Factors Associated With Visually Assessed Quality of Movement During a Lateral Step-down Test Among Individuals With Patellofemoral Pain

An altered lower extremity movement pattern has been previously implicated in the pathogenesis of patellofemoral pain (PFP). It has been suggested that altered hip, knee, foot, and ankle kinematics combine to result in excessive medial collapse of the lower extremity during various functional activities. This movement pattern, which is also termed dynamic knee valgus, is hypothesized to shift the line of pull of the quadriceps laterally, which may result in higher patellofemoral joint contact pressure, possibly leading to pain. An understanding of the physical characteristics associated with excessive dynamic knee valgus could therefore help guide preventive as well as rehabilitative efforts. Much of the literature related to lower extremity movement pattern is based on 3-D motion analysis. Although this type of analysis is very accurate and sensitive to subtle movement deviations, its clinical application may be limited. For example, diminished hip abductor and external rotator muscle strength has been previously associated with greater hip adduction and greater contralateral pelvic drop during a 1-legged mini-squat, when assessed by 3-D motion analysis. However, it is questionable whether a clinician can visually detect these subtle kinematic differences. Reliable and valid clinical tools for assessing quality of movement are therefore needed to overcome this limitation. One such tool is the lateral step-down (LSD) test, which can

STUDY DESIGN: Cross-sectional.

OBJECTIVE: To determine what physical measures are associated with visually assessed quality of movement among patients with patellofemoral pain (PFP).

BACKGROUND: An altered movement pattern has been implicated as a risk factor for PFP. An understanding of physical measures associated with an altered movement pattern could potentially help guide prevention and management efforts in patients with PFP.

METHODS: Seventy-nine (40 women) Israel Defense Forces soldiers referred to physical therapy with a diagnosis of PFP were included. Movement pattern was assessed visually during a lateral step-down test and rated as “good” or “moderate,” based on previously established criteria. Weight-bearing and non–weight-bearing ankle dorsiflexion (DF) range of motion (ROM); hip internal and external rotation ROM; and hip abduction, hip external rotation, and knee extension strength were also assessed. Differences in physical measures between those with good versus moderate quality of movement were assessed.

RESULTS: Weight-bearing DF ROM was more limited among participants with a moderate quality of movement compared to those with a good quality of movement (P<.01). Among men, non–weight-bearing DF ROM was more limited in those with a moderate quality of movement as well (P<.01). In addition, quality of movement was associated with weight-bearing DF ROM for both women (r = −0.39, P = .01) and men (r = −0.46, P<.01), and with non–weight-bearing DF ROM for men (r = −0.66, P<.01). When the subgroup of participants who exhibited more than 25° of non–weight-bearing DF ROM was assessed, those with a good quality of movement displayed greater hip external rotator and knee extensor muscle strength compared with those with a moderate quality of movement (P<.01).


KEY WORDS: ankle, anterior knee pain, chondromalacia, hip, patella

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be used to rate the quality of movement based on the alignment of the trunk, pelvis, and knee. The LSD test has previously demonstrated moderate interrater reliability (0.59-0.67), which makes it suitable for clinical practice.

It is often assumed that weakness of the hip abductors and external rotators leads to greater hip adduction and internal rotation, which are components of excessive dynamic knee valgus during a functional task. Although individuals with PFP have repeatedly demonstrated hip muscle weakness and interventions to increase hip muscle strength have resulted in improved clinical outcomes in patients with PFP, the association between hip muscle strength and movement pattern seems much less clear. Furthermore, the ability to immediately modify movement pattern does not seem to be associated with hip muscle strength, and interventions targeting hip muscle strength have not consistently resulted in improved movement pattern. Additional investigation into the nature of the association between hip muscle strength and lower extremity movement pattern is warranted.

