Lumbopelvic Manipulation for the Treatment of Patients With Patellofemoral Pain Syndrome: Development of a Clinical Prediction Rule

Patellofemoral pain syndrome (PFPS) is a significant clinical problem and one of the most common knee disorders in young, active individuals. Despite its prevalence, the etiology of PFPS is not well understood. It has been proposed that abnormal neuromuscular and biomechanical factors alter patellar tracking and contribute to increased patellofemoral joint contact pressures that ultimately lead to pain and dysfunction.

Because the etiology is unclear, and due to variations in the clinical presentation of patients with PFPS, numerous nonoperative interventions have been proposed for the disorder. A common goal of most treatment regimens for PFPS is the restoration of quadriceps muscle strength and function. Suter and colleagues recently showed that sacroiliac joint (SLJ) or lumbopelvic region manipulation led to a significant decrease in quadriceps inhibition in the involved knees of patients with PFPS. Similarly, Hillermann et al reported that quadriceps muscle strength increased significantly if there was any change in pain ratings. An immediate overall 50% or greater reduction in pain, or moderate or greater improvement on a global rating of change questionnaire, was considered a treatment success. Likelihood ratios (LRs) were calculated to determine which examination items were most predictive of treatment outcome.

**STUDY DESIGN:** Prospective cohort/predictive validity study.

**OBJECTIVE:** To determine the predictive validity of selected clinical exam items and to develop a clinical prediction rule (CPR) to determine which patients with patellofemoral pain syndrome (PFPS) have a positive immediate response to lumbopelvic manipulation.

**BACKGROUND:** Quadriceps muscle function in patients with PFPS was recently shown to improve following treatment with lumbopelvic manipulation. No previous study has determined if individuals with PFPS experience symptomomatic relief of activity-related pain immediately following this manipulation technique.

**METHODS AND MEASURES:** Fifty subjects (26 male, 24 female; age range, 18-45 years) with PFPS underwent a standardized history and physical examination. After the evaluation, each subject performed 3 typically pain-producing functional activities (squatting, stepping up a 20-cm step, and stepping down a 20-cm step). The pain level perceived during each activity was rated on a numerical pain scale (0 representing no pain and 10 the worst possible pain). Following the assessment, all subjects were treated with a lumbopelvic manipulation, which was immediately followed by retesting the 3 functional activities to determine the change in perceived pain.

**RESULTS:** Data for 49 subjects were included in the data analysis, of which 22 (45%) had a successful outcome. Five predictor variables were identified. The most powerful predictor of treatment success was the presence of a side-to-side difference in hip internal rotation range of motion greater than 14° (+LR, 4.9). This variable was present, the chance of experiencing a successful outcome with the lumbopelvic manipulation improved from 45% to 80%.

**CONCLUSION:** A CPR was developed to predict an immediate successful response to lumbopelvic manipulation in patients with PFPS. However, in light of a limited sample size and potential omission of meaningful predictor variables, future studies are necessary to validate the CPR.


**KEY WORDS:** Anterior knee pain, physical examination, rehabilitation, spinal manipulation

---

1 Staff Physical Therapist, Blanchfield Army Community Hospital, Fort Campbell, KY. 2 Associate Professor, US Army-Baylor University Doctoral Program in Physical Therapy, San Antonio, TX. 3 Staff Physical Therapist, Winn Army Community Hospital, Fort Stewart, GA. 4 Staff Physical Therapist, Reynolds Army Community Hospital, Fort Sill, OK. 5 Staff Physical Therapist, Moncrief Army Community Hospital, Fort Jackson, SC. 6 Assistant Chief, Physical Therapy, Brooke Army Medical Center, San Antonio, TX. 7 Professor and Director, US Army-Baylor University Doctoral Program in Physical Therapy, Fort Sam Houston, TX. 8 Associate Professor, Physical Therapy, Texas State University, San Marcos, TX. The protocol of this study was approved by The Institutional Review Board of Brooke Army Medical Center, Fort Sam Houston, TX. Opinions or assertions herein are the private views of the authors and are not to be construed as official or as reflecting the views of the United States Army or the Department of Defense. Address correspondence to Thomas G. Sutlive, US Army-Baylor University Doctoral Program in Physical Therapy, 3150 Stanley Road, Room 1303, ATTN: MCCS-HMT, Fort Sam Houston, TX 78234. E-mail: thomas.sutlive@amedd.army.mil
significantly following SIJ manipulation in patients with the disorder. However, the investigators did not measure the patients’ symptomatic response to the treatment in any of these previous manipulation studies.38,67,68

While recent evidence suggests that lumbopelvic manipulation can be effective in restoring quadriceps function in patients with PFPS, there is no evidence that patients with PFPS will experience symptomatic relief following the intervention. Furthermore, no published study has identified specific clinical examination variables that are predictive of which patients with PFPS, if any, will respond successfully to lumbopelvic manipulation. Identification of these clinical examination items could lead to the development of a clinical prediction rule (CPR) to identify patients likely to respond positively to lumbopelvic manipulation. Such a CPR could potentially enhance clinical decision making, reduce treatment time, and optimize outcomes.39,44

Therefore, the purpose of our study was to (1) determine the predictive validity of selected clinical examination items for identifying patients with PFPS who have an immediate successful response to lumbopelvic manipulation, and (2) develop a CPR derived from these same historical and physical examination findings.

METHODS

Subjects

Fifty subjects were recruited from the active duty military population at Fort Sam Houston, San Antonio, TX. Volunteers were included in the study if they were military healthcare beneficiaries between 18 and 50 years of age and had a clinical diagnosis of PFPS. Subjects were determined to have symptomatic PFPS if they had a complaint of anterior knee pain that was provoked by 2 or more of the following: squatting, stair ascent, stair descent, prolonged sitting, kneeling, or isometric quadriceps contraction.11,43,55,61 Exclusion criteria included pregnancy, signs of nerve root compression, palpation tenderness of the tibiofemoral joint lines or patellar tendon, or a positive finding on any special tests aimed to identify knee ligament or meniscal injuries. Volunteers were also excluded if they had a history of any of the following: prior surgery on the spine or the symptomatic knee, osteoporosis, compression fracture, or a history of systemic, connective tissue, or neurological diseases. Individuals currently receiving treatment for their knee pain were also excluded. Informed consent was obtained from each subject prior to participation, and the rights of each subject were protected. This study was approved by the Institutional Review Board of Brooke Army Medical Center, Fort Sam Houston, San Antonio, TX.

