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A Systematic Review of the Effects of Therapeutic Taping on Patellofemoral Pain Syndrome

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Objective: To investigate the efficacy of patellar taping on pain control, patellar alignment, and neuromuscular control (ie, vastus medialis oblique activation, knee extensor moment, etc) in subjects with patellofemoral pain syndrome.

Data Sources: We searched MEDLINE, SPORT Discus, PEDro, and CINAHL through December 2004, using the key words *patellar taping, therapeutic taping, McConnell taping, taping, chronic injury, patellofemoral pain,* and *knee.*

Study Selection: Criteria for inclusion criteria were studies that exclusively recruited patients diagnosed with patellofemoral pain syndrome or anterior knee pain and outcome measures specific to pain reduction, neuromuscular control, and patellar positioning.

Data Extraction: We identified and reviewed 16 studies with an average PEDro score of 4.25/10. Articles were divided into 3 categories based on primary outcome measures: 4 randomized controlled trials on treatment methods and pain, 9 studies on neuromuscular control, and 3 on patellar positioning.

Data Synthesis: Although patellar taping seems to reduce pain and improve function in people with patellofemoral pain syndrome during activities of daily living and rehabilitation exercise, strong evidence to identify the underlying mechanisms is still not available.

Key Words: knee, patellar taping, rehabilitation

Patellofemoral pain syndrome (PFPS) is a condition presenting with anterior knee pain or pain behind the patella (retropatellar pain).[1,2] It is commonly experienced during running, squatting, stair climbing, prolonged sitting, and kneeling.[3,4] In the patellofemoral joint, the patella serves as a link to converge the fibers of the quadriceps femoris muscle group to increase its lever arm and maximize its mechanical advantage.[5,6] To ensure this functional efficacy, maintaining the patellar alignment in the trochlear groove of the femur is necessary. Malalignment of the patella, or altered patellar tracking, may be a predisposing factor for patellofemoral pain, chondromalacia, and articular cartilage degeneration.[1,2,5]

Several factors may be associated with patellar malalignment. An increase in Q angle (more than 15°) may increase the lateral pull of the patella, causing the patella to glide on the lateral ridge of the femoral groove and producing pain.[5,7,8] Tightness of the muscles that cross the knee joint may have an effect on patellar alignment.[5] A tight rectus femoris muscle can limit patellar movement, reducing the functional and mechanical efficacy of the patellofemoral joint.[5] A tight iliotibial band may pull the patella laterally during knee flexion, whereas tightness in the hamstring muscle group may increase patellofemoral joint reaction forces because of an increased knee flexion moment.[5,9] Gastrocnemius tightness may limit ankle dorsiflexion, which can result in increased subtalar joint pronation and tibial internal rotation, contributing to abnormal pulling of the patellar tendon and the patellar malalignment.[10]

The contribution of hip musculature weakness on patellar malalignment has been discussed. Ireland et al[11] demonstrated that hip abduction and external rotation strengths were significantly less in subjects with PFPS than in healthy controls. Dysfunction of the gluteus medius muscle may induce excessive internal rotation at the hip. This increased internal rotation of the hip can contribute to a greater valgus force vector at the knee, thus adding to PFPS.[12]

Patella alta is associated with a longer patellar tendon, which may be a predisposing factor for frequent patellar subluxations or dislocations and can cause increased pain at the patellofemoral joint.[13] The vastus medialis oblique (VMO) muscle has been suggested to act as a dynamic medial stabilizer, which helps to realign the patella during the last 20° to 30° of knee extension.[5,14,15] Insufficiency of the VMO, including diminished VMO activity, may increase the lateral pull of the patella and reduce function at the knee joint.[1,3,16,17]

Physical therapy interventions for PFPS often are intended to alleviate pain by correcting or improving proper patellar tracking within the patellofemoral groove. Nonoperative management includes patellar taping; stretching of the lower extremity muscles, including the quadriceps, hamstrings, gastrocnemius, anterior tibialis, iliotibial band, and gluteal muscles; stretching of tight structures such as the lateral retinaculum; strengthening of the VMO; activity modification; biofeedback; neuromuscular electric stimulation; ultrasound; thermotherapy; bracing; and foot orthotics.[5,18–21]

Figure 1. A, Neutral patellofemoral joint position (anterior view). B, Patella in excessive lateral glide. L indicates lateral aspect; M, medial aspect.

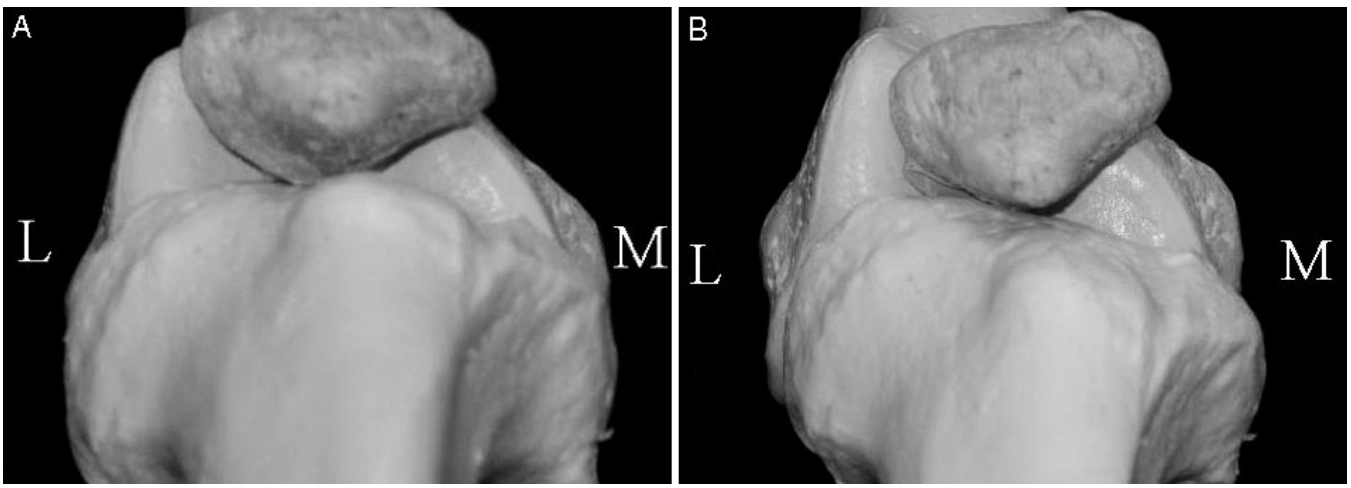

Figure 2. A, Neutral patellofemoral joint position (inferior view). B, Patella in excessive lateral tilt. L indicates lateral aspect; M, medial aspect.