Another possible contributor to excessive dynamic knee valgus is limited ankle dorsiflexion (DF) range of motion (ROM). Under weight-bearing (WB) conditions, decreased DF ROM will limit the forward progression of the tibia over the talus. This may result in compensatory subtalar pronation, which, in turn, may displace the knee medially. Previous studies suggest that limited ankle DF may be associated with a greater medial displacement of the knee during various functional activities. As the quadriceps eccentrically controls knee flexion under WB conditions, weakness may limit the willingness to bend the knee during various functional activities. This limited knee flexion may subsequently cause compensatory frontal and/or axial plane knee or hip motion, thereby altering patellofemoral kinematics. Both diminished quadriceps strength as well as decreased knee flexion during jump landing have been implicated as risk factors for developing PFP. Finally, limited hip external rotation ROM has also been associated with the amount of dynamic knee valgus among healthy females, presumably because of a tendency to maintain the hip in a more internally rotated position.

To our knowledge, the association of these previously mentioned physical measures with the quality of lower extremity movement during a functional task, as assessed by visual observation in patients with PFP, has not previously been examined. Therefore, our purpose was to examine whether differences in ROM and strength measures exist between patients with PFP who exhibit differing quality of lower extremity movement based on visual observation during an LSD. Separate analyses were performed for men and women based on previous literature indicating differences in both the magnitude and the timing of lower extremity movements in men and women.

METHODS

Participants

M A L E A N D F E M A L E S O L D I E R S O F T H E I s r a e l D e f e n c e F o r c e s , r e f e r r e d f o r p h y s i c a l t h e r a p y in 1 of the Israel Defense Forces outpatient clinics with a diagnosis of unilateral or bilateral PFP, were recruited for this study. Recruitment took place from February 2013 to January 2014. Potential participants were included if they were 18 years or older, had nontraumatic peripatellar or retropatellar pain for a duration of at least 4 weeks, and reported aggravation or reproduction of their symptoms with 3 or more of the following: (1) prolonged sitting, squatting, kneeling, or running; (2) palpation of the medial/lateral patellar facets; (3) compression of the patella into the trochlear groove, either with or without quadriceps contraction; and (4) resisted knee extension at 60° of flexion. Potential participants were excluded if they sustained a traumatic injury to the knee; had knee instability; had a history of femur, tibia, or patellar fracture; had a previous knee surgery; had their symptoms reproduced primarily with palpation of the inferior patellar pole; or presented with a positive patellar apprehension sign or McMurray, Lachman, valgus, varus, or posterior drawer test. Prior to participation, all procedures were explained to each potential participant, and informed consent was obtained as approved by the Institutional Review Board of the Israel Defense Forces. The rights of participants were protected throughout the study.

Examiners

Two examiners performed data collection for this investigation, one with 15 years of clinical experience in physical therapy management of musculoskeletal conditions (A.R.) and the other with more than 28 years of teaching and clinical experience in the field of kinesiology and neurological rehabilitation (Z.K.). Prior to data collection, the 2 examiners met for a 4-hour session to review and operationally define each of the procedures of the study. Following this session, pilot testing was performed on 9 individuals and final modifications to all testing procedures were made.

Procedures

Following informed consent, participants in the study completed a questionnaire for demographic information, an 11-point (0-10) numeric pain rating scale, and the Lower Extremity Functional Scale (0-80). This was followed by a physical examination that included the LSD test and measurements of ankle DF ROM in WB and non–weight bearing (NWB); hip internal and external rotation ROM; and hip abductor, hip external rotator, and knee extensor strength. All tests were
performed on the more affected side of patients with bilateral symptoms. If the participant could not determine which side was the more affected, the side tested was based on a coin toss. The order of tests was set so that the LSD test was performed first to eliminate any potential tissue preconditioning or muscle fatigue resulting from the ROM or strength tests. Weight-bearing ankle DF ROM was measured next, followed by NWB ankle DF ROM; hip internal and external rotation ROM; and hip abductor, hip external rotator, and knee extensor strength. The order of the ROM and strength tests was standardized to minimize positional changes to eliminate potential discomfort and to complete the tests in a timely manner. A typical testing session for a single participant took less than 1 hour.