Instrumentation

Numeric Pain Rating Scale The numeric pain rating scale (NPRS) was used to establish the subject’s pain level after each functional test. The NPRS is an 11-point scale that ranges from 0 (no pain) to 10 (worst imaginable pain). This type of scale has been shown to be a reliable, generalizable, and internally consistent measure of clinical and experimental pain sensation intensity.57,58 After performing each of the 3 functional tests, subjects were instructed to circle the number on the NPRS that best represented their knee pain. Subjects with bilateral PFPS were instructed to complete the NPRS based on their most symptomatic knee. The most symptomatic knee was determined by the subject’s self-report.48 A composite NPRS score (total score from the 3 functional tests) was established for each subject and used for data analysis.

Global Rating of Change Questionnaire The global rating of change questionnaire (GRC) is a single-item, self-report instrument used to measure the subject’s impression of the change in his or her condition following an intervention (APPENDIX A). A GRC measures the overall changes in the quality of life of individuals.53 The use of a GRC is a common, feasible, and useful method for assessing outcome,71 and has been shown to be a valid measurement of change in patient status in other populations complaining of pain.21 Each subject was instructed to mark the statement that best represented his/her status in response to the intervention on a 15-point GRC.

Examination Items

Each subject completed a medical history questionnaire (APPENDIX B) and received a standardized physical examination. A list of all clinical tests and measures performed on each subject, along with their operational definitions and measurement properties, is shown in APPENDIX C. The symptomatic knee was considered the unit of analysis. All measurements were taken on the side of the symptomatic knee (or most symptomatic knee for those with bilateral PFPS), and all angular measurements were taken with a 17.8-cm plastic goniometer.

Procedures

Each subject made 1 visit to the clinic. Following the history (completion of questionnaire shown in APPENDIX B and submission of general demographic data), the subject was instructed to remove his or her shoes and socks and to sit on the examining table. The examiner performed a neurological screening examination of the lower extremities that consisted of manual muscle tests, muscle stretch reflex testing, and sharp/dull sensation testing to rule out lumbosacral nerve root compression. The examiner then performed selected tests and measures of each subject’s low back and lower extremities (APPENDIX C). The subject was instructed to lie prone on the examining table. The symptomatic lower extremity was extended so that the ipsilateral foot hung off the end of the table and the contralateral knee was flexed to 90º, with the hip externally rotated (figure-four position, as described by Donatelli23). Pen marks were made on the following anatomical landmarks of each subject’s lower leg and foot for measurement purposes: the calcaneus and Achilles tendon was bi-
ected with a marker, and the navicular tuberosity was marked with a dot. The battery of clinical measurements then commenced as listed in **APPENDIX C** on the side of the symptomatic knee only. A second examiner repeated the series of tests and measures on the first 25 subjects prior to the functional testing to assess the interrater reliability of the measurements. An assistant recorded all measurements that were taken by both the first and second examiners. To prevent order effects, as well as to expedite the examination process, the examiner order (first or second examiner) was alternated sequentially.

Following completion of the examination, subjects were asked to complete 3 functional activities (stepping up a 20-cm step, stepping down a 20-cm step, and squatting). After each functional test, the subject immediately assessed his or her knee pain during the activity and circled the number that represented this pain on the NPRS. During the squat test, the angle of knee flexion at which the subject first experienced pain was measured with a plastic goniometer and recorded. By doing this, the subject was able to assess the pain experienced when he or she squatted to the same angle following the intervention.

After the first set of functional tests was completed, the subject returned to the examination table and was treated with a lumbo pelvic manipulation technique to the symptomatic side, performed as previously described3,19 and illustrated in **FIGURE 1**. A video demonstration of the manipulation technique has previously been published on-line.7 The second examiner always performed the manipulation if the subject was part of the interrater reliability study (ie, 1 of the first 25 subjects). If the subject or examiner felt a cavitation at any point during the setup for the manipulation or during the first manipulation, the intervention was considered complete. If no cavitation was heard or felt by the subject or examiner after the first manipulation, the examiner repeated the manipulation on the same side. If a cavitation was still not felt or heard by manipulating the symptomatic side, the examiner repeated the manipulation on the opposite side in the exact same manner. Therefore, each subject received up to a maximum of 2 manipulations on each side. Following the intervention, the subject then repeated each functional test and again rated the pain experienced during each activity on the NPRS. The subject concluded the visit by assessing the overall change in his or her condition on the GRC.

**Data Analysis**

All statistical analyses were performed using Microsoft Excel 2000 (Microsoft Corp, Redmond, WA) and SPSS for Windows, Version 12.0 (SPSS Inc, Chicago, IL). Interrater reliability statistics were computed using intraclass correlation coefficients (ICC2,1) for continuous variables and Cohen’s kappa coefficients for categorical measurements.

For the predictive validity portion of the study, each subject was first classified as either a treatment success or nonsuccess. The reference criterion used to define treatment success was either a 50% or greater improvement on the composite NPRS or a score of +4 (moderately better or improved) or higher on the GRC. It has been proposed that a 30% change in a NPRS represents a clinically meaningful reduction in pain in subjects with a variety of disorders.18 Juniper et al13 proposed that changes of at least 4 on the GRC indicate a moderate change in the person’s condition. Therefore, we felt that a 50% threshold on the NPRS or a score of +4 or greater on the GRC was sufficiently high to identify individuals who responded to the intervention.