McConnell[5] introduced a rehabilitation program that incorporates patellar taping techniques to improve patellar tracking within the patellofemoral groove, as well as stretching of lateral knee soft tissues, VMO strengthening, and closed kinetic chain training. The McConnell patellar-taping program is intended to correct patellar tracking by medializing the patella, allowing patients to engage in pain-free physical therapy exercises.[22]

McConnell[5] suggested 3 components of patellar orientation that need to be assessed before patellar tape is applied:

1. Glide component. The amount of gliding is characterized by the distance between the midpoint of the patella and the medial and lateral femoral epicondyles (Figure 1A and B). Patellar glide depends on the tightness of the static lateral structures as well as the contribution of the VMO activity relative to the vastus lateralis.
2. Tilt component. Patellar tilt is characterized by the difference in the heights of the medial and lateral borders of the patella (Figure 2A), which indicates the tightness of the lateral structures (especially the lateral retinaculum). With a lateral patellar tilt, the anteromedial border of the patella is more anterior than the anterolateral border of the patella (Figure 2B).
3. Rotation component. Internal and external rotation of the patella is represented by the alteration in alignment between the longitudinal axis of the patella (from the superior to the inferior poles) and the longitudinal axis of the femur (Figure 3A). Excessive internal rotation of the patella may be present in PFPS patients (Figure 3B), possibly because of the weak VMO and tight lateral structures such as the lateral retinaculum and iliotibial band.

Although the McConnell patellar-taping program has become a popular practice among athletic trainers and other health care professionals treating PFPS, its true clinical efficacy is not well established. The purpose of this systematic review is to assess the current literature on patellar taping to investigate its effectiveness related to selected outcome measures: controlling patellofemoral pain, improving patellar alignment, and enhancing neuromuscular control.

Review of Articles

We searched the English-language literature using MEDLINE (1966–present), SPORT Discus (1972–present), and CINAHL (1982–present). Key words searched were *patellar taping, therapeutic taping, McConnell taping, taping, chronic*

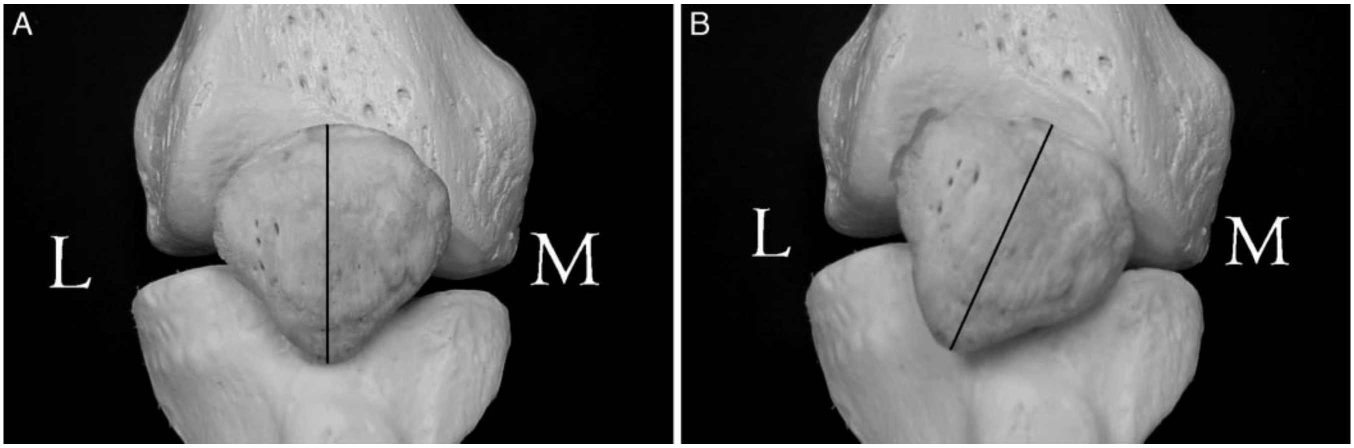

Figure 3. A, Neutral patellofemoral joint position (anterior view). Longitudinal axis of the patella extends between the superior and inferior poles. B, Patella in excessive internal rotation. L indicates lateral aspect; M, medial aspect.

Table 1. PEDro Scale[23]

1	Eligibility criteria were specified (no points awarded).	Yes	No
2	Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated in order in which treatments were received).	Yes	No
3	Allocation was concealed.	Yes	No
4	The groups were similar at baseline regarding the most important prognostic indicators.	Yes	No
5	There was blinding of all subjects.	Yes	No
6	There was blinding of all therapists who administered the therapy.	Yes	No
7	There was blinding of all assessors who measured at least one key outcome.	Yes	No
8	Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups.	Yes	No
9	All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by ''intention to treat.''	Yes	No
10	The results of between-group statistical comparisons are reported for at least one key outcome.	Yes	No
11	The study provides both point measures and measures of variability for at least one key outcome.	Yes	No

injury, patellofemoral pain, and *knee.* The initial search using multiple combinations of these key words generated 63 articles. The following inclusion criteria were applied to these 63 studies:

1. Studies utilizing subjects described as having, or as having been diagnosed with, PFPS or anterior knee pain syndrome were included. Studies with subjects possessing knee osteoarthritis, patellar tendinitis or tendinopathy, patellar subluxation or dislocation, or other knee conditions were excluded from this review, because these conditions may present with a severe case of osteochondral or cartilage degeneration beyond the normal limits of degeneration seen in the PFPS population. Studies involving only healthy subjects were also excluded from this review, although some studies with only healthy subjects will be addressed in the Discussion section. The effects of patellar taping on healthy subjects may not necessarily reflect the possible characteristics or effects of patellar taping in patients with PFPS; thus, assumptions regarding the possible benefits of patellar taping on PFPS patients cannot be concluded from the studies of healthy subjects only.
2. Outcome measures reported in the studies included pain reduction; neuromuscular control, such as quadriceps (VMO in particular) strength, electromyographic (EMG) activity, proprioception, and patellar positioning, or a combination of any of these measures.