Reliability

The interrater reliability of all ROM and strength tests was previously reported as good to excellent (intraclass correlation coefficient [ICC] = 0.82-0.95). The interrater reliability of the LSD test has been previously reported as moderate ($\kappa = 0.59-0.67$) and was therefore assessed again in this study. Both examiners simultaneously scored the LSD of all participants. Each examiner scored the test independently, and no discussion was allowed during the test or until the participant underwent all other measurements. For data analysis, the LSD scores of only 1 examiner (Z.K.) were used. All ROM and strength measurements were performed by the other examiner (A.R.).

Measures

LSD Test The LSD test was performed using a 15-cm step, which requires most people to bend the knee approximately 60° to complete the test. Nevertheless, before performing the test, participants were asked to reach down and touch their noninvolved heel to the floor while the knee flexion angle of the tested leg was measured with a universal goniometer. This angle was later used to rule out a possible effect of step height on the LSD score. During the test, participants were asked to stand with their foot close to the edge of the step and place their second toe over a white piece of tape, while their uninvolved leg was off the side of the step. Participants were asked to keep both hands on their waist and bend their knee until the heel of their uninvolved leg lightly touched the floor, then to immediately return to the starting position. No other instructions were given prior to performing the test. Following the verbal explanation, participants were allowed 5 practice repetitions. The test itself consisted of 6 repetitions; however, only the last 5 repetitions were assessed by the examiners. Immediately following the test, participants were asked to verbally rate any knee pain experienced during the test on an 11-point (0-10) numeric pain scale.

The 2 examiners, positioned 3 m in front of the participant during the test, scored the test based on a 7-point (0-6) scale, as described in Table 1. If any of the movement deviations outlined in Table 1 were identified during any of the test repetitions, the participant was considered to have demonstrated a deviation and the corresponding score was assigned. To assist with the scoring of the knee criterion, a 50-cm-high, 3-mm-thick pole was placed 20 cm in front of the step, in line with the second toe of the participant. This pole served as a visual reference to help assess the position of the tibial tuberosity during the test. The tibial tuberosity was also marked with a 1-cm red sticker prior to performing the test to further assist with its visualization. The knee criterion was scored positive when the entire red sticker crossed from the lateral to the medial aspect of the pole during the test.

Originally, the quality of movement during the LSD test was assigned 1 of 3 levels: good (score, 0-1), moderate (score, 2-3), or poor (score, 4-6). However, as previous research indicated that very few participants are assigned a poor score, it was decided a priori to score the test dichotomously as either good (score, 0-1) (FIGURE 1, ONLINE VIDEO) or moderate (score, 2 or greater) (FIGURE 2, ONLINE VIDEO).

### TABLE 1

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Interpretation</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm strategy</td>
<td>Removal of a hand from the waist</td>
<td>1</td>
</tr>
<tr>
<td>Trunk alignment</td>
<td>Leaning in any direction</td>
<td>1</td>
</tr>
<tr>
<td>Pelvic plane</td>
<td>Loss of horizontal plane</td>
<td>1</td>
</tr>
<tr>
<td>Knee position</td>
<td>Tibial tuberosity medial to second toe</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tibial tuberosity medial to medial border of foot</td>
<td>2</td>
</tr>
<tr>
<td>Steady stance</td>
<td>Stepping down on noninvolved limb or the foot wavering from side to side</td>
<td>1</td>
</tr>
</tbody>
</table>
hip rotation was determined by positioning the tibial plateau of the tested limb parallel to the support surface. The inclinometer was first zeroed on the lateral surface of the tibia, just proximal to the lateral malleolus. The participant’s hip was moved into internal rotation until no further movement was possible, and the range was measured. The average of 3 measurements was recorded. The same procedure was repeated for hip external rotation ROM.