After dichotomizing the subjects into 2 outcome groups (success or nonsuccess), each element of the history and physical examination was then analyzed to determine if it was a predictor of treatment success. Sensitivity (Sn), specificity (Sp), and likelihood ratios (LR) were calculated for each variable. Sn of a test reflects the true positive rate, and Sp of a test is the true negative rate.50 To calculate the Sn and Sp for each clinical measurement item, 2-by-2 contingency tables were used. When a zero cell value was encountered, 0.5 was added to all cell values in the table to permit calculation of LRs and their 95% confidence intervals (CI). Continuous variables were dichotomized using a receiver operator characteristic (ROC) curve.50 We defined the cut-off of a positive test to be the point on the curve nearest the upper left-hand corner that maximized the area under the curve, representing the value with the best diagnostic accuracy.50

Positive likelihood ratios (+LR), negative likelihood ratios (–LR), and their associated 95% CIs were also computed for all clinical measurement items. LRs were calculated as follows: +LR = Sn/(1 – Sp) and –LR = (1 – Sn)/Sp. The LR is the statistic most often used to determine the usefulness of a CPR. According to the **User’s Guide to Medical Literature,**2 a +LR greater than 10.0 or a –LR less than 0.1 generate large and often conclusive changes from pretest to posttest probability for a given condition. LRs of 5.0 to 10.0 and 0.1 to 0.2 generate moderate shifts in pretest-to-posttest probability. LRs of 2.0 to 5.0 and 0.5 to 0.2 generate small (but sometimes important) changes in probability, and LRs of 1.0 to 2.0 and 0.5 to 1.0 alter probability to a small (and rarely important) degree. We considered a +LR greater than 1.9 and a –LR less than 0.5 to be clinically meaningful.26,38 Because several variables in our study had +LRs between 1.9 and 2.0, we included any characteristic with a +LR greater than 1.9 to avoid discarding any
potentially useful predictors of intervention success.

A binary logistic regression model was used to develop a CPR for predicting treatment success with the lumbopelvic manipulation.29 A forward stepwise selection procedure was used to enter the variables of those who were in the treatment success group only. A liberal P value of .15 was chosen to prevent potentially useful variables from being excluded from the model.29 Clinical measurement items selected by the regression model as predictors of treatment success were combined into a clinical cluster for the CPR and were treated as a single test item. The Sn, Sp, and LR s for the CPR were calculated as previously described for other dichotomous variables.

RESULTS

Fifty subjects (26 male and 24 female) were enrolled in the study, and 49 were included in the data analysis. One subject was excluded from the study due to significant inconsistencies in self-reported symptoms to the 2 examiners. Subject demographics and baseline historical and physical examination items for the entire sample, as well as for the successful and nonsuccessful outcome groups, are shown in Tables 1 and 2. Interrater reliability data were collected on the first 25 subjects. Nine of the 26 (35%) measurements had moderate to good reliability based on a threshold greater than or equal to 0.40 for kappa values and greater than or equal to 0.50 for ICCs.36,50 The ICCs and kappa coefficients for the clinical measurement items are listed in Table 3, along with their associated standard error of measurement (SEMs).

Twenty-two (45%) of the 49 subjects were considered to be a treatment success, based on a 50% or greater improvement on the final composite NPRS or a score of at least +4 on the GRC. All 22 subjects were considered intervention successes based on just the NPRS score, and 17 of the 22 were considered successes based on the GRC score. Therefore, 17 of the subjects in the success group met the criteria for success on both the NPRS and the GRC. The composite NPRS score for each group (success, nonsuccess) at baseline and after the manipulation is depicted in Figure 2. The mean ± SD percent NPRS improvement in the success group was 80% ± 17%, while in the nonsuccess group, the mean improvement was 12% ± 28%. The median GRC for subjects in the success group was 5 (range, 0 to 7), while the median GRC score for the nonsuccess group was 1 (range, −1 to 3).

Based on the univariate analysis, 6 characteristics were identified as predictors of a successful treatment outcome based on their LR s. Of these 6 clinical predictors, 5 were identified by the logistic regression analysis to form a diagnostic test item cluster for treatment success. These 5 variables and their associated accuracy statistics are shown in Table 4. The combinations of these variables and the accuracy of the combinations for predicting treatment success are shown in Table 5. The number of subjects within each group (success, nonsuccess) that exhibited each of the predictors is shown in Table 6.
powerful predictor of treatment success of variables that proved to be the most increasing to 80%. The combination of a subject exhibited hip internal rotation asymmetry greater than 14° (+LR, 4.9; 95% CI: 1.2 to 20.8). If a subject exhibited a side-to-side hip internal rotation asymmetry greater than 14° (+LR, 4.9), the posttest probability of success increased markedly to 80%.

If a subject exhibited at least 3 of the 5 predictors, the posttest probability of success increased to 94%. The posttest probability of treatment success was 100% if a subject exhibited at least 4 of the variables constituting the CPR. However, the 3 latter combinations of predictors were associated with extremely wide CIs and in some instances crossed 1.0, creating uncertainty with the predictive accuracy and clinical application of this estimate (TABLE 5).

The pretest probability for the likelihood of treatment success with lumbopelvic manipulation was 45% (ie, 22 out of 49 subjects responded successfully to the intervention). The most robust predictor of treatment success was a side-to-side difference in hip internal rotation greater than 14° (+LR, 4.9; 95% CI: 1.2 to 20.8). If a subject exhibited hip internal rotation asymmetry greater than 14°, the clinician may still opt to perform the lumbopelvic manipulation technique. To our knowledge, no previous study has shown that lumbopelvic manipulation can lead to a reduction in symptoms in patients with PFPS. Forty-five percent of the subjects in our study experienced a successful immediate response to the manipulation, as defined by the criteria for success we established in this study. Based on this pretest probability (45%) of treatment success, if a subject exhibited a side-to-side hip internal rotation asymmetry greater than 14° (+LR, 4.9), the posttest probability of success increased markedly to 80%.

If a subject exhibited at least 3 of the 5 predictors, the posttest probability of success increased to 94%. The posttest probability for treatment success was 100% if a subject exhibited at least 4 of the variables constituting the CPR. However, the 3 latter combinations of predictors were associated with extremely wide CIs and in some instances crossed 1.0, creating uncertainty with the predictive accuracy and clinical application of this estimate (TABLE 5). Based on this observation, we suggest that clinicians can have greater accuracy and confidence when determining the likelihood that a patient will exhibit a rapid response to lumbopelvic manipulation by relying on the hip internal rotation asymmetry variable alone (+LR, 4.9; 95% CI: 1.2 to 20.8). If a patient does not demonstrate hip internal rotation asymmetry greater than 14°, the clinician may still opt to perform the lumbopelvic manipulation based on the presence of at least 3 of the remaining predictors.