A total of 16 research articles met the inclusion criteria and were reviewed. We applied the PEDro scale to rate the quality of each article. The PEDro scale is an evaluation checklist developed for the Physiotherapy Evidence Database by the Centre for Evidence-Based Physiotherapy.[19] The database contains randomized controlled trials, systematic reviews, and evidence-based clinical practice guidelines in the field of physiotherapy. The PEDro scale examines 2 aspects of quality of the trial in the database: the ''believability,'' or internal validity, and the interpretability of the trial. The 11-item checklist (Table 1) yields a maximum score of 10 points if all criteria are satisfied (no points are awarded for the first criterion). The PEDro scale was applied because it tested reliability data and was specifically developed for physiotherapy studies. We rated each article independently using the PEDro scale. Two of the reviewed articles had a discrepancy of 1 point on the scale between the authors,[4,24] but after discussion, the discrepancy was resolved and a consensus score assigned. Three articles had previously been rated and were listed in the PEDro database,[18,21,25] so we used those ratings.

RESULTS

The PEDro scale scores ranged between 3 and 9 of 10, with an average of 4.25/10 (Table 2). The 16 articles were grouped into 3 categories based on specific outcome measures: treatment methods and pain, neuromuscular control, and patellar positioning.

Treatment Methods and Pain

In the randomized controlled trial by Clark et al,[18] 81 subjects with anterior knee pain were randomly assigned to 4 groups: (1) exercise, taping, and education, (2) exercise and education, (3) taping and education, and (4) education alone. Each group received the designated intervention for 3 months. At 3 and 12 months after treatment began, each subject was assessed for patient satisfaction, indicated as the discharge rate, visual analog scale (VAS) rating for pain, Western Ontario and McMaster University lower limb function scores, the Hospital Anxiety and Depression Scale, and quadriceps strength. Measurements of the subjects' quadriceps strength will be discussed in the ''Neuromuscular Control'' section.

Using a categorical variable analysis, patients who exercised (groups 1 and 2) were significantly more likely to be discharged at the 3-month assessment than the nonexercise patients ($P < .001$). Taping alone did not improve the discharge rate over patients in the nontaped groups. No significant differences were noted in improvement of VAS for pain, Western Ontario and McMaster University lower limb function scores, or Hospital Anxiety and Depression scores among any of the groups at the 3-month or 12-month assessments. However, the patients engaged in exercise programs were significantly more likely to be satisfied and have less pain after a year ($P < .001$). Limitations of this study include a low percentage of patient return after a year of treatment and the authors' failure to indicate whether those patients who were discharged at 3 months continued any form of exercise between the 3- and 12-month assessments. The PEDro scale rating for this study was 7/10. Allocation was not concealed, and the therapists and assessors were not blinded.

Harrison et al[21] investigated the efficacy of different physical interventions on 113 patients randomly allocated to a group with a home strengthening and flexibility exercise program (group 1), a group with a similar exercise program but carried out in a clinical setting and monitored by a physical therapist 3 times a week for 1 month (group 2), or a group with a physiotherapist-directed program including exercise similar to the other 2 groups, McConnell patellar taping, and biofeedback 3 times a week for 1 month (group 3). At the 1-month reassessment, group 3 demonstrated significant improvement on various pain scales and questionnaires (visual analog scale for pain, Functional Index Questionnaire, clinical change score, and Patellofemoral Function Score) and knee pain threshold (time to pain experience) during a step test compared with group 2 ($P < .05$) but showed no significant improvement over group 1. The authors concluded that biofeedback and patellar taping both had a significant improvement on pain, but in a long-term follow-up, any treatment program could improve the patients' pain and function. For short-term reduction of pain, it appeared that the addition of taping and biofeedback was beneficial; however, because of the confounding variable of biofeedback in group 3, it is difficult to conclude that patellar taping as an individual rehabilitation component was superior to the exercise interventions in reducing pain. This study yielded a PEDro score of 5/10. No points were awarded for concealed allocation, blinding of the therapists and subjects, obtaining more than 85% of follow-up measurements, or intention-to-treat analysis.

In the randomized study by Kowall et al,[25] 25 subjects with PFPS were randomly allocated to 2 groups: patellar taping and control (no patellar taping). Both groups were instructed to pursue physical therapy and home exercise programs. Their VAS scores for pain as well as isokinetic strength and EMG activity of the quadriceps were assessed. (Isokinetic strength and EMG activity will be discussed in the ''Neuromuscular Control'' section.) Both groups had significantly less pain ($P < .05$) with activities of daily living after physical therapy. However, improvement of pain, isokinetic quadriceps strength, and quadriceps EMG activity between the groups did not differ, indicating that adding patellar taping to a standard physical therapy program did not affect these measures. The PEDro scale rating for this study was 3/10. This study lacked concealed allocation; information about baseline characteristics; blinding of the subjects, therapists, and assessors; intention-to-treat analysis; and information on point measures and measures of variability.

In the study by Whittingham et al,[26] 30 subjects diagnosed with PFPS (24 men, 6 women) were randomly allocated to a patellar taping and exercise group, a placebo taping and exercise group, or an exercise group (no taping). The subjects performed the daily exercise program, consisting of lower extremity muscle stretching (hamstrings, quadriceps, gastrocnemius, and iliotibial band), non–weight-bearing knee flexion-extension and straight-leg raises, and weight-bearing knee and hip strengthening exercises, after tape application (no tape for the exercise-only group). The subjects' VASs for average pain over the 24 hours before the study and pain after a step-down with and without the tape (for the patellar taping and placebo taping groups) were measured and the Functional Index Questionnaire was administered on 5 occasions: at the beginning of the study and at 4 weekly assessments.