**Hip Abductor Strength** Abductor muscle strength was measured with a handheld dynamometer, as previously described. The participant assumed a sidelying position on the nontested side, with the lower leg slightly bent at the hip and knee. The tested hip was positioned in approximately 10° of abduction using 2 to 3 pillows between the lower extremities. A strap placed just proximal to the iliac crest and secured firmly around the underside of the table was used to stabilize the participant’s trunk. The dynamometer was secured to the lateral aspect of the thigh, just proximal to the lateral femoral epicondyle, by another belt wrapped around the underside of the table. The participant was asked to abduct the hip as hard as possible against the dynamometer. After 1 practice repetition, the participant performed three 5-second test repetitions, with a 30-second rest between each repetition. To calculate torque, the distance from the greater trochanter to the lateral femoral epicondyle was measured and served as the external moment arm, expressed in meters. The average of the 3 test repetitions, expressed in Newtons, was multiplied by the moment arm to determine the hip abductor torque (N·m). The hip abductor torque was normalized to the participant’s body mass, expressed in kilograms.

**Hip External Rotator Strength** Hip external rotator muscle strength was measured with a handheld dynamometer in a seated position, as previously described. The participant was seated on a Biodex isokinetic dynamometer (Biodex System 3 Pro; Biodex Medical Systems, Inc, 2014). The dynamometer was secured to the lateral aspect of the thigh, just proximal to the lateral femoral epicondyle, by another belt wrapped around the underside of the table. The participant was asked to adduct the hip as hard as possible against the dynamometer. After 1 practice repetition, the participant performed three 5-second test repetitions, with a 30-second rest between each repetition. To calculate torque, the distance from the greater trochanter to the lateral femoral epicondyle was measured and served as the external moment arm, expressed in meters. The average of the 3 test repetitions, expressed in Newtons, was multiplied by the moment arm to determine the hip adductor torque (N·m). The hip adductor torque was normalized to the participant’s body mass, expressed in kilograms.
Frequency of Individual Movement Deviations

TABLE 2

<table>
<thead>
<tr>
<th>Arm Strategy</th>
<th>Trunk Alignment</th>
<th>Pelvic Plane</th>
<th>Knee Alignment</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rater 1</td>
<td>11</td>
<td>3</td>
<td>62</td>
<td>55</td>
</tr>
<tr>
<td>Rater 2</td>
<td>11</td>
<td>10</td>
<td>59</td>
<td>57</td>
</tr>
</tbody>
</table>

The correlation between the raw score of the LSD test and all physical measures was assessed separately for men and women using the Spearman rank correlation coefficient (r). All analyses were performed with SPSS Version 20 (SPSS Inc, Chicago, IL), with an a priori level of significance of P≤.05.

RESULTS

Sixty-nine (40 women) participants were recruited, among whom 46 had bilateral involvement. Thirty participants performed the LSD test with a good quality of movement, whereas 49 participants displayed a moderate quality of movement. No interaction or main effects for sex or quality of movement were noted for the knee angle required to perform the LSD test. The frequency of each of the movement deviations displayed by the participants during the LSD test is presented in TABLE 2. Percent agreement and kappa coefficient (95% confidence interval) for the interrater reliability of the LSD test were 91% and 0.81 (0.68, 0.94), respectively, indicating an excellent level of agreement.

TABLE 3 presents demographic and self-reported variables for all groups and subgroups. No interaction or main effects were noted for body mass index, duration of symptoms, regular performance of physical activity, or pain level during the performance of the LSD test. A main effect of sex was noted for age (men older than women, P = .01), numeric pain rating scale (greater pain level among women, P = .01), and the Lower Extremity Functional Scale (greater self-reported functional level among men, P<.01). In addition, a main effect of LSD was noted for the numeric pain rating scale, with...
participants with a moderate score reporting a greater pain level \( (P = .05) \).