One might argue that it would be more practical for the clinician to simply try the manipulation technique to see if the patient responds to the intervention, rather have symptoms and a functional status that change very little following the same treatment. The ability to predict a priori which patients will respond favorably to a specific intervention would be extremely beneficial to practicing clinicians. Therefore, the purpose of our study was to identify clinical examination items that are predictive of an immediate successful response to a specific lumbopelvic manipulation technique. To our knowledge, no previous study has shown that lumbopelvic manipulation can lead to a reduction in symptoms in patients with PFPS.
than taking the time to determine if the patient fits the CPR. However, given the various treatment strategies that have been proposed for the management of patients with PFPS, it seems impractical to use a trial-and-error approach for numerous possible interventions. Goniometric assessment of the most powerful predictor of treatment success, hip internal rotation, can be obtained readily in the clinic setting. Furthermore, a side-to-side difference in hip internal rotation of at least 14° is clearly evident with the patient lying in the prone position (FIGURE 3).

The fact that a measure related to hip range of motion was the most robust predictor of treatment success is consistent with recent published studies suggesting that impairment of the lumbopelvic-hip complex is associated with PFPS. In a case report, Cibulka and Threlkeld-Watkins described evaluation and intervention for a patient with a side-to-side difference in hip internal rotation of 20°. The patient also exhibited weakness of the hip internal rotator and abductor muscles on the involved side, and was treated with a 2-week regimen of stretching and strengthening exercises aimed at addressing these impairments. Based on the patient’s successful outcome, the authors concluded that femoral or hip joint asymmetry may be related to patellofemoral pain. Similarly, Powers reported that excessive femoral rotation during weight-bearing activities may contribute to PFPS, and recommended that interventions aimed at controlling hip and pelvic motion should be considered when treating patients with PFPS.

Several investigators have suggested that proximal hip muscle weakness, particularly of the hip abductors and external rotators, may be associated with patellofemoral pain, and Tyler and colleagues showed that improvements in hip flexor strength and flexibility were associated with symptomatic improvement in patients with PFPS. The implication of the findings of these studies is that addressing proximal impairments may be an important element in the successful rehabilitation of patients with PFPS.

**Outcome Measures**

We defined treatment success as either an at least 50% improvement on the composite NPRS or at least a 4-point change on the GRC questionnaire. By setting our reference criteria at 50%, we were confident that we identified those subjects who experienced a clinically meaningful positive immediate response to the manipulation. While results indicate an association between the manipulative intervention and outcome, our study design is not sufficient to establish a cause-and-effect relationship. In particular, the lack of a control...
group or competing intervention and the fact that we measured an immediate response to the treatment leave the possibility that a placebo effect took place for those expressing a reduction of symptoms. It is important to emphasize that we developed the CPR based only on the subjects’ immediate response to the intervention. Although duration of symptoms did not emerge as a predictor variable in the CPR, the participants in this study generally had chronic PFPS (mean duration of symptoms, 95 weeks). Nevertheless, the development of the current CPR is a reasonable initial foray at identifying the characteristics of patients with PFPS who are most likely to experience symptomatic improvement following manipulation of the lumbopelvic region. Future validation of the proposed CPR in a randomized clinical trial is required and should include a longer follow-up period.

Additionally, the CPR developed in this study was based on establishing the predictive validity of a limited number of examination variables. We recognize that the clinical examination we performed was selective and may not have included some items that otherwise might have emerged as predictors of intervention success. For instance, we did not include the assessment of hip external rotator muscle strength in the physical examination. Several investigators recently identified weakness of the hip external rotator muscles as a possible contributing factor in individuals with PFPS. Therefore, assessment of the strength of this muscle group should be included in future studies aimed at validation of the proposed CPR. The clinical examination items included in this study were chosen because in our opinion they (1) are routinely obtained from patients with knee pain, (2) are measures that guide clinical

<table>
<thead>
<tr>
<th>Predictor of Success</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>+LR</th>
<th>−LR</th>
<th>Cutoff Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference in hip IR (deg)</td>
<td>0.36 (0.16, 0.56)</td>
<td>0.93 (0.83, 1.02)</td>
<td>4.9 (12, 20.8)</td>
<td>0.7 (0.5, 1.0)</td>
<td>&gt;14°</td>
</tr>
<tr>
<td>Ankle dorsiflexion with knee flexed (deg)</td>
<td>0.59 (0.39, 0.80)</td>
<td>0.70 (0.53, 0.86)</td>
<td>2.0 (10, 39)</td>
<td>0.6 (0.3, 1.0)</td>
<td>&gt;16°</td>
</tr>
<tr>
<td>Navicular drop (mm)</td>
<td>0.64 (0.44, 0.84)</td>
<td>0.67 (0.49, 0.84)</td>
<td>1.91 (10, 36)</td>
<td>0.5 (0.3, 1.0)</td>
<td>&gt;3 mm</td>
</tr>
<tr>
<td>No stiffness with sitting &gt;20 min (%)</td>
<td>0.73 (0.54, 0.91)</td>
<td>0.63 (0.45, 0.81)</td>
<td>2.0 (13, 34)</td>
<td>0.4 (0.2, 0.9)</td>
<td>NA</td>
</tr>
<tr>
<td>Squatting is most painful activity</td>
<td>0.59 (0.39, 0.80)</td>
<td>0.74 (0.58, 0.91)</td>
<td>2.3 (11, 47)</td>
<td>0.6 (0.3, 1.0)</td>
<td>NA</td>
</tr>
</tbody>
</table>

* Success defined as an immediate 50% or greater pain reduction or moderate (+4 or greater) improvement on the Global Rating of Change scale for functional activities consisting of squatting, stepping up a 20-cm step, and stepping down a 20-cm step. 95% confidence intervals shown in parentheses.