A significant interaction was noted between time and group on the VAS scores for pain over the last 24 hours ($F_{7.953} = 9.093$, $P < .001$). (Note: The authors only provided 1 *df*.) The patellar taping and exercise group demonstrated significantly lower VAS scores for pain at weeks 2, 3, and 4 (VAS average $= 1.1 \pm 0.4$) than the placebo taping and exercise group (2.4 ± 1.0) and the exercise-alone group (2.9 ± 1.1). Additionally, a significant interaction was seen between time and group for VAS scores for pain during the step-down task under the taped conditions ($F_{6.377} = 13.361$, $P < .001$), with the patellar taping and exercise group reporting significantly lower VAS scores during the step-down with tape (VAS average for weeks 1–4: 1.8 ± 0.45) compared with the placebo taping and exercise group (3.4 ± 1.0) and the exercise-alone group (3.4 ± 1.1) at all time periods.

The authors also found a significant interaction between time and group on the mean Functional Index Questionnaire scores ($F_{6.350} = 11.020$, $P < .001$). The patellar taping and exercise group significantly improved on their Index scores compared with the placebo taping and exercise group at weeks 2, 3, and 4 and with the exercise-alone group at weeks 1 through 4 ($P = 0.01$). No differences were noted in the 2 VAS scores and the Index scores between the placebo taping and exercise group and the exercise-alone group at any time.

Whittingham et al[26] suggested that although pain and function were improved in subjects in all groups, patellar taping seemed to enhance such improvement with a 4-week exercise program. The authors noted, however, that the subjects in this study received a supervised exercise protocol and patellar taping on a daily basis for 4 weeks, which may be difficult to conduct in other clinical situations, such as outpatient sports medicine settings. This paper was awarded 9/10 on the PEDro scale. One point was not awarded for blinding of the therapists.

In Herrington's preliminary study,[27] the efficacy of patellar taping on quadriceps peak torque and perceived pain in 14 female subjects with PFPS was investigated through repetitive maximum isokinetic quadriceps contractions. These exercises were performed at different velocities (60°/s and 180°/s), and under different taping conditions (tape and no tape) by each subject. Patellar taping significantly decreased perceived pain on VAS (60°/s: untaped = 5.9 ± 1.8, taped = 1.8 ± 1.8; −69.5%, $P < .001$; 180°/s: untaped = 3.9 ± 1.7, taped = 0.9 ± 0.9; −76.9%, $P < .001$) during isokinetic quadriceps contractions. Herrington suggested that patellar taping may create a change in afferent fiber input, which may increase the alpha motor neuron excitability via the spinal cord. This study generated a 3/10 on the PEDro scale. Points were not awarded for random allocation of subjects; concealed allocation; information about baseline characteristics; blinding of the subjects, therapists, and assessors; and between-group comparisons.

Ng and Cheng[4] examined the effects of patellar taping on pain and the EMG activity ratio of VMO to vastus lateralis (VL) during exercise in 15 subjects diagnosed with PFPS. Subjects performed single-leg squat exercises with and without tape. Subjects demonstrated a significant decrease in pain on VAS (untaped = 2.3 ± 2.02, taped = 1.2 ± 1.66, $P < .001$) with patellar taping. (The effects of patellar taping on VMO and VL EMG activity will be discussed in the following section.) The PEDro scale rating was 4/10 for not concealing the allocation; not blinding the subjects, therapists, and assessors; no information about the subjects' baseline characteristics; and no between-group statistical comparisons.

Cowan et al[2] investigated the influence of patellar taping on the onset of VMO activity relative to VL on PFPS and healthy subjects. The level of pain was significantly decreased under the patellar-taping condition in the PFPS group after the stair-ambulation task ($F_{18,2} = 30.95$, $P < .0001$). Findings regarding the onset of VMO activity relative to VL and the PEDro scale rating will be discussed later.

Christou[3] examined the effect of patellar taping on force production, EMG activity of the VMO and VL, and perceived pain in 30 female subjects, 15 of whom were diagnosed with PFPS. Subjects performed maximal isokinetic leg presses under no-tape (control), no-glide (placebo), and medial- and lateral-glide (experimental) conditions. The medial-glide and placebo-tape conditions significantly decreased pain in the group with PFPS ($P < .001$). Information regarding force production and EMG activity of VMO and VL will be discussed in the ''Neuromuscular Control'' section. Christou's study yielded a score of 5/10 on the PEDro scale. Points were withheld for no concealment of allocation; no baseline comparability; and no blinding of the subjects, therapists, and assessors.

Salsich et al[1] demonstrated a 92.6% reduction in pain measured on the VAS after tape application in 10 subjects with PFPS during stair ambulation (5.4 ± 2.2 pretape versus 0.4 ± 0.5 posttape). This study will be discussed in more detail in the ''Neuromuscular Control'' section, because the authors also examined knee biomechanics and EMG during stair ambulation with and without patellar taping.

Powers et al[24] investigated the effects of patellar taping on stride characteristics and reported an immediate average pain reduction of 78% on the VAS for pain after the tape application (untaped = 7.7 ± 1.4, taped = 1.7 ± 1.1), although pain was not a variable included in the statistical analysis of the study. Findings on stride characteristics will be discussed in the ''Neuromuscular Control'' section.

Bockrath et al[15] assessed the effects of patellar taping on patellar position and perceived pain. Twelve subjects with PFPS currently using patellar taping as a means of pain control underwent radiographic examination with the Merchant view before and after patellar taping while contracting their quadriceps isometrically. Subjects also completed a VAS pain rating after performing a step-down task before and after taping. Although the position of the patella did not change significantly, patellar taping reduced the subjects' perceived pain after a step-down (untaped = 4.38 ± 3.73, taped = 2.02 ± 2.86; $t_{15} = 4.99$, $P < .0005$). The PEDro score for this study was 3/10 because of no randomization or concealment of allocation; no baseline comparability; no blinding of the subjects, therapists, and assessors; and no between-group comparisons.

