the ground reaction force vector closer to the hip joint center.

In this study, strength of the hip external rotators was not reduced in those with moderate quality of movement, suggesting that the trunk lean and pelvic rotation exhibited in the moderate group during the FSD test were not caused by weak hip external rotators. Our findings showed that there was no significant difference in hip external and internal rotation range of motion between the groups with good and moderate quality of movement. Rabin and Kozol investigated hip external and internal rotation range of motion during the lateral step-down test in healthy females and reported no significant difference between groups with different levels of movement quality. In our sample, our findings, Sigward et al demonstrated decreased hip external rotation range of motion among subjects with greater medio-lateral displacement of the knee during the drop-land task. The difference between our findings and those of Sigward et al may be due to differences in the functional task used in the 2 studies (drop landing versus FSD).

The subjects with moderate movement quality had relatively lower quadriceps flexibility compared to those with good movement quality. As the knee only needed to be flexed to 60° during the FSD test, it is not clear how reduced flexibility could be associated with poor quality of movement. Our data also indicated that individuals with moderate movement quality had less ITB/TFL flexibility. Decreased muscle flexibility of the ITB/TFL may lead to ipsilateral rotation of the pelvis in the transverse plane, internal rotation of the hip, and external rotation of the tibia, thus facilitating dynamic knee valgus alignment. Finally, our study found no difference in hamstring and gastrocnemius flexibility between subjects with good and moderate quality of movement on the FSD, suggesting that hamstring and gastrocnemius flexibility may not be responsible for the movement deviation observed in asymptomatic women exhibiting moderate quality of movement during the FSD test.

Our study has some limitations. First, the findings are limited to asymptomatic women, which limits the generalizability of the results to other populations, including asymptomatic males or patients with a knee disorder. Second, because the subjects of this study were recruited from the Department of Physical Therapy, we cannot rule out subject bias, as these individuals could have had knowledge of good and bad movement patterns. However, we provided consistent verbal instruction to each subject to reduce this bias. Third, because the functional movement test was performed first and the musculoskeletal measurements second, the potential for examiner bias during the musculoskeletal measurements cannot be excluded. Fourth, we examined reliability using a categorical distribution (good, moderate, and poor) and not each movement deviation, which could have affected reliability ratings. Although the frequency distribution was similar between raters, it does not guarantee that for each trial the raters observed the same movement deviation. Fifth, a cause-and-effect relationship between movement pattern and noted strength and flexibility differences between groups cannot be assumed, given the cross-sectional design of the study. Finally, the validity of using movement quality on the FSD test to predict those at greater risk of injuries is unknown.

CONCLUSION

ASSESSMENT OF MOVEMENT QUALITY on the FSD test had good interrater reliability. Asymptomatic women with moderate movement quality during the FSD test exhibited less hip abduction strength and decreased quadriceps and ITB/TFL flexibility compared to those with good movement quality.

KEY POINTS

FINDINGS: Assessment of movement quality on the FSD test had good interrater reliability. Asymptomatic women with moderate movement quality during the FSD test exhibited less hip abduction strength and decreased quadriceps and ITB/TFL flexibility compared to those with good movement quality.

IMPLICATIONS: Clinicians should consider assessment of hip abductor strength and flexibility of the quadriceps and ITB/TFL when individuals demonstrate poor quality of movement on the FSD test. CAUTION: The results of this study are limited to asymptomatic women.

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