<table>
<thead>
<tr>
<th>Variables Present</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>+LR</th>
<th>−LR</th>
<th>Probability of Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>All 5 predictors</td>
<td>0.09 (0.02, 0.31)</td>
<td>1.00 (0.84, 100)</td>
<td>Infinite (0.31, infinite)</td>
<td>0.91 (0.78, 1.1)</td>
<td>100% (20-100)</td>
</tr>
<tr>
<td>At least 4 predictors</td>
<td>0.32 (0.15, 0.55)</td>
<td>1.00 (0.84, 100)</td>
<td>Infinite (0.90, infinite)</td>
<td>0.68 (0.51, 0.92)</td>
<td>100% (47-100)</td>
</tr>
<tr>
<td>At least 3 predictors</td>
<td>0.68 (0.45, 0.86)</td>
<td>0.96 (0.81, 100)</td>
<td>18.4 (3.6, 105.3)</td>
<td>0.33 (0.17, 0.55)</td>
<td>94% (68-99)</td>
</tr>
<tr>
<td>At least 2 predictors</td>
<td>0.91 (0.71, 0.99)</td>
<td>0.56 (0.35, 0.75)</td>
<td>2.05 (1.3, 2.9)</td>
<td>0.16 (0.04, 0.69)</td>
<td>63% (50-70)</td>
</tr>
<tr>
<td>At least 1 predictor</td>
<td>0.91 (0.71, 0.99)</td>
<td>0.15 (0.04, 0.35)</td>
<td>1.1 (0.87, 1.3)</td>
<td>0.61 (0.12, 3.0)</td>
<td>47% (41-52)</td>
</tr>
</tbody>
</table>

* 95% confidence intervals in parentheses.
† The probability of success is calculated using the +LR and assumes a pretest probability of 45%.

### TABLE 6

The 5 Variables Forming the Clinical Prediction Rule and the Number of Subjects in Each Group at Each Level

<table>
<thead>
<tr>
<th>Number of Predictor Variables Present</th>
<th>Successful Outcome Group</th>
<th>Nonsuccessful Outcome Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
decision making for lumbopelvic manipulation, and (3) allow for comparison of the results of the present study with our previous work. 39,69

It is possible that the predictor variables that emerged in this developmental study may have occurred by chance. However, we believe that each of the physical examination variables that emerged as predictors of a successful response to lumbopelvic manipulation are biologically plausible in subjects with PFPS, and that the predictors that surfaced from the history are also relevant in this population. Nevertheless, future investigations should include all relevant clinical examination variables and larger sample sizes to minimize the possibility that predictors emerge by chance.

Possible Mechanisms for Successful Response to Lumbopelvic Manipulation

A reduction in distal muscle inhibition immediately following the manipulation may affect or contribute to a patient’s primary complaint. 14,64,77 The biomechanical link between the lumbopelvic-hip complex and the knee region suggests that alterations in joint mobility in the lumbar spine, SIJ, or hip joint may serve as an underlying contributor to the development of patellofemoral pain. For instance, previous research has shown that femoral internal rotation during weight-bearing activities can influence patellar alignment and kinematics. 32,60 Furthermore, impairments in femoral rotation have been associated with individuals with PFPS. 53 Given that hip internal rotation asymmetry was the most powerful predictor of treatment success in the current study, it is certainly plausible that the manipulation worked by affecting lower extremity kinematics. 56 However, we did not use any imaging techniques in our study, nor did we repeat any of the clinical measurements after the manipulation and, therefore, do not know if a change in hip internal rotation asymmetry occurred following the treatment. In our subjects there was no consistent pattern with regard to hip internal rotation range of motion being greater on the side of the symptomatic versus the asymptomatic lower extremity. A current investigation in this laboratory is directed at determining whether a successful response to the manipulation is correlated with a reduction or correction of hip internal rotation asymmetry in subjects with PFPS who meet the CPR. It is interesting that the presence of a hip internal rotation measurement was also a predictor of a successful response to manipulation in patients with low back pain, 2,19 suggesting that there may be a common underlying mechanism or biomechanical link for a successful response to this treatment technique. None of the subjects in the current study reported having low back pain. It is important to note that the lumbopelvic manipulation used in this study is contraindicated in individuals with serious spinal conditions, with signs of nerve root compression, who are pregnant, and who have previous surgery to the lumbar spine, pelvis, or buttock. 3,19

Interrater Reliability

In addition to developing the CPR, we examined the interrater reliability of the measurements obtained in our study. Nine of the 26 (35%) clinical measurements exhibited moderate to good reliability. 36,50 The low interrater reliability for some of the measures may pose a threat to the internal validity of our investigation and ultimately limit the interpretation and application of the CPR. Taking a mean value of multiple measurements may have provided improved reliability values, 50 but we chose to obtain each measurement just once because we believe this is most representative of what is done in clinical practice.

The ICC for the measurement of hip internal rotation was 0.45, which is consistent with reliability values reported for the same measure in previous studies of healthy individuals (ICC = 0.44 to 0.51) 73 and patients with unilateral hip osteoarthritis (ICC = 0.48), 56 but much lower than the goniometric and inclinometer values reported by Ellison and colleagues 17 in their study of healthy individuals and subjects with low back pain (ICC = 0.96 to 0.99). The method error as it relates to the coefficient of variation (CVMI) can be used when examining response stability because it reflects percentage of variation from trial to trial. 2,9 The CVMI for hip internal rotation was 17% (equivalent to 5°-8°), which we considered to be an acceptable level. A Cohen kappa coefficient (κ) was calculated to determine the chance-corrected agreement between raters for this predictor (κ = 0.71). A more clinically meaningful way to examine the reliability data for this continuous variable is in a dichotomous fashion (greater than 14° or less than or equal to 14°), which is how it would be used in the context of this CPR. 2,9 For instance, how often did the raters agree that a subject had a greater than 14° measurement of hip internal rotation asymmetry? The percent agreement between the raters using the
Subjects With Bilateral PFPS
A possible limitation of our study was the fact that the majority of our data were taken from individuals with bilateral knee pain. Thirty-two of the 49 subjects who completed the study presented with bilateral PFPS. Therefore, one might argue that our results were potentially biased due to a lack of independence of data. To examine this issue, we compared the NPRS scores between subjects with unilateral PFPS and those with bilateral pain. Descriptive statistics were calculated for the mean percent NPRS change scores of the 17 subjects with unilateral knee pain and compared with the mean percent NPRS change scores of 17 randomly selected subjects with bilateral pain. The mean NPRS change score in the subjects with unilateral pain was 38.8% (SD, 39.2%), and the mean NPRS change score in subjects with bilateral pain was 39.1% (SD, 46.1%). These results suggested that the subjects with bilateral PFPS responded similarly to those with unilateral knee pain. While the internal validity of data from future studies of PFPS may be strengthened by including only subjects with unilateral knee pain, we believe that the inclusion of subjects with bilateral symptoms is more reflective of clinical practice and will ultimately increase the generalizability of future investigations.