**TABLE 4** presents the values of all physical measures among all groups and subgroups. A sex-by-LSD interaction was noted for NWB DF ROM \( (P = .01) \). Men with a moderate quality of movement exhibited less NWB DF compared to those with a good quality of movement \( (P < .01) \); however, no such difference was noted among women \( (P = .13) \). A main effect for LSD was found for WB DF ROM, such that both women and men with a moderate quality of movement displayed less WB DF ROM compared to those with a good quality of movement \( (P < .01) \).

A sex-by-LSD interaction was also noted for hip internal rotation ROM \( (P = .02) \). Women with a moderate quality of movement displayed less hip internal rotation ROM compared with women with a good quality of movement \( (P = .02) \), whereas no such difference was detected among men \( (P = .29) \).
Correlation (Spearman Rho) Between the Raw Score of the Lateral Step-down Test and the Range-of-Motion and Strength Measures for Women and Men

<table>
<thead>
<tr>
<th>Measure</th>
<th>Women, r</th>
<th>P Value</th>
<th>Men, r</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight-bearing dorsiflexion</td>
<td>-0.39</td>
<td>.01</td>
<td>-0.46</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Non-weight-bearing dorsiflexion</td>
<td>-0.24</td>
<td>.13</td>
<td>-0.66</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hip internal rotation ROM</td>
<td>-0.18</td>
<td>.26</td>
<td>0.13</td>
<td>.42</td>
</tr>
<tr>
<td>Hip external rotation ROM</td>
<td>0.14</td>
<td>.39</td>
<td>0.21</td>
<td>.20</td>
</tr>
<tr>
<td>Hip abductor torque</td>
<td>-0.13</td>
<td>.44</td>
<td>-0.22</td>
<td>.17</td>
</tr>
<tr>
<td>Hip external rotator torque</td>
<td>-0.22</td>
<td>.18</td>
<td>-0.22</td>
<td>.18</td>
</tr>
<tr>
<td>Knee extensor torque</td>
<td>-0.05</td>
<td>.75</td>
<td>0.11</td>
<td>.49</td>
</tr>
</tbody>
</table>

Abbreviation: ROM, range of motion.

No interactions were noted for any of the strength measures; however, as expected, a main effect for sex was noted for all strength measures, with men displaying greater strength values compared with women (P<.01).

A negative correlation was found between the raw score of the LSD test and WB ankle DF ROM for both sexes (women: r = -0.39, P = .01; men: r = -0.46, P<.01), as well as between the raw score of the LSD test and NWB ankle DF ROM for men (r = -0.66, P<.01). The nature of these correlations indicates that lower scores on the LSD test (expressing a better quality of movement) were associated with greater ankle DF ROM.

The correlations between the raw score of the LSD test and hip rotation ROM, hip rotation muscle strength, and knee extensor strength were not significant for either sex.

Discussion

As the most readily available clinical method of assessing quality of movement is visual observation, it is imperative to recognize factors associated with the findings of such an assessment. Our study indicates that among participants with PFP, a visually observed faulty lower extremity movement pattern during an LSD maneuver is associated with limited WB ankle DF ROM. Our findings are in agreement with previous studies demonstrating the same association for healthy populations during various functional activities.

Our findings imply that when individuals with PFP exhibit a faulty movement pattern, ankle DF ROM should be assessed. Whether interventions to increase ankle DF ROM will result in an improved movement pattern is unknown; however, some evidence already exists to suggest that improved ankle DF ROM may be associated with improved dynamic balance in individuals with chronic ankle instability.

Limited ankle DF ROM has been previously implicated as a risk factor for various sport-related injuries, including PFP. Evidence also exists to suggest that altered movement pattern may play a role in the pathogenesis of the same pathologies. Our findings suggest that these 2 impairments may be related, and, although no cause-and-effect relationship can be established, it is reasonable to assume that a more limited ankle DF ROM would adversely affect movement pattern. During the LSD, the joints of the stance leg are required to flex to bring the contralateral foot to the floor. A limitation in flexion ROM in any of these joints (hip, knee, or ankle) may require compensation from other joints. One such compensation is contralateral pelvic drop, which will serve to lower the contralateral foot to the floor. Another possible compensation is excessive dynamic knee valgus, which will substitute the lack of sagittal motion of the extremity by greater frontal plane motion. These 2 movement deviations were by far the most commonly seen during the LSD test in our sample.