Neuromuscular Control

In this section, we will discuss the effects of patellar taping on different aspects of neuromuscular control, such as quadriceps activity, the onset of VMO activity relative to the VL, and biomechanics of the knee during activities.

Quadriceps Activity. The results of the previously mentioned study by Clark et al[18] indicated that quadriceps power was significantly improved in all subjects with PFPS ($P < .001$) after 3 months of treatment. However, the observed improvement was more prominent in the exercise and education groups than in the group with tape alone.

Kowall et al,[25] as described above, found that isokinetic quadriceps strength and quadriceps EMG activity showed improvement after the physical therapy ($P < .05$ for quadriceps strength, and $P < .001$ for EMG activity), but there were no differences between the tape and no-tape groups.[20] They concluded that adding patellar taping to a physical therapy program did not affect improvement in pain, quadriceps strength, or EMG activity.

In Herrington's study described earlier,[27] the efficacy of patellar taping on quadriceps peak torque and perceived pain in 14 female subjects with PFPS was investigated. In addition to pain reduction, patellar taping significantly increased quadriceps peak torque (concentric 60°/s: 20.5%, $P < .001$; eccentric 60°/s: 25.9%, $P < .001$; concentric 180°/s: 20.5%, $P < .001$; eccentric 180 °/sec: 18.8%, $P < .001$) during isokinetic quadriceps contractions. Herrington suggested that repositioning the patella with corrective patellar taping may alter the leverage of the patella, maximizing the mechanical advantage of the quadriceps.[27] However, when the patella is repositioned in the center of the trochlear groove of the femur, it is possible that the moment arm of the quadriceps is actually decreased, because the patellar tendon may be oriented closer to the knee joint center. Although pain was reduced immediately after the patella was taped, it is questionable whether efferent pathways were immediately restored, allowing the quadriceps to demonstrate improved torque immediately. Another consideration

Table 2. Description, Results, and PEDro Scores of Reviewed Articles*

Article	Description	Results	PEDro Score
Treatment methods and pain			
Clark et al[18]	Group 1: exercise, taping, and education Group 2: exercise and education Group 3: taping and education Group 4: education alone All groups were assessed at 3 and 12 months.	Exercise groups had better discharge rate and less pain; taping alone did not improve discharge rate.	7
Harrison et al[21]	Group 1: home exercise Group 2: supervised exercise Group 3: exercise, taping, and biofeedback All groups were assessed at 1 month.	Significant improvement in pain in group 3 over group 2 but no difference compared with group 1.	5
Kowall et al[25]	Group 1: patellar taping Group 2: control (no tape)	No statistically significant differences between groups.	3
Whittingham et al[26]	Group 1: patellar taping and exercise Group 2: placebo taping and exercise Group 3: exercise alone All groups were assessed at pretest and weekly for 4 weeks.	Patellar taping and exercise group had significantly better pain and function scores after 4 weeks of treatment compared with other 2 groups.	9
Neuromuscular control			
Quadriceps activity			
Herrington[27]	PFPS subjects performed maximum isokinetic quadriceps contractions under tape and no-tape conditions.	Taping significantly decreased pain and increased quadriceps peak torque.	3
Vasus medialis obliquus activity relative to vastus lateralis activity			
Ng and Cheng[4]	PFPS subjects performed single-leg squat with and without patellar taping.	Significant decrease in pain and EMG ratio of VMO:VL under taping condition.	4
Gilleard et al[14]	PFPS subjects performed stair ambulation with and without patellar taping.	VMO onset on EMG was earlier than VL with patellar taping.	4
Cowan et al[2]	Subjects with and without PFPS performed stair-stepping test under 3 conditions: patellar tape, placebo tape, and no tape.	VMO onset occurred earlier than VL in PFPS group with taping; significant reduction in pain with tape in PFPS group.	4
Christou[3]	PFPS subjects and healthy subjects performed maximal isokinetic leg presses under 3 conditions: no tape (control), no glide (placebo), and medial and lateral glide (experimental).	Experimental and placebo groups had significantly decreased pain; PFPS group under experimental condition produced increased VMO and decreased VL activities.	5
MacGregor et al[28]	Changes in firing rate of VMO motor unit and amplitude of VMO activity relative to VL and effects of direction of pull were assessed in 8 PFPS subjects.	No overall difference in mean firing rate of VMO motor units; individual differences in firing pattern were observed.	4
Knee joint kinematics			
Salsich et al[1]	PFPS subjects performed stair ambulation with and without patellar taping.	92.6% pain reduction under taped condition as well as increase in cadence, knee flexion angles, and knee extensor moments; no difference in VL EMG.	3
Powers et al[24]	PFPS subjects performed walking at various speed and ramp and stair ambulation under taped and untaped conditions.	78% pain reduction after tape application; taping gave a statistically significant increase in loading-response knee flexion.	3
Ernst et al[19]	Vertical jump height and knee extensor kinetics were evaluated in PFPS subjects under 4 conditions: patellar tape on involved limb, placebo tape on involved limb, no tape on involved limb, and no tape on uninvolved limb.	Greater knee extensor moment and power under patellar-tape condition.	5

for the observed torque increases may be a placebo effect in which the tape application created higher levels of central motivation to perform the strength test.

Onset of Vastus Medialis Obliquus Activity Relative to the Vastus Lateralis. Ng and Cheng[4] reported that subjects presented a significant decrease in the EMG ratio of VMO to VL (ratio $\Delta: -0.2$, $P = .05$) with patellar taping. The decrease in the relative activity ratio of VMO to VL was attributed to the realignment of the patella by taping, which reduces the demand of the VMO to pull the patella medially. Although not specifically stated by the authors, there could be a relationship between the alteration in the VMO:VL ratio and the reduction in knee pain.