Conclusion
We developed a CPR that identified the characteristics of patients with PFPS who would experience an immediate, positive response to treatment with lumbopelvic manipulation, as based on a 50% or greater reduction in the composite NPRS or a score of +4 or higher on the GRC for 3 functional tests (squatting, stepping up a 20-cm step, and stepping down a 20-cm step). Based on the results of this preliminary study, patients with PFPS who demonstrate a side-to-side difference in hip internal rotation range of motion greater than 14° and are treated with a lumbopelvic manipulation have an 80% posttest probability of experiencing a positive outcome. However, future studies are necessary in light of a limited sample size, the marginal reliability of some predictors, and the potential omission of possibly useful clinical examination variables in this study. The predictors identified in this study may help investigators assemble a more homogenous subgroup of patients with PFPS for a future validation study in the form of a randomized clinical trial, which is necessary before the CPR can be used confidently in the clinic.

Key Points
Findings: A preliminary CPR was developed to predict an immediate successful response to lumbopelvic manipulation in patients with patellofemoral pain syndrome (PFPS). The most robust predictor of a successful response to the manipulation was a side-to-side difference in hip internal rotation range of motion of greater than 14°.

Implication: The clinical prediction rule developed in this study may help clinicians identify patients with PFPS who will respond successfully to lumbopelvic manipulation.

Caution: Limitations of this study included a small sample size (n = 49), marginal reliability of some predictors, and the omission of some potentially useful clinical examination variables. Future randomized clinical trials are needed to validate the findings of this study.

References
17. Ellison JB, Rose SJ, Sahrman PA. Patterns

Cutoff score of greater than 14° was 76%, while the kappa coefficient (κ) was 0.32, which is considered poor to fair.36


61. Salsich GB, Brechter JH, Farwell D, Powers CM. The effects of patellar taping on knee kinetics, kinematics, and vastus lateralis muscle activi- ty during stair ambulation in individuals with
Compared to your condition prior to treatment with the manipulation, which item on the scale below best describes your present condition (choose only one):

**Patient Global Rating Scale**

- A very great deal worse
- A great deal worse
- Quite a bit worse
- Moderately worse
- Somewhat worse
- A little bit worse
- A tiny bit worse (almost the same)
- About the same
- A tiny bit better (almost the same)
- A little bit better
- Somewhat better
- Moderately better
- Quite a bit better
- A great deal better
- A very great deal better

**APPENDIX A**

**GLOBAL RATING OF CHANGE QUESTIONNAIRE**

Compared to your condition prior to treatment with the manipulation, which item on the scale below best describes your present condition (choose only one):

**Patient Global Rating Scale**

- A very great deal worse
- A great deal worse
- Quite a bit worse
- Moderately worse
- Somewhat worse
- A little bit worse
- A tiny bit worse (almost the same)
- About the same
- A tiny bit better (almost the same)
- A little bit better
- Somewhat better
- Moderately better
- Quite a bit better
- A great deal better
- A very great deal better

**MORE INFORMATION**

[www.jospt.org](http://www.jospt.org)
APPENDIX B

QUESTIONS USED TO OBTAIN INFORMATION DURING THE HISTORY-TAKING SESSION

How long have you had your present episode of knee pain?
Is your knee pain on just one side or both?
  • If you experience pain in both knees, is one side worse than the other?
  • If yes, which side is worse?
Was there trauma associated with the onset of the present episode of pain?
Do you have a prior history of knee pain?
Have you ever had surgery on either knee? If yes, on which knee?
Do you have a history of any systemic diseases (diabetes, rheumatoid arthritis, heart disease, etc)?
Females: Are you pregnant?
With regards to your knee, do you ever experience:
  • Locking?
  • Giving way?
  • Clicking?
  • Crepitus (grinding or crunching noises)?
  • Swelling?
Does your knee get stiff after sitting still for more than 20 minutes?
Which of the following activities is MOST painful for you:
  • Squatting
  • Up steps
  • Down steps
  • Running
  • Lifting

APPENDIX C

OPERATIONAL DEFINITIONS FOR TESTS AND MEASURES

**Tibial Torsion**
Measured with the subject placed in the prone position, with the patellae placed on a widthwise line on the plinth.13 With the knee flexed to 90°, the investigator measured tibial torsion as the angle created by the line on the table and a line bisecting the malleoli

**Subtalar Joint Neutral (Non-Weight Bearing)**
Measured with the subject in prone and the knees extended. The investigator drew 2 lines on the subject using a felt-tipped pen. The first was a line bisecting the lower leg, and the second bisected the calcaneus. The subject was placed by the investigator into what we believed was subtalar joint neutral judged by palpation of the head of the talus, and measurements of subtalar joint neutral (measured as the angle between the 2 lines)13 were taken

**Measurements for Forefoot Alignment**
Taken using the same subtalar neutral position and forefoot alignment.24 The angle created by an axis perpendicular to the calcaneal line previously drawn and an axis along the metatarsal heads was measured as forefoot alignment

**Ankle Dorsiflexion (Active)**
Measured with the knees flexed and with the knees extended in the prone position with the feet and ankles off the edge of the plinth

**Measurements of Hip Internal Rotation**
Taken with the subject in prone and the knees both flexed to 90° (FIGURE 3)

**The Craig Test**
Performed to determine if femoral retroversion or anteversion was present as described according to Magee10

**Hip Extensor Manual Muscle Testing on a 5-Point Scale**
Performed with the patient prone and the knees flexed10

**Relaxed Calcaneal Stance**
Measured with the subject standing on a 20-cm step stool. The subject stood relaxed with the feet 15 cm apart as the examiner measured the angle between the 2 lines previously drawn on the leg and heel12

