Journal of Orthopaedic & Sports Physical Therapy
Official Publication of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association

# Development of a Clinical Prediction Rule for Classifying Patients With Patellofemoral Pain Syndrome Who Respond to Patellar Taping

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**Study Design:** Predictive validity/diagnostic test study.

**Objective:** To determine the predictive validity and interrater reliability of selected clinical exam items and to develop a clinical prediction rule (CPR) to determine which patients respond successfully to patellar taping.

**Background:** Patellar taping is often used to treat patients with PFPS. However, the characteristics of the patients who respond best to patellar taping intervention have not been identified.

**Methods and Measures:** Fifty volunteers (27 males, 23 females) with PFPS underwent a standardized clinical examination. Diagnosis of PFPS was based on the complaint of retropatellar pain that was provoked by a partial squat or stair ascent/descent. Subjects performed 3 functional activities and rated their pain during each activity on a numerical rating scale (NPRS). All subjects received treatment with a medial glide patellar-taping technique and repeated the functional activities and pain ratings. An immediate 50% reduction in pain or moderate improvement on a global rating of change (GRC) questionnaire was considered a treatment success. Likelihood ratios (LRs) were calculated to determine which examination items were most predictive of treatment outcome. Logistic regression analysis identified items included in the CPR.

**Results:** Twenty-six subjects (52%) had an immediate successful response to the intervention. Two examination items (positive patellar tilt test or tibial varum greater than 5°, +LR = 4.4) comprised the CPR. Application of the CPR improved the probability of a successful outcome from 52% to 83%. Fifty-eight percent of the lower extremity measures were associated with moderate to good reliability (reliability coefficient range, 0.52-0.84). The reliability coefficients for the items that comprised the CPR were 0.49 (patellar tilt) and 0.66 (tibial varum).

**Conclusion:** A CPR was developed to predict an immediate successful response to a medial glide patellar taping technique. Validation of the CPR in an independent sample is necessary before widespread clinical use can be recommended. *J Orthop Sports Phys Ther 2006; 36(11):854-866.* doi:10.2519/jospt.2006.2208

***Key Words:*** *bracing, knee pain, physical examination, physical therapy, rehabilitation*

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Patellofemoral pain syndrome (PFPS) is a significant clinical problem and the most prevalent knee disorder seen in many physical therapy and orthopedic clinics.[20,33,53] Despite its prevalence, the etiology of the disorder remains unclear.[34,42,46,47,53,58,59,62] The most widely accepted theory for the etiology of PFPS suggests that it results from abnormal patellar tracking.[34,42,46,47,58,59,62] Alternatively, Dye and colleagues[12] suggested that the onset of PFPS may be due to a complex pathophysiologic process that includes peripatellar synovitis, increased intraosseous pressure and remodeling.

Because of the multifactorial nature of PFPS, numerous intervention strategies have been proposed for the disorder. One technique that has gained acceptance as an effective component of treatment for anterior knee pain is patellar taping.[8,43,67] Australian physical therapist Jenny McConnell developed patellar taping and reported a 96% success rate using taping as a component of a treatment regimen for PFPS.[43] The approach is based largely on the premise that patellar malalignment and a poorly tracking patella can lead to patellofemoral pain.[43] The aim of patellar taping is to create a mechanical shift of the patella, thereby purportedly centering the patella within the trochlear groove and improving patellar tracking.[9]

Since McConnell's landmark paper,[43] several clinical trials demonstrated that patellar taping can be an effective part of an intervention plan for reducing pain and improving function in patients with PFPS, but effect sizes vary.[2,8,48,66,67] While evidence suggests that taping can be effective, no published study has identified specific clinical examination variables that are predictive of which patients with the condition will respond successfully to patellar taping. Identification of these variables would provide clinicians with a useful clinical decision-making tool and may help increase the efficacy of the technique. Furthermore, development of a clinical prediction rule (CPR) to identify patients likely to succeed with patellar taping would both enhance clinical decision making, reduce treatment time, and result in optimum outcomes.[38,44]

Therefore, the purpose of our study was 2-fold: (1) to determine the interrater reliability and predictive validity of selected clinical examination items for identifying patients who would respond to patellar taping, and (2) to develop a CPR derived from the clinical examination findings that would incorporate the fewest clinical variables and provide the most certain outcome. To do so, all subjects needed to undergo the same tests and measures, receive identical treatment, and be compared against the same reference standard (ie, response to treatment).[44] The diagnostic value of each test, measure and historical question was calculated to determine the characteristics of the subjects who responded best to the intervention. Thus, the research design employed in this investigation was one traditionally used in CPR or diagnostic accuracy studies.[6,17]