Gilleard et al[14] investigated the effect of patellar taping on the timing of VMO and VL muscle activity in 14 female subjects with PFPS during stair ambulation with and without patellar taping. Measuring the knee angle at the onset of muscle activity, the onset of VMO EMG activity compared with VL occurred earlier in the knee movement with patellar taping than without taping during a step-up and step-down test ($F_{1,13} = 18.657$, $P = 0.0008$). The authors discussed the possibility that patellar taping may enhance the onset of VMO activity, which may result in improved patellar tracking. They suggested that this early activation of the VMO may be caused by cutaneous stimulation brought by the patellar tape, although the precise mechanisms for this phenomenon are unclear. The PEDro scale for this study was a 4/10, because of no concealment of allocation; no baseline comparability; no blinding of the subjects, therapists, and assessors; and no between-group statistical comparisons.

Cowan et al[2] examined the effects of patellar taping on the timing of VMO and VL EMG activity in subjects with and without PFPS. Ten subjects with PFPS and 12 healthy, asymptomatic subjects performed a stair-stepping test under 3 conditions (patellar tape, placebo tape, and no tape). The VMO activity began earlier than the VL activity during stair ascent in the PFPS group with patellar taping ($P < .001$), whereas no differences were noted in muscle activation patterns between the placebo and no-tape conditions in the PFPS group. Subsequently, in the asymptomatic group, applying patellar tape made no difference in the timing of VMO activity versus VL activity. The authors concluded that the method of tape application may have caused alterations in the onset of VMO and VL activity. This study was awarded a score of 4/10 on the PEDro scale because of no concealment of allocation; no information about the subjects' baseline characteristics; no blinding of the subjects, therapists, and assessors; and no point estimates and variability.

As mentioned earlier, Christou[3] showed a significant reduction in perceived pain in subjects with PFPS after patellar taping. Also, peak leg press force did not differ between conditions or groups. However, in the PFPS subjects, patellar taping was associated with increased VMO activity ($F_{1,58} = 18.4$, $P < .01$), whereas VL activity did not differ between the groups ($F_{1,58} = 0.18$, $P > 0.05$). The author proposed that the improved knee function from patellar taping may have been caused not by a change in patellar positioning but rather by enhanced medial ligament support of the patellofemoral joint as well as pain modulation via cutaneous stimulation.[3]

MacGregor et al[28] utilized 8 PFPS patients to assess the change in the firing rate of the VMO motor unit after tape application, the change in the relative amplitude of VMO and VL EMG activity with tape application, and the effects of the

Table 2. Continued

Article	Description	Results	PEDro Score
Patellar positioning			
Gigante et al[20]	Computed tomography images were obtained from PFPS subjects before and after patellar taping.	No statistically significant differences in patellar lateralization or tilt.	3
Bockrath et al[15]	Patellar position and perceived pain were assessed in PFPS subjects under taped and untaped conditions.	No significant differences in patellar positioning; taping significantly reduced perceived pain after step-down.	3
Worrell et al[29]	PFPS subjects underwent magnetic resonance imaging under patellar-taping, bracing, and no-tape conditions.	Taping and bracing significantly decreased patellofemoral congruence angle.	3

*PFPS indicates patellofemoral pain syndrome; VMO, vastus medialis obliquus muscle; EMG, electromyography, and VL, vastus lateralis muscle.

direction of stretch applied by the tape. A 9% increase in the surface EMG amplitude of VMO was noted when a lateral stretch was applied compared with the other directions (medial and superior) of stretch ($P < .001$); however, VL activity did not change among directions of tape pull.

No significant difference was seen in the mean firing rate of the VMO motor units among directions of stretch. However, when the firing rates of individual motor units were analyzed, some motor units responded to skin stretch with an increased firing rate and some with a decreased firing rate. The authors suggested that these results may support the notion that cutaneous stimulation of afferent fibers via tape application may have an effect on the VMO activation pattern. This study was rated 4/10 on the PEDro scale because of no randomization or concealment of subject allocation; no blinding of the subjects, therapists, and assessors; and no between-group comparisons.

Knee Joint Biomechanics During Activity. Salsich et al[1] studied 10 subjects with PFPS who performed stair ambulation under taped and untaped conditions. Lower extremity kinematics, ground reaction forces, and EMG of the VL were measured under each condition to assess the effects of patellar taping on improving gait variables. As described earlier, under the taped condition, pain was significantly reduced as measured on the VAS; increased were cadence ($P = 0.02$), knee flexion angles (ascent: no tape, $34.3 \pm 4.5°$, taped, $39.2 \pm 5.8°$, $P < .001$; descent: no tape, $38.5 \pm 5.6°$, taped, $46.6 \pm 5.6°$, $P < .001$), and knee extensor moments (ascent: no tape, 0.12 ± 0.17 Nm/kg; taped, 0.30 ± 0.17 Nm/kg, $P < .001$; descent: no tape, 0.37 ± 0.13 Nm/kg; taped, 0.55 ± 0.14 Nm/kg, $P < .001$). However, no difference was noted between conditions in VL EMG activity. The authors suggested that this phenomenon may be caused by increased efficiency in quadriceps force generation by improved knee extensor moments and a possible change in lower extremity movement pattern during gait from patellar taping, allowing increased recruitment of other muscles that cross the patellofemoral joint. However, Salsich et al[1] were not specific as to which muscles may experience this purported increase in recruitment. This study was rated 3/10 on the PEDro scale. There was no randomization or concealment of subject allocation; no information about baseline characteristics of the subjects; no blinding of the subjects, therapists, and assessors; and no between-group comparisons.

Powers et al,[24] as described earlier, investigated the effects of patellar taping on stride characteristics and joint motion in patients with PFPS. Fifteen subjects performed walking, fast walking, ramp walking, and stair ambulation under taped and untaped conditions. No significant changes were seen in stride characteristics except for a significant increase in stride length during ramp ascent. However, patellar taping had a small (Δ: $3.4°$, $P < .05$) but statistically significant increase in loading-response knee flexion under all conditions. The authors stated that this increase in loading-response knee flexion may have enhanced the patients' willingness to load the knee joint, which may improve shock absorption, quadriceps activity, and tolerance to increased patellofemoral joint reaction force. The PEDro scale rating for this study was 3/10 for no concealment of allocation; no baseline comparability; no blinding of the subjects, therapists, and assessors; no between-group comparisons; and not providing point estimates and variability.