**Tibial Angulation**
Measured with the patient standing relaxed on the 20-cm step stool with the feet 15 cm apart. Tibial angulation was measured as the angle created by the line on the lower leg with a line created by the surface of the step stool. Tibial valgum was recorded if the proximal tibia was more medial than the distal tibia, and tibial varum was recorded if the proximal tibia was more lateral than the distal tibia

**Navicular Drop**
Measured with the patient assuming a stance position on the floor with feet 15 cm apart (maintained by placing a wooden block between the subject’s heels before each measurement, then removing it to perform the measurement).49 The navicular drop measurement was taken by marking a dot on the navicular tuberosity using a felt tipped pen. The subject then shifted their weight away from the side to be measured. The foot was then placed by the examiner into subtalar joint neutral, and a mark was made on an index card placed vertically next to the navicular tuberosity and flush with the floor. The subject was then asked to relax his or her stance onto both feet, and the new position of the navicular tuberosity was marked on the same index card. The difference between the 2 markings was measured in millimeters and reflected the navicular drop or rise49

**Q-Angle**
Measured as described by Magee42

**Pelvic Obliquity**
Measured using the palpation meter (PALM) as described by Petrone.47 After the Q-angle measurement was taken, the subject was asked to march in place 5 times, ending with the feet 15 cm apart. With the subject remaining in the standing position with the feet 15 cm apart, the standing flexion test and stork test were performed as described by Magee to indicate the presence or absence of sacroiliac joint abnormality40
First Metatarsophalangeal (MTP) Joint Extension
Measured with the subject in the tailor-sit position on the edge of the plinth (one ankle crossed over the contralateral knee). In this position, a measurement of the great toe passive extension was taken. The stationary arm of the goniometer was positioned parallel to the first metatarsal, the moving arm was positioned along the proximal phalanx of the great toe, and the axis of motion was at the first MTP joint.

McConnell’s Test
Used as a provocative test to reproduce PFPS pain with the subject sitting on the edge of the plinth with both knees flexed. The examiner placed the knee into varying degrees of flexion (0°, 30°, 60°, 90°, and 120°). At each position, the subject isometrically contracted the quadriceps against resistance from the examiner. If pain was produced at one of those positions, a second isometric contraction was then performed at the same angle with the patella manually glided medially by the examiner. The test was positive if the subject’s pain was significantly reduced with the patella glided medially. The subject then moved to the edge of the plinth so that both feet contacted the floor. From this starting position, the Thomas test was used to measure hip flexor or quadriceps tightness. A positive test was indicated if the angle of knee flexion was less than 80°.

The 90/90 Straight-Leg Raise Test
Performed with the subject in supine and the hip and knee of the limb to be tested flexed to 90°. Normal hamstring flexibility was documented if the subject was able to extend the knee to within 20° of full extension.

The Patellar Glide Test
Used to assess patellar position. With the subject supine and the knees extended, the examiner marked the center of the patella and the medial and lateral epicondyles. The test was positive if the center of the patella was greater than or equal to 0.5 cm from the point halfway between epicondyles, measured by a tape measure.

The Patellar Tilt Test
Used to assess patellar mobility as the examiner glided the patella laterally and attempted to lift the lateral border of the patella anteriorly. The measurement was recorded as: no lift, lift to neutral, or lift above the horizontal plane.

The Lateral Patellar Pull Test
Detects any excessive lateral pull of the patella by the quadriceps or from the lateral retinaculum. The subject, in supine, isometrically contracted the quadriceps as the examiner observes the path of the patella. A positive test was indicated if there was greater lateral than superior movement of the patella.

Ober’s Test
Used to assess the presence or absence of iliobibial band tightness with the patient in the sidelying position.

A Manual Muscle Test of the Gluteus Medius
Performed as described by Kendall.

INVITED COMMENTARY
The article by Iverson et al regarding the use of lumbopelvic manipulation as a treatment for patellofemoral pain raises some interesting questions and, at the same time, poses some potential concerns. I appreciate the opportunity to comment on this study and hope to stimulate some discussion within the clinical and research communities.

The theoretical construct underlying the use of lumbopelvic manipulation to treat patellofemoral pain is based on 2 studies that have shown that lumbopelvic manipulation decreases quadriceps inhibition and increases quadriceps muscle strength in persons with patellofemoral pain. In their introduction, Iverson et al correctly point out that a limitation of these 2 previous studies was that investigators did not measure the symptomatic responses of their subjects. As a result, it could not be determined whether the observed change in quadriceps muscle function resulting from manipulation had any bearing on patellofemoral symptoms. However, one could argue that the current study is equally limited, in that the potential causes for the observed decrease in pain in those who responded to manipulation were not quantified.

Unlike the spine, where a manipulative procedure would be expected to have a direct mechanical influence on a functional spinal unit, the link between manipulation and the patellofemoral joint is not as obvious. In their discussion, the authors proposed 2 possible hypotheses to explain why certain patients may respond favorably to lumbopelvic manipulation: (1) improved quadriceps function and (2) the concept of regional interdependence. I would like to comment on both of these proposed hypotheses, as well as offer some alternative explanations.

The premise that improved quadriceps force production would result in a decrease in patellofemoral symptoms is in contrast to what is known about patellofemoral joint biomechanics. Given that the forces generated by the quadriceps muscle group are responsible for the compressive loads experienced by the patella, one could argue that an increase in quadriceps muscle action would increase patellofemoral joint stress and, therefore, pain. For example, if a patient performed a knee extension maneuver with a 5-kg ankle weight, and this activity reproduced pain, would increasing the weight to 6 kg be expected to cause a decrease in symptoms? While I appreciate the fact that improved quadriceps strength has been shown to be associated with better long-term outcomes in this population, one must be careful in using this argument to make a case in explaining immediate changes in pain.

An alternative explanation proposed by the authors to explain the favorable response seen in their success group is based on concept of regional interdependence (ie, that impairments in remote regions may contribute to the patient’s primary complaint). This theory makes more sense from a mechanistic standpoint, particularly because recent studies have pointed to abnormal hip function as being contributory to patellofemoral joint problems. To make a valid argument for the concept of regional interdependence, however, it would have to be shown that manipulation resulted in a change in...
a remote impairment that could explain a change in symptoms. With that being said, there is no reason to suspect that lumbopelvic manipulation would have an influence on the most powerful predictor of treatment success found in this study (ie, side-to-side differences in hip internal rotation range of motion greater than 14°). However, given the recent focus on diminished gluteus maximus and medius function in this population, it would be interesting to know if lumbopelvic manipulation had an influence on the activation of these muscles, along with possible alterations in lower-extremity alignment during functional testing.