## METHODS

### Subjects

Fifty subjects were recruited from the active duty and beneficiary population at Fort Sam Houston in San Antonio, TX. Twenty-seven males and 23 females between the ages of 18 and 36 years (mean ± SD, 22.8 ± 4.2 years) were enrolled, and all subjects completed the study. Subjects were included if they were military healthcare beneficiaries between the ages of 18 and 50 and had a clinical diagnosis of PFPS. Because the predominant symptom of PFPS is retropatellar pain that increases during weight-bearing activities such as running, squatting, and stair climbing,[21,28,43] the diagnosis of PFPS was determined by the complaint of retropatellar pain that was provoked by either a partial squat or stair ascent/descent.[10,43,54,59] Exclusion criteria included an abnormal neurological status, a recent history of trauma to the knee, ligamentous laxity of the painful knee, palpation tenderness of the joint lines or patellar tendon, or a history of any of the following: prior knee surgery on the symptomatic knee, systemic disease, neurologic disease, or connective tissue disease. Subjects who reported additional lower extremity conditions, such as stress fractures or shin splints, or those already receiving treatment for their knee pain were also excluded. All subjects were required to be fluent in the English language. 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) is a self-reported measure that established pain levels after the subject performed 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.[55,56] After performing each of the 3 functional tests, subjects were instructed to circle the number on the NPRS that best represented their knee pain. A mean NPRS score (average score from the 3 functional tests) was established for each subject and used for data analysis.

*Global Rating of Change Questionnaire* The GRC scale is a single-item, self-reported measure used to measure the subject's impression of the change in his or her condition following an intervention. A GRC questionnaire measures the overall changes in the quality of life of the subject.[32] The use of a GRC is a common, feasible, and useful method for assessing outcome,[30] and has been shown to be a valid measurement of change in patient status in other pain populations.[16] For the GRC the subjects were instructed to check the statement that best represented their status in response to the patellar taping intervention (Appendix A).

## Examination Items

A list of all clinical tests and measures performed on each subject, along with their operational definitions and measurement properties, is shown in Appendix B. The symptomatic knee was considered the unit of analysis. All measurements were taken on the side of the symptomatic knee and all angular measurements were taken with a 17.8-cm (7-in) plastic goniometer.

## Procedures

Following the history (demographic data, duration of current symptoms, time since previous episode, history of knee locking or giving way, clicking, swelling, or crepitus; see Appendix C) and a lower extremity neurological screening, the subject was instructed to remove his or her shoes and socks and lie prone on the examining table. The symptomatic leg was extended so that the ipsilateral foot hung off the end of the table and the contralateral knee was flexed to 90° with the hip externally rotated (figure-4 position as described by Donatelli[11]). 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 on the same side of the symptomatic knee was bisected with a marker, and the navicular tuberosity was marked with a dot. The battery of clinical measurements then commenced, as listed in Appendix B, on the side of the symptomatic knee only. To prevent order effects as well as expedite the examination process, the first examination item was alternated sequentially. The series of tests and measures were repeated by a second examiner on the first 30 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.

**FIGURE 1.** Application of patellar tape using the medial glide technique. The examiner displaced the subject's patella medially with her thumb and a single piece of tape was applied to maintain the patella in position. The arrow indicates the direction of pull of the tape.

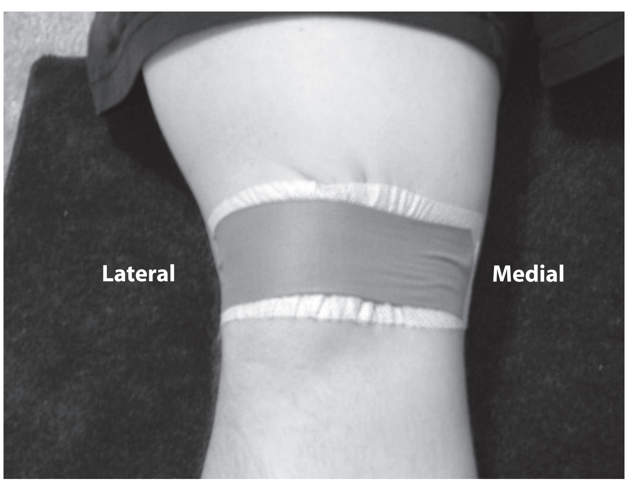


**FIGURE 2.** Patellar tape (medial glide technique) applied to subject's knee.

After the clinical measurements were obtained, 3 functional activities (stepping up onto a 20-cm step, stepping down from a 20-cm step, and squatting) were performed by each subject. After each functional test, the subject immediately assessed his or her knee pain during the activity and circled the number that represented their 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 after the patellar tape was applied. After the first set of functional tests was performed, the subject returned to the examining table to the supine position, with legs extended and relaxed. The second examiner applied the patellar tape using a medial glide component as described by McConnell (Figures 1 and 2). The examiner displaced the subject's patella medially with her thumb and a single piece of tape was applied to maintain the patella in position. Several authors report that an excessive lateral tilt[18,19,43,68] or displacement[18,43,68] of the patella, with an associated tight lateral retinaculum, can provoke the symptoms of PFPS. We therefore chose to use the medial glide technique based on the assumption that lateral tracking of the patella is a common etiology for PFPS,[18,19,43,68] and that centering of the patella within the trochlea would be accomplished best by utilizing a correction that shifts the patella in a medial direction.[9,43] The subject then repeated each functional test with the patellar tape on and again recorded the pain experienced during each activity on the NPRS. The subject concluded the examination by assessing the overall change in his or her condition on the GRC.