In a study conducted by Ernst et al,[19] the effects of patellar taping on single-leg vertical jump height, knee extensor moment, and power during a vertical jump and lateral step-up were assessed. Fourteen female subjects with unilateral PFPS performed the testing procedures under different taping conditions in a randomized order: (1) patellar tape on involved limb, (2) placebo tape on involved limb, (3) no tape on involved limb, and (4) no tape on uninvolved limb. Condition 4 served as a control condition for bilateral comparisons.

Greater knee extensor moment ($F_{3,39} = 5.50$, $P = .003$) and power ($F_{3,39} = 4.23$, $P = .011$) were observed in the patellar-tape condition than in the placebo or no-tape conditions. Additionally, the uninvolved lower extremity produced a significantly greater vertical jump height than all conditions of the involved limb, but vertical jump height did not differ significantly among the 3 conditions of the involved limb ($F_{3,39} = 6.97$, $P = .001$).

Ernst et al[19] argued several possible causes for an increase in knee extensor moment and power from the patellar-taping application. First, patellar taping may limit distal displacement of the patella during knee flexion, which can increase knee extensor moment arm and thus knee extensor moment. Second, although they did not assess pain and stability, the authors suggested that perhaps decreased pain or an increased sense of stability from the patellar taping alters trunk position to allow a greater knee extensor moment. Additionally, patellar taping potentially modifies VMO activity to promote more efficient and stronger quadriceps contraction. Finally, an alteration in proprioceptive/cutaneous input may improve knee extensor moment and power. The PEDro scale rating for this study was a score of 5/10 for no concealment of allocation, no baseline comparability, and no blinding of the subjects, therapists, and assessors.

Patellar Positioning

Gigante et al[20] assessed the effect of patellar taping on patellofemoral incongruence. Computed tomography images of the knees of 16 female subjects with PFPS were captured before and after patellar taping. No statistically significant differences were demonstrated in patellar lateralization or patellar tilt between the taped and untaped conditions. The authors suggested that the patellar taping did not correct patellofemoral incongruence in the subjects with PFPS and that pain reduction from patellar taping may be achieved by other mechanisms, such as increased cutaneous stimulation and the altered order of motor unit recruitment. However, they did not investigate other outcome measures, such as pain reduction and functional improvement, associated with patellar taping. This study was assigned a score of 3/10 on the PEDro scale. No points were awarded for randomized or concealed allocation of the subjects; providing the baseline characteristics of the subjects; blinding the subjects, therapists, and assessors; or reporting between-group comparisons.

Bockrath et al[15] examined the effects of patellar taping on patellar position and perceived pain. Although patellar taping significantly reduced the subjects' perceived pain after a step-down task, no significant differences were noted in patellofemoral congruency angles or patellar rotation angles before and after tape application. The authors explained that the subjects who had been applying patellar taping and experiencing pain reduction were selected in order to investigate the relationship between a change in patellar positioning and the reduction in pain. However, the authors did not discuss the possibility of biasing because of regular patellar taping by the subjects. If patellar taping changed the position of the patella and quadriceps muscle activity well before the start of the study, these measures may not have changed very much during the study.

Worrell et al[29] investigated the differences in the effects of patellar taping, bracing, and no tape on patellar position. Twelve subjects diagnosed with PFPS underwent magnetic resonance imaging assessment at 8 angles of knee flexion under the 3 conditions. Patellar taping and bracing significantly decreased patellofemoral congruence angle compared with the control condition at 10° of knee flexion ($F_{2,284} = 5.2$, $P = .01$), whereas lateral patellar displacement was more medial in the patellar-bracing condition than in the patellar-taping and control conditions at 10° of flexion ($F_{2,284} = 4.6$, $P = .01$). The PEDro score for this study was 3/10 because of no concealment of allocation; no baseline comparability of the subjects; no blinding of the subjects, therapists, and assessors; no between-group statistical comparisons; and no information on point measures and measures of variability.

DISCUSSION

Although our review yielded positive results related to the effect of patellar taping on neuromuscular control and muscle activity,[1–4,14,24,27] the mechanisms underlying the improvement of neuromuscular activity by application of patellar taping are not very clear. A few hypotheses have been offered throughout the literature to explain how patellar taping may improve pain, strength, mechanical function, and patellar alignment at the patellofemoral joint.

First, some have suggested that the mechanical advantage of the quadriceps is maximized because of increased leverage by the patella via a medial shift as it returns to the trochlear groove of the femur.[4,19,27,30] However, Worrell et al,[29] using magnetic resonance imaging, reported that altered patellar positioning and patellofemoral congruency after patellar taping were not associated with an improvement in pain. Although a mechanical advantage may be achieved by the quadriceps when the patella is repositioned, the associated reduction in pain experienced by the individual may allow a more comfortable quadriceps contraction.

Some hypothesize that the application of patellar taping may reduce neural inhibition of the quadriceps and modulate pain via large afferent fiber input.[15,27,30] This may be attributed to the fact that large afferent fiber input travels more rapidly to the brain than pain signals, as described in the gate control theory and Castel's[31] level I pain theory. Herrington[27] proposed that patellar taping may lead to altered large fiber afferent input to the dorsal horn, decreasing the perceived pain that may be contributing to quadriceps inhibition. With a reduction in pain, Herrington[27] suggested that there is potential for restoration of quadriceps function through increased alpha motor neuron excitation. Many authors[1–4,15,18,21,24–27] reported a significant reduction in pain via tape application; however, evidence is scarce to claim that the reduction in pain is caused by increased alpha motor neuron excitability. Additional contributions along small-diameter afferent pathways or a potential placebo effect needs to be considered when pain modulation is observed with patellar taping. Regardless of the mechanism of pain alteration, it does appear that clinicians may effectively and immediately reduce patellofemoral pain with patellar taping.

However, the effectiveness of pain reduction from patellar taping application during athletic activity is still unclear. Patellar tape is designed to be applied over a long period of time and during activities of daily living and rehabilitation exercises. It is yet to be determined how effectively patellar taping may reduce pain during a sustained high level of activity.