Apart from the theories put forth by the authors, one cannot discount the possibility of a placebo effect in this study. The placebo effect is well documented in studies evaluating the immediate effects of pain relief using various interventions in persons with patellofemoral pain. For example, a study by McCrory et al demonstrated that a placebo brace condition resulted in a 30% decrease in patellofemoral symptoms, which was similar in magnitude to the actual brace condition. Similarly, Christou reported that a sham tape condition reduced pain by 70%, which was statistically similar in magnitude to the actual tape condition (80% reduction in pain). A recent systematic review and meta-analysis of studies evaluating the effects of patella taping and bracing on chronic knee pain concluded that approximately 50% of the benefit of medially directed tape could be explained by sham treatment effects. Although it could be argued that a sham intervention that provides local sensory input and/or proprioceptive feedback may produce a stronger placebo effect than a remote intervention such as lumbopelvic manipulation, one cannot discount the possibility of a placebo effect in this study.

Another possible explanation for the decrease in symptoms in the success group may be related to “pain avoidance” behavior. For example, it has been suggested that individuals with patellofemoral pain adopt compensatory movement strategies when asked to perform activities that reproduce symptoms. Subtle, self-selected changes in foot position, trunk position, and knee flexion angle could explain changes in pain levels with repeated provocative testing. While I applaud the authors’ efforts to propose possible treatment approaches for a difficult clinical problem, I would argue that additional data are needed before lumbopelvic manipulation can be considered a viable treatment option for patellofemoral pain. Most importantly, it needs to be established whether the decrease in pain associated with manipulation has any lasting effect. I would be more persuaded of the value of lumbopelvic manipulation if pain reduction could be maintained following a vigorous bout of activity (eg, a 20-minute run) or at least persisted 24 to 48 hours. While spinal manipulation has been shown to benefit persons with acute low back symptoms, it is relevant to wonder whether the decrease in pain associated with manipulation has any lasting effect on persons with chronic symptoms (subjects in the current study had an average length of symptoms of 95 weeks).

Lastly, I would encourage future investigations in this area to address some of the methodological issues that were acknowledged in the current study. In particular, the poor reliability of predictor measures that were obtained, combined with the small sample size for the number of prediction variables under consideration, casts a level of suspicion on the stability of the proposed clinical prediction rule. I would urge the authors to consider these issues as they move forward in replicating these findings and/or validating the proposed clinical prediction rule. Furthermore, the addition of objective measures to support an underlying mechanism behind the apparent effectiveness of lumbopelvic manipulation in a subgroup of patients with patellofemoral pain would provide a more compelling argument for this treatment approach.

Christopher M. Powers, PT, PhD
Division of Biokinesiology and Physical Therapy

Musculoskeletal Biomechanics Research Laboratory
University of Southern California
Los Angeles, CA

REFERENCES
We appreciate Dr Powers’ comments in response to our paper entitled “Lumbopelvic manipulation for the treatment of patients with patellofemoral pain syndrome: development of a clinical prediction rule.” We hope that discussion of this study will stimulate further questions, ideas, and research that ultimately contribute to the successful management of patients with this challenging disorder.

As stated in our paper, this was a preliminary study and the initial step in the development of a clinical prediction rule that identifies patients with patellofemoral pain syndrome (PFPS) who respond successfully to lumbopelvic manipulation. We also acknowledged that there were a number of limitations in this developmental study. Dr Powers stated that one of the limitations of our study was the fact that “the potential causes for the observed decrease in pain in those who responded to manipulation were not quantified.” However, the research design that we employed in this study does not allow us to elucidate or quantify the reasons for the observed pain relief in those who responded to the manipulation. We can only be sure that we predicted who responded to manipulation. We think it is plausible that the manipulation may have simply facilitated normal activation of the quadriceps muscles.

An alternative explanation that we proposed for the clinical improvement seen in the success group is based on the concept of regional interdependence.

Based on this theory, alterations in joint mobility in remote regions such as the lumbar spine, sacroiliac joint, or hip may contribute to the development of PFPS. Given that hip internal rotation asymmetry is the most powerful predictor of treatment success in the current study, it is possible that the manipulation worked by affecting lower extremity kinematics. We agree with Dr Powers’ statement that this explanation makes more sense from a mechanistic viewpoint, in light of the growing body of evidence which suggests that impairments in the hip joint and gluteal region are associated with PFPS.

Dr Powers also stated that a placebo effect may have occurred in our study, and we certainly agree that this is possible. As he noted, the placebo effect is well documented in investigations involving other treatments in individuals with patellofemoral pain. Future studies that include control subjects and possibly sham interventions are necessary to determine the efficacy of the treatment that we used in the current study. A future validation study in the form of a randomized clinical trial is necessary before the proposed clinical prediction rule can be used confidently in the clinic.

We developed a preliminary clinical prediction rule and recognize that other limitations of the study include a short follow-up period, a limited sample size, and marginal reliability of some of the predictors of treatment success, as delineated in the discussion and conclusion sections. As Dr Powers suggested, future replication or validation studies should address each of these issues. Nevertheless, we believe that the current study was a reasonable initial investigation to identify persons with PFPS who may benefit from lumbopelvic manipulation with less pain.

Authors’ Response


benefit from lumbopelvic manipulation. We hope that our findings will eventually contribute to the development of a useful clinical decision-making model for the effective management of patients with the condition.

Christine A. Iverson, PT, DPT
Blanchfield Army Community Hospital
Fort Campbell, KY

Thomas G. Sutlive, PT, PhD
US Army-Baylor University Doctoral Program in Physical Therapy
San Antonio, TX

Josef H. Moore, PT, PhD
US Army-Baylor University Doctoral Program in Physical Therapy
Fort Sam Houston, TX

Robert S. Wainner, PT, PhD
Texas State University
San Marcos, TX

REFERENCES