## Data Analysis

All statistical analyses were performed using SPSS software, Version 10.1 (SPSS Inc, Chicago, IL). Interrater reliability coefficients of the physical examination measurements were calculated using Cohen's kappa coefficients for dichotomous data and intraclass correlation coefficients ($ICC_{2,1}$) for continuous variables.

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% improvement on the mean NPRS or a score of +4 or higher on the GRC. Advocates of patellar taping state that taping should decrease the patient's pain by at least 50% during the performance of a provocative task.[9] Furthermore, it has been proposed that a 30% change on a NPRS represents a clinically meaningful reduction in pain in subjects with a variety of disorders.[14] Juniper et al[32] 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 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, 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 (LRs) were calculated for each variable. Sensitivity of a test reflects the true positive rate, and specificity of a test is the true negative rate.[52] To calculate the Sn and Sp for each clinical measurement item, 2 × 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.[52] 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.[52]

Positive likelihood ratios (+LR), negative likelihood ratios (–LR), and their associated 95% CIs were also computed for all clinical measurement items. Likelihood ratios were calculated as: $+LR = Sn/(1 - Sp)$ and $-LR = (1 - Sn)/Sp$. Likelihood ratios are convenient summary measures of diagnostic test performance that indicate how much a given diagnostic test will raise or lower the pretest probability of the target disorder of interest.[29] A high +LR would be indicative of a more favorable response to patellar tape whereas a lower –LR would be indicative of a less favorable response to patellar tape. According to the *User's Guide to Medical Literature*,[24] a +LR greater than 10 or a –LR less than 0.1 generates large and often conclusive changes from pretest to posttest probability. LRs of 5 to 10 and 0.1 to 0.2 generate moderate shifts in pretest to posttest probability. LRs of 2 to 5 and 0.5 to 0.2 generate small, though sometimes important, changes in probability, and LRs of 1 to 2 and 0.5 to 1 alter probability to a small, and rarely important, degree. In our study, we considered +LR greater than or equal to 2.0 and a –LR less than or equal to 0.5 to be clinically meaningful.[24,29]

A binary logistic regression model was used to develop a CPR for predicting treatment success with the patellar taping intervention.[26] 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 0.15 was chosen to prevent potentially useful variables from being excluded from the model.[15] The Hosmer-Lemeshow (HL) summary goodness-of-fit statistic was used to assess fit of the model to the data and to test the hypothesis that the model fits the data. Higher *P* values indicated a better fit.[27] 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 LRs for the CPR were calculated as previously described for other dichotomous variables (Table 4).

## RESULTS

Descriptive statistics and baseline clinical characteristics of continuous variables for all subjects are shown in Table 1. Interrater reliability data were collected on the first 30 subjects. The values for the reliability coefficients ($ICC_{2,1}$) for the continuous measurements ranged from an ICC of 0.01 to 0.84. The Cohen kappa coefficient values for the categorical variables ranged from 0.29 to 0.81. Eleven of the 19 (58%) lower extremity measurements had moderate to good reliability based on a threshold of 0.40 or more for Kappa values and at least 0.50 for ICCs.[36,52] The ICCs and kappa coefficients for the clinical measurement items are listed in Table 2 along with associated standard error of measurement (SEMs).

Twenty-six of the 50 subjects (52%) were considered to have successful interventions based on a 50% improvement on the final composite NPRS or a score of at least +4 on the GRC. Twenty of the subjects were considered intervention successes based on just the NPRS score and 19 were considered successes based on the GRC score alone. Fourteen subjects met the criteria for success on both the NPRS and the GRC. The mean NPRS score for each group (success, nonsuccess), at baseline and after taping, is depicted in Figure 3. The mean percent improvement for all subjects in our study was 41.6% ± 36.2%. The mean improvement in the success group was 63.5% ± 24.0%, while in the nonsuccess group, the mean improvement was 30.6% ± 22.4%. Each subject also

**TABLE 1.** Subject characteristics (n = 50). All values expressed as mean ± SD.

| Characteristic | All Subjects | Successful Group‖ | Unsuccessful Group |
|---|---|---|---|
| Age (y) | 22.8 ± 4.2 | 21.7 ± 3.8 | 23.9 ± 4.4 |
| Duration of symptoms (d) | 75.4 ± 123.8 | 67.2 ± 112.3 | 84.3 ± 136.9 |
| Rearfoot in subtalar joint neutral position (°)* | 2.8 ± 7.9 | 2.8 ± 8.5 | 2.7 ± 7.3 |
| Forefoot alignment (°)* | 3.8 ± 6.8 | 4.8 ± 6.9 | 2.7 ± 6.6 |
| Ankle dorsiflexion/knee extended (°) | 10.3 ± 6.1 | 9.6 ± 5.6 | 11.0 ± 6.6 |
| Ankle dorsiflexion/knee flexed (°) | 18.6 ± 15.5 | 20.7 ± 20.7 | 16.3 ± 6.0 |
| Tibial torsion (°) | 22.6 ± 7.2 | 23.8 ± 6.9 | 21.3 ± 7.4 |
| Craig test (°)† | 7.2 ± 10.6 | 7.9 ± 20.5 | 6.4 ± 9.7 |
| Relaxed calcaneal stance (°)‡ | 0.0 ± 8.7 | 1.8 ± 9.2 | –2.0 ± 7.7 |
| Tibial varus/valgus (°)* | 1.6 ± 5.2 | 2.5 ± 5.8 | 0.7 ± 4.5 |
| Navicular drop test (mm) | 5.4 ± 3.4 | 5.4 ± 3.6 | 5.3 ± 3.2 |
| Q-angle (°) | 15.4 ± 5.8 | 15.8 ± 5.4 | 15.1 ± 6.3 |
| Great toe extension (°) | 76.7 ± 21.1 | 76.2 ± 20.5 | 77.2 ± 22.2 |
| Pelvic obliquity (mm)§ | 5.0 ± 6.4 | 5.4 ± 7.8 | 4.6 ± 4.5 |