Although WB DF was more limited for participants of both sexes who displayed a moderate quality of movement, NWB DF was limited only for men with a moderate quality of movement. This may be because the assessment of quality of movement was based on a composite of several items. Non-weight-bearing DF ROM might have been related to some of these items more than others. In fact, post hoc testing revealed that if quality of movement was determined solely by pelvic rating, it would have resulted in a main effect on NWB DF (P<.01), with participants of both sexes who demonstrated a positive pelvic rating presenting with a more limited NWB DF ROM (24.5° versus 29.9° among women, P = .02; and 21.9° versus 27.4° among men, P = .01). However, if quality of movement was determined solely by knee rating, a trend toward an interaction of sex by knee rating would have been found (P = .09). Though women with different knee ratings did not display differences in NWB DF ROM (25.1° versus 25.6°, P = .80), men with a positive knee rating exhibited less NWB DF ROM compared with men with a negative knee rating (21.9° versus 26.1°, P = .03). It may be that different factors are associated with knee alignment during the LSD test for both sexes. This could be a potentially insightful line of future study.

In addition to having greater ankle DF ROM, women with a better quality of movement also displayed greater hip internal rotation ROM. While this finding may seem counterintuitive, it is in agreement with previous findings among healthy female participants. Although hip external rotation ROM was reciprocally more limited among women with a good quality of movement, this difference did not reach statistical significance.
It does seem, however, that women with a better quality of movement on the LSD test displayed a shift in their total hip rotation toward greater internal rotation and decreased external rotation. This could suggest a greater amount of hip anteversion in that group. Why a greater amount of hip anteversion would be associated with better quality of movement on the LSD is not clear and warrants further investigation.

In contrast to previous studies, we did not find an association between the quality of movement pattern and hip muscle strength. There are several possible explanations for this. First, visual observation may not be sensitive enough to detect more subtle movement deviations that may be associated with hip muscle strength. This is supported by several studies in which visual observation failed to detect differences in hip muscle strength between participants with differing qualities of movement. Secondly, given that this study was conducted in a military setting, it is possible that our participants were stronger compared with civilian populations with PFP, which could have lessened the effect of hip muscle strength on movement pattern. Comparison with previous studies using similar strength-testing techniques suggests that, though hip abductor strength may be lower than that found in some studies and higher than that found in others, hip external rotator strength was consistently stronger in the present study’s participants.

Third, it is possible that diminished activation, rather than strength, is more associated with the quality of movement. Finally, movement pattern is likely determined by several factors. Therefore, hip muscle strength may be related to movement pattern in some cases, but not in others. For example, when ankle DF is limited, it may force compensatory hip and knee movement despite the presence of adequate hip muscle strength. On the other hand, when ankle DF is sufficient to obviate the need for any compensatory movements, lower extremity kinematics may become more associated with hip muscle strength.

To explore this possibility further, we used a median split to dichotomize NWB DF ROM into low (25° or less, n = 41) or high (greater than 25°, n = 38) and performed several post hoc 2-way analysis of variance models using DF ROM (low versus high) and LSD score (good versus moderate) as independent variables, with hip abductor, hip external rotator, and knee extensor strength as dependent variables. These analyses included men and women together, as separate analyses would have likely resulted in too few participants in each group to detect interactions. An interaction for DF ROM by LSD was found for hip external rotator strength (P < .01 (FIGURE 5)), indicating that among participants with relatively more DF ROM, hip external rotator strength was greater among those with a good quality of movement compared to those with a moderate quality of movement (mean ± SD torque, 0.80 ± 0.24 versus 0.62 ± 0.18 Nm/kg; P < .01). A significant interaction (P < .01) was also found for knee extensor strength (FIGURE 6), indicating that among participants with relatively more DF ROM, mean ± SD knee extensor strength was greater among those with a good quality of movement compared to those with a moderate quality of movement (mean ± SD torque, 240.2 ± 57.2 versus 204.8 ± 62.0 Nm/kg × 100; P < .05). While hip abductor strength was also greater among participants with relatively high DF ROM and a good versus a moderate quality of movement, this difference did not reach statistical significance (mean ± SD torque, 1.53 ± 0.42 versus 1.26 ± 0.33 Nm/kg; P = .11).