* Value shown is degree of varus; negative value would indicate valgus.
† Value shown is amount of anteversion; negative value would indicate retroversion.
‡ Value shown is degree of valgus; negative value would indicate varus.
§ Measured using the palpation meter.
‖ Success defined as an immediate 50% pain reduction or moderate improvement on the global rating of change scale.

**TABLE 2.** Interrater reliability values of clinical examination items.

| Test/Measure | Kappa | $ICC_{2,1}$ | SEM |
|---|---|---|---|
| McConnell test | 0.81 | | |
| Patellar glide | 0.73 | | |
| Hamstring 90/90 test | 0.64 | | |
| Ober test | 0.54 | | |
| Patellar tilt | 0.49 | | |
| Thomas test | 0.44 | | |
| Patellar orientation | 0.29 | | |
| Ankle dorsiflexion/knee extended | | 0.84 | 3° |
| Great toe extension | | 0.71 | 13° |
| Tibial angulation | | 0.66 | 3° |
| Relaxed calcaneal stance | | 0.61 | 5° |
| Q-angle | | 0.52 | 4° |
| Craig test | | 0.47 | 7° |
| Tibial torsion | | 0.42 | 5° |
| Pelvic obliquity | | 0.34 | 6 mm |
| Navicular drop | | 0.30 | 3 mm |
| Forefoot alignment | | 0.26 | 6° |
| Rearfoot in subtalar joint neutral | | 0.26 | 6° |
| Ankle dorsiflexion/knee flexed | | 0.01 | 18° |

completed the GRC questionnaire. The mean GRC for all subjects was 2.4 ± 2.6 (range, –2 to 6). The mean score on the GRC for subjects in the success group was 4.0 ± 1.7 (range, –2 to 6), while the mean score for the nonsuccess group was 0.4 ± 1.8 (range, –4 to 2).

Based on the univariate analysis, 4 characteristics were identified as predictors of intervention outcome based on their LRs. The Sn, Sp, LRs, and cutoff scores for the predictors are shown in Table 3. Of these 4 clinical predictors, 2 were identified by the logistic regression analysis to form a CPR for intervention success. The predictive validity of the variables that comprised the CPR were further examined under 2 separate conditions: (1) if both of the variables were positive for intervention success, and (2) if just 1 (either) of the variables was positive for intervention success. The largest +LR was associated with the condition if just 1 (either of the tests) was positive for success (Table 4).

## DISCUSSION

PFPS is a complex and significant clinical problem. Although the etiology of the syndrome remains unclear, most investigators and clinicians concur that there are subgroups of patients with different features that may contribute to the development of the disorder.[9] Similarly, it is likely that there are subgroups of patients with distinct characteristics that will respond best to specific interventions.[61]

The aim of this study was to identify the characteristics of patients with PFPS that were predictive of an immediate successful response to patellar taping with a medial glide component. The clinical utility of any examination item is determined largely by the accuracy with which it identifies the presence of the target condition,[29] and the accuracy measure that is most helpful for determining that a target condition is present is the positive LR. Jaeschke and colleagues[29] proposed that +LRs greater than or equal to 2.0 and –LRs less than or equal to 0.5 can generate clinically meaningful changes from pretest to posttest probability for a given diagnosis. Based on these guidelines, 4 subject characteristics in our study were associated with clinically meaningful LRs: tibial angulation (+LR = 2.1, 95% CI = 1.3-3.5; –LR = 0.30, 95% CI = 0.11-0.87), ankle dorsiflexion measured with the knee flexed (+LR = 2.1, 95% CI = 0.19-23.70), patellar tilt

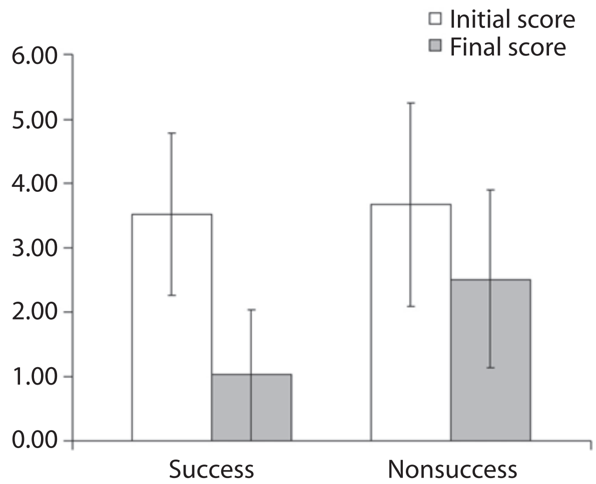


**FIGURE 3.** Initial and final mean numeric pain rating scale scores for the successful and nonsuccess groups. The mean improvement in the success group was 63.5% ± 24.0%, while in the nonsuccess group, the mean improvement was 30.6% ± 22.4%.

(–LR = 0.24, 95% CI = 0.02-3.30), and relaxed calcaneal stance (–LR = 0.50, 95% CI = 0.24-1.0). The LRs for the individual variables in this study were associated with wide CIs and the lower limits for 3 of the characteristics crossed 1.0, which may limit the precision of our findings. The number of subjects who met the cut scores for each of these predictors of treatment success was 15 for tibial angulation, 29 for ankle dorsiflexion, 17 for patellar tilt, and 22 for relaxed calcaneal stance.

## Application of the CPR

A CPR is, by definition, an optimum number of clinical examination items used for predicting a diagnosis or prognosis. Two items were identified by the logistic regression model to comprise this stage 1 CPR: the patellar tilt test and the measure of tibial angulation. Specifically, the CPR consisted of a positive patellar tilt test or tibial varum greater than 5°, and resulted in a +LR of 4.4 (95% CI = 1.3-12.3) and a –LR of 0.53 (0.38-0.86) (Table 4). In contrast to the CIs for the individual predictors, it is important to note that the CIs for the CPR were narrower and did not cross 1.0. The CPR in this study represents a level IV CPR and requires validation in a separate sample before it can be implemented on a broad basis.[44]

Fagan[13] developed a nomogram (Figure 4) to facilitate the use of LRs and to provide clinicians with a tool for determining the probability that a condition is present given the results of a diagnostic test. In our study, 52% (26/50) of the subjects were considered to have intervention success immediately after the application of the patellar tape. Therefore, the pretest probability of success with the intervention used for the subjects in our study was 52%, as shown in the first column of Figure 4. The second column of the nomogram represents the +LR (4.4) for the CPR, and the third column of the nomogram shows the change in the probability of intervention success after applying the LRs to the pretest probability. As shown in the figure, the probability of intervention success improved substantially after application of the CPR. Given a positive response to either of the 2 items that comprised the CPR, the posttest probability for intervention success improved to 83%. Consequently, if a patient with PFPS has either a positive patellar tilt test or tibial varum greater than 5°, there is an 83% probability of achieving a 50% or greater reduction in pain or moderate improvement on the GRC immediately following application of a medial glide patellar taping technique.

The argument can be made that it may be more practical to simply try the taping technique and see if the patient responds to the intervention, rather than determining if the patient fits the CPR. However, given the numerous treatment strategies that have been proposed for the management of PFPS, it seems impractical to use a trial-and-error approach for every possible intervention. The goal of developing, and ultimately validating, CPRs such as the one in this study is to provide the clinician with the ability to predict a priori which patients will respond favorably to a specific intervention, thereby improving the efficiency of the examination and intervention process.

It is important to note that we developed the CPR based only on the subjects' immediate response to the intervention, and that we employed just one aspect of patellar taping. Although McConnell states



**TABLE 3.** Sensitivity, specificity, likelihood ratios (LR), and successful* cutoff scores for the predictors of intervention success (95% confidence intervals shown in parentheses).

| Predictor of Success | Sensitivity | Specificity | +LR | –LR | Cutoff Score |
|---|---|---|---|---|---|
| Tibial angulation | 0.81 (0.62-1.00) | 0.62 (0.45-0.78) | 2.1 (1.3-3.5) | 0.30 (0.11-0.87) | >5° varus |
| Ankle dorsiflexion with knee flexed | 0.53 (0.39-0.67) | 0.75 (0.15-1.35) | 2.1 (0.19-23.7) | 0.63 (0.27-1.5) | ≤15° |
| Patellar tilt | 0.88 (0.77-1.00) | 0.51 (0.37-0.65) | 1.8 (1.1-2.9) | 0.24 (0.02-3.3) | Tilt above the horizontal plane |
| Relaxed calcaneal stance | 0.70 (0.50-0.90) | 0.60 (0.42-0.78) | 1.8 (1.0-3.0) | 0.50 (0.24-1.0) | >4° varus |

*Success defined as an immediate 50% pain reduction or moderate improvement on the Global Rating of Change scale.