When repeating the correlation analysis separately among participants with low and participants with high NWB DF ROM, a significant negative correlation was found between the raw score of the LSD test and hip external rotator strength only among participants with high DF ROM (r = −0.40, P = .01).

Collectively, these findings suggest that when DF ROM exceeds a certain threshold, hip muscle strength becomes associated with the quality of movement. This implies that different subgroups...
may exist based on factors associated with the quality of movement. More specifically, hip strength may be more associated with the quality of movement when ankle DF ROM exceeds a minimal threshold that allows a good quality of movement on the LSD test. This finding may help explain some of the inconsistencies in previous studies regarding the association between hip muscle strength and lower extremity movement pattern. This finding also implies that clinicians may need to incorporate different treatment strategies when attempting to modify a patient’s movement pattern based on findings from the physical examination. While some patients may require hip muscle strengthening, others may need to increase their ankle ROM to facilitate better quality of movement. Future investigations are warranted to establish the minimal DF ROM threshold that allows proper performance of the LSD.

The present study has several limitations. First, due to the cross-sectional methodology, it is not possible to determine whether limited ankle DF ROM is the cause of lower quality of movement or its consequence. Second, our findings are limited to visual assessment of the quality of movement during the LSD test. Other factors may be associated with the quality of movement during other functional activities, or when an instrumented analysis of movement is performed. Third, our subgroup analysis based on ankle DF ROM was not preplanned. We attempted this analysis only after observing that, whereas most patients with limited ankle DF could not perform the LSD with a good pattern, some patients with relatively good DF ROM were still unable to demonstrate a good movement pattern. This subgroup analysis, which most likely lacked adequate power, will need to be validated in a prospective investigation. Fourth, the examiner performing the physical measures was not completely blinded to the quality-of-movement assessment, as he also observed and rated the LSD test to establish its inter-rater reliability. Finally, our sample was somewhat younger compared with other populations with PFP, and had a relatively shorter duration of symptoms. This might have been the result of the military setting from which participants were recruited. Nevertheless, self-reported disability seemed fairly similar to that reported in other populations of individuals with PFP.

**CONCLUSION**

Participants, both men and women, with a visually assessed lower quality of movement during the LSD test presented with more limited WB ankle DF ROM. Non-weight-bearing ankle DF ROM was also more limited, but for the men only. When assessed among the entire sample, hip muscle strength was not different between participants with differing qualities of movement. However, a post hoc analysis among participants with good ankle DF ROM revealed greater hip external rotator and knee extensor muscle strength among those with a better quality of movement.

**KEY POINTS**

**FINDINGS:** Both men and women with PFP who exhibited a visually assessed lower quality of movement on the LSD test presented with more limited WB ankle DF ROM. For male participants, a difference was also found for NWB ankle DF ROM. The association of hip muscle strength with quality of movement may increase when ankle DF ROM surpasses a certain threshold.

**IMPLICATIONS:** Ankles DF ROM may need to be assessed when a faulty movement pattern is observed during the LSD test. Interventions to increase ankle DF may need to be considered when a faulty lower extremity movement pattern is observed. CAUTION: No cause-and-effect relationship between quality of movement and ankle DF can be ascertained from this study.

**REFERENCES**