**TABLE 4.** Validity indices (Sn, Sp, LRs) for the clinical prediction rule (CPR). The 2 items that comprised the CPR were the patellar tilt test and tibial angulation measure. If either item was a positive predictor of treatment success, then the CPR applies with the values shown below. Success defined as an immediate 50% pain reduction or moderate improvement on the Global Rating of Change Scale (95% confidence intervals in parentheses).

| Validity Index | Value (Mean [Range]) |
|---|---|
| Sensitivity | 0.53 (0.31-0.69) |
| Specificity | 0.88 (0.74-1.00) |
| +LR | 4.4 (1.3-12.3) |
| –LR | 0.53 (0.38-0.86) |

that tilt, glide, and rotation components must be corrected prior to initiating an exercise regimen with patellar taping,[43] the development of the current CPR is a reasonable initial foray into identifying the characteristics of patients with PFPS who are most likely to experience symptomatic improvement immediately following a specific taping technique. Because our study was not a randomized clinical trial, we were unable to determine whether the subjects' response was due solely to the intervention. We used our study design as a first step in determining which patients might respond best to a specific taping technique. Validation of the proposed CPR is the goal of a future randomized trial.

Additionally, it is important to note that the CPR developed in this study was based on establishing the predictive validity of a limited number of examination variables. It is certainly possible that the predictor variables that emerged in this developmental study may have occurred by chance. We recognize that the clinical examination we performed was not fully comprehensive, and did not include some items that may have emerged as predictors of intervention success. We chose the clinical examination items used in this study because we believe they (1) are routinely obtained from patients with knee pain, (2) measures that guide clinical decision making for patellar taping intervention (ie, patellar glide, patellar orientation, patellar tilt), and/or (3) allowed for comparison of the results of the present study with our previous work.[61]

## Predictors of Intervention Success

One of the key predictors of treatment success in our study was the patellar tilt test. The patellar tilt test was originally described as a convenient clinical measure to determine if a patient has a tight lateral retinaculum.[35,65] Kolowich et al[35] proposed that an excessively tight lateral retinaculum is identified by the inability of the examiner to lift the lateral border of the patella above the true horizontal plane (with the patient supine and relaxed and knee in full extension). If the lateral border of the patella can be

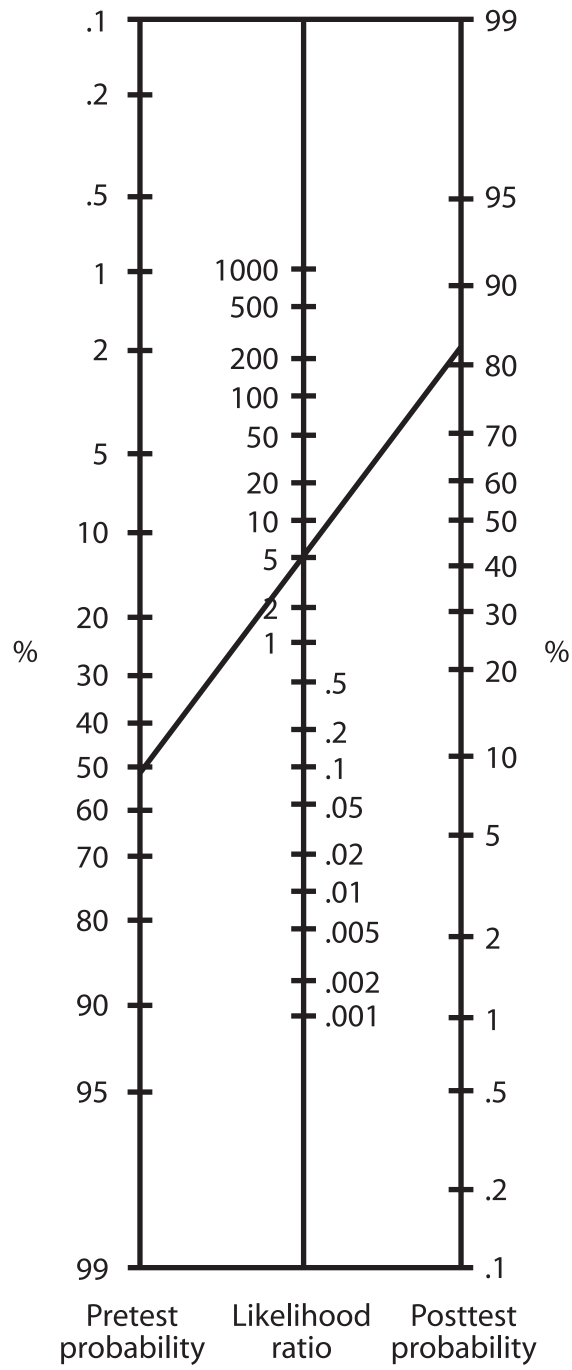


**FIGURE 4.** Nomogram showing the pretest probability of intervention success using patellar taping (52%), and the improved posttest probability (83%) for intervention success after applying the clinical prediction rule.

tilted above the horizontal plane, the test is considered positive (ie, positive angle with respect to the horizontal).[35] Our findings indicate that it was subjects with a positive patellar tilt test that responded favorably to medial glide taping. Presumably, individuals with a positive patellar tilt have a flexible lateral retinaculum. While a positive test does not necessarily imply that the individual has a hypermobile patella, it is interesting to relate our finding with that of Witvrouw and colleagues,[70] who reported in their prospective study that a hypermobile patella was 1 of 4 intrinsic risk factors that played a dominant role in the genesis of anterior knee pain.

In addition, we found that individuals with a tibial angulation more than 5° of varum responded favorably to the patellar taping intervention. Ten of the subjects in the current study had a measure of tibial varum of over 5°, and 8 of them were considered intervention successes. In studies of healthy populations without known impairments or pathology, the mean values of tibial angulation range from 6° to 8° of varum.[1,39,45] In contrast, the mean value for tibial angulation in the current study of patients with symptomatic PFPS was approximately 2° varum. The measure of tibial angulation was associated with both a clinically meaningful +LR and a quite small and clinically meaningful negative likelihood ratio (–LR = 0.30, 95% CI = 0.11-0.87). Based on this finding, –LR may have actually been the most powerful property of this variable as a component of the CPR. For example, using the nomogram, application of the –LR for the tibial varum measure alone would decrease the posttest probability of treatment success from 52% to 18%. Clinically, therefore, it may be more useful to consider that an examination finding of tibial varum less than or equal to 5°, including tibial valgum, will decrease the probability of a successful response to patellar taping with a medial glide component.

## Possible Mechanisms for Pain Reduction

The results of previous investigations purport that patellar taping leads to pain reduction in 1 of 2 probable ways: (1) via mechanical realignment of the patella[37,57,60] or (2) by providing cutaneous sensory input and improved kinesthetic awareness.[4,7,40] The evidence for patellar taping causing a realignment of the patella is controversial. Several investigations have demonstrated an unchanged patellar position following taping in symptomatic patients using a variety of imaging techniques.[2,7,22,50,71] Other studies have shown a medial displacement of the patella after taping, but the realignment was temporary.[37,57,60] Several researchers suggest that the clinical benefits of patellar taping are not due to a change in patellar position, but rather due to the effects of cutaneous stimulation.[4,7,9,40,69] Proponents of this theory believe that cutaneous input from the taping leads to an analgesic effect by increasing activity of the vastus medialis oblique muscle,[7,40] pain modulation via the gating mechanism,[2,7] and/or improved proprioception and kinesthetic awareness of the patellofemoral joint.[4] In their recent study of the effects of 4 different taping methods (medial, lateral, neutral, or untaped), Wilson et al[69] reported that the greatest reduction in pain was seen in the neutral and lateral groups. The neutral group consisted of subjects who simply had tape applied to the front of the knee (neutral) without any attempt to alter patellar position.

The findings of the current study raise questions with regards to possible clinical effects and mechanisms of action for patellar taping. The patellar tilt test was a key predictor of intervention success. Kolowich and colleagues[35] proposed that patients with a negative patellar tilt test have an excessively tight lateral retinaculum, and presumably a laterally tracking patella. According to McConnell,[43] these patients will respond well to taping with a medial glide component, by stretching the tight lateral restraints and shifting the patella medially, centering it within the femoral trochlea. However, the subjects in our study who responded best to the medial glide patellar-taping technique were those with a positive patellar tilt, which would be associated with a supple lateral retinaculum. Based on this finding and on the recent evidence discussed in the preceding paragraph, we believe that it is unlikely that the symptom reduction seen in the responders in our study was due to an alteration in patellar alignment. However, we did not use any imaging techniques in our study and therefore do not know if a change in patellar position occurred following the taping procedure.

## Interrater Reliability

In addition to identifying the characteristics of those subjects who responded best to patellar taping, we also examined the interrater reliability of the measurements obtained in our study. Moderate (0.40 to 0.60 for kappas and 0.50 to 0.75 for ICCs) to good (over 0.60 for kappas and over 0.75 for ICCs) reliability[36,52] was demonstrated in 11 (58%) of the 19 lower extremity measurements. With regard to the variables that comprised the CPR, our ICC of 0.66 for the measure of tibial angulation was slightly higher than the value of 0.41 reported in 2 earlier studies.[39,63] For the patellar tilt test, our kappa coefficient value of 0.49 was also somewhat higher than the range of values (0.20-0.35) reported in a previous study.[65] Perhaps a more clinically meaningful way to examine the reliability data for this continuous variable is to interpret the data within the context of its intended use.[64] For instance, how often did the raters agree that a subject had a tibial angulation measure greater than or less than or equal to the cutoff score of 5° varum? The percentage of agreement between the raters with regard to this cutoff score was 90%. A Cohen kappa coefficient ($\kappa$) was calculated to determine the chance-corrected agreement between raters for this predictor ($\kappa = 0.71$). Nevertheless, the interrater reliability for some of the measures may pose a

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threat to the internal validity of our investigation and ultimately limit the interpretation and application of the CPR.

### Future Research

A 3-step process for developing and testing a CPR has been recommended.[44] The first step (the purpose of the present study) was to develop a CPR that would identify the characteristics of those individuals who would respond immediately to patellar taping with a medial glide component. The second step is validation. These findings need to be validated in a separate sample before the CPR can be used confidently in the clinic.[24] The use of these predictors as inclusion criteria for a future randomized clinical trial will strengthen the investigation by targeting the sample to a classification of patients who are likely to respond to patellar taping. The third step is an assessment of the impact of the CPR on clinical behavior. Ultimately, any CPR must be shown to improve outcomes and clinical decision making before it can be advocated for widespread use.[38,44]

## CONCLUSION

We identified the characteristics of patients with PFPS who respond favorably to a specific patellar taping technique and developed a CPR incorporating those findings. Our results suggest that patients who present with tibial varum over 5° or a positive patellar tilt test will respond favorably immediately following patellar taping with a medial glide. Based on the results of this study, patients with PFPS who have 1 of the 2 characteristics identified in the CPR may benefit from patellar tape with a medial glide component as an initial treatment strategy. Validation of the proposed CPR should be the goal of a future randomized clinical trial and is required before it can be advocated for widespread use.

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# Appendices

## APPENDIX A

Compared to your condition prior to treatment with the patellar taping, 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 B

### Clinical Measurement Items: Operational Definitions

- *First metatarsophalangeal (MTP) passive extension* was measured with the subject sitting and the ankle in neutral (0°) dorsiflexion. The axis of the goniometer was positioned over the joint axis, the stationary arm of the goniometer was positioned over the first metatarsal and the moving arm along the proximal phalanx of the great toe.[3]
- *McConnell test*[43] is a provocative test designed to reproduce patellofemoral pain syndrome (PFPS). In a seated position, the examiner placed the symptomatic knee into varying degrees of flexion (0°, 30°, 60°, 90°, 120°). At each position, the subject isometrically contracted the quadriceps and held the contraction for 10 seconds. 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.
- *Patellar orientation* was visually categorized as medial, neutral, or lateral with the subject seated with both knees flexed to 90°.
- The *Thomas test* assessed hip flexor tightness as described by Magee.[41]
- The *hamstring 90-90 test* measured hamstring length in supine.[41] The test was considered positive if the subject was unable to extend the symptomatic knee within 20° of full extension.
- The *patellar glide test* was used to assess patellar position with the subject supine. The center of the patella was marked, and a tape measure was then placed across the anterior aspect of the knee from the lateral femoral epicondyle to the medial femoral epicondyle. The test was positive if the center of the patella was displaced at least 0.5 cm in either (medial or lateral) direction.
- The *patellar tilt test* assessed patellar mobility with the subject supine. With the subject relaxed, the examiner glided the patella laterally and attempted to lift the lateral border of the patella anteriorly. The measurement was recorded as: no lift (negative), lift to neutral (level with a horizontal plane), or lift above (positive) the horizontal plane.[65]

- The *lateral patellar pull test* detected any lateral over-pull of the patella by the quadriceps. With the subject supine, the examiner observed the path of the patella as the subject isometrically contracted the quadriceps on the symptomatic side. A positive test was recorded if movement of the patella was greater laterally than superiorly.[65]
- *Ober test* assessed iliotibial band tightness with the subject side lying as described by Magee.[41]
- *Craig test* assessed the degree of femoral angle of torsion and was performed with the subject prone and the symptomatic knee flexed to 90°.[41]
- *Tibial torsion* was measured with the subject prone and the symptomatic knee flexed to 90° as described by Gross.[23]
- *Ankle dorsiflexion* active range of motion (AROM) was recorded with the subject prone and the knee extended. Ankle dorsiflexion AROM was also recorded with the knee flexed to 90°.
- Both *subtalar joint neutral* (non-weight bearing) and forefoot alignment were measured in the figure-4 position as described by Gross.[23]
- *Relaxed calcaneal stance* measured rearfoot alignment with the subject weight bearing as described by Jonson and Gross.[31] The subject stood on a stepstool with the heels flush with the edge of the stool. The degree of deviation of the line that bisected the calcaneus from vertical was recorded.
- *Tibial angulation* (varum/valgum) was measured as described by Donatelli.[11] The subject stood on a 20-cm step, and the rater measured the angle formed by the horizontal surface of the step and the line that bisected the Achilles tendon. Tibial varum was defined as the distal end of the tibia being more medial than the proximal end.
- The *navicular drop test* was performed in standing as described by Picciano and colleagues.[51]
- *Q-angle* was measured with the subject standing as described by Caylor et al.[5] The proximal end of a string was held over the inferior angle of the anterior superior iliac spine (ASIS). The distal end of the string was then taped to the center of the patella and to the tibial tuberosity. The angle of the string formed from the center of the patella to the ASIS, and the center of the patella to the tibial tuberosity was recorded.
- *Pelvic obliquity* was measured with the Palpation Meter (PALM).[25,49] With the subject facing away from the examiner and arms crossed across chest, the PALM was placed over the tops of the iliac crests. The subject was then instructed to inhale deeply and exhale. As the subject held the exhale, the measurement was taken. The PALM calibrated slide rule converted the measurement to centimeters. This measurement was rounded to the nearest centimeter.

## APPENDIX C

### Questions from the History

- What is your age?
- What is your occupation?
- What are your hobbies?
- 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? If so, how long ago?
- Have you ever had surgery on either knee? If yes, on which knee? What type of surgery was performed?
- Do you have a history of any systemic diseases (diabetes, rheumatoid arthritis, heart disease, etc)? If yes, please describe.
- With regards to your knee, do you ever experience: - Locking? - Giving way? - Clicking? - Crepitus (grinding or crunching noises)?