A third hypothesis is that patellar taping improves proprioception and the sense of mechanical stability of the patella to promote normal knee function.[32] Under the influence of patellar taping, altered afferent input from the muscular, ligamentous, articular, and cutaneous structures in and around the patellofemoral joint may improve proprioceptive functions in patients with PFPS.[3,19,32] Although further investigation is needed to understand the mechanism of this phenomenon, improved knee joint biomechanics, such as extensor moment and power, quadriceps torque, and knee flexion angles, have been reported in several studies.[1,19,24,27] The altered neural input implicated in these findings does not necessarily equate with improved muscle function, but it does appear that patellar taping is associated with an increased ability to generate muscle performance.

Additionally, cutaneous stimulation from the patellar tape may change the order and timing of motor unit recruitment.[2,28] This may alter the timing of force distribution on the patellofemoral joint and reduce pressure acting on the articular cartilage, restoring normal loading at the patellofemoral joint and reducing pain.[2,14] Changes in EMG activity of the VMO relative to VL after the application of patellar tape have been reported in several studies[2,4,14]; however, these authors did not investigate other functional outcomes of patellar taping, such as ground reaction force and knee joint kinematics. Salsich et al[1] reported no significant difference in VL activity between the taped and untaped conditions, although pain level and lower extremity kinematics improved after tape application.

The findings of Ernst et al[19] and Whittingham et al[26] contradict this theory that cutaneous input from applied tape to the knee improves knee function, as those with patellar taping had a greater knee extensor moment[19] and reduced pain[26] than those in the placebo-tape condition. If cutaneous input is the source of improved knee function, we would expect to see similar outcomes between the patellar-taped and placebo-taped conditions, with improvement over the nontaped condition, as was the case in the studies by Cowan et al[2] and MacGregor et al.[28] As with other hypotheses, evidence is insufficient to support this hypothesis, and there is some discrepancy in the reviewed literature. We feel that additional investigation is needed to quantify the role of cutaneous input in improving knee function and decreasing PFPS before it may be isolated as an explanation for the efficacy of this intervention.

It is not clear whether the pain reduction because of changes in afferent input via patellar taping promotes the restoration of neuromuscular function or whether improved neuromuscular function is attributable to an alteration in the knee extensor mechanism from the tape. The quality of the studies related to pain and neuromuscular control was moderate to fair according to the PEDro rating (between 3/10 and 5/10). The limitations of the reviewed studies should be addressed, so that quality of future studies may be improved and stronger evidence of the effects of patellar taping may be provided.

The major limitation to fully investigating the efficacy of patellar taping is that very few of the authors used randomized controlled trials,[18,21,25,26] with most employing a single-subject, repeated-measures design. The second criterion on the PEDro scale considered random allocation to include randomized order of treatments in a crossover study design, and this criterion was satisfied in several of the articles we reviewed.[2–4,14,19,24] However, many of the authors did not randomize the order of the treatment conditions,[1,15,20,22,27] increasing the risk of biases and learning effects. Although adding a control group (no treatment) presents an ethical dilemma, this should be considered a factor that might alter the results related to biasing. Additionally, the inability to blind the subjects, therapists, and/or assessors creates the potential for biased results.

A wide variety of outcome measures were assessed, which may increase the difficulty of finding the single factor that contributes the most to the cause of PFPS symptoms. When investigating the effects of patellar taping on neuromuscular efficiency, the authors of the reviewed studies used various outcome measures as indicators of neuromuscular function (eg, EMG onset of VMO relative to VL, knee flexion angles, knee extensor moments, and quadriceps peak torque).[1–4,14,19,24,27,30,32] In order to provide strong evidence for the efficacy of patellar taping, clarification of the clinical definition of neuromuscular deficit may be needed, whether through EMG recording, isokinetic strength assessment, or other testing protocols.

Another very important limitation is that the specificity of the patellar-taping techniques is not clear in several studies.[14,15,20,24–27,32] This factor can limit the validity of the results related to the potential inconsistencies of the utilized techniques. Although the McConnell patellar-taping technique is commonly referred to in the articles we reviewed as the chosen intervention, this technique varies in the length, angle, and force of the applied materials, which may result in differences when comparing the results of several studies. Future investigators may consider standardizing the employed technique for better control of external validity of the results.

Although these articles were not included in this review, several authors tested only asymptomatic subjects. In a study by Herrington,[30] 40 healthy subjects demonstrated significantly less single-leg hop distance and quadriceps concentric peak torque in the patellar-taping condition than in the nontaped condition. In 52 healthy subjects, Callaghan et al[32] demonstrated no significant differences in active angle reproduction, passive angle reproduction, and threshold to detection of passive movement tests between the taped and untaped conditions. However, when the subjects were divided into ''good'' and ''poor'' proprioception groups, the subjects in the ''poor'' group significantly improved their active and passive angle reproduction accuracy after tape application. Ng[33] investigated the effects of patellar taping on the onset of VMO and VL activities before and after fatigue in 29 healthy subjects. No significant change was seen between VMO or VL onset times with taping condition or fatigue. Pfeiffer et al[22] also found that patellar taping was not effective in maintaining the medialization of the patella after exercise in healthy subjects.

In the 4 above-mentioned studies of asymptomatic subjects, the results of the patellar-taping interventions were inconsistent. Healthy, asymptomatic subjects are assumed to lack pain, muscle weakness, or anatomical abnormality of the patellofemoral joint. Repositioning an asymptomatic patellofemoral joint may provide uncomfortable afferent input from altered joint contact, creating pain and potentially diminishing neuromuscular performance at the joint. Therefore, it is difficult to determine the efficacy of patellar taping using healthy subjects only, because the results obtained from asymptomatic subjects may not represent the results from subjects with PFPS. Only a few authors used a placebo group or condition.[2,3,19,26] Future investigators should include a placebo group to more accurately assess the efficacy of particular taping techniques or types of tape in those with PFPS.

Finally, most of the authors used a single treatment of patellar taping.[1–4,14,19,20,22,24,27,29,30,32] Future researchers should investigate the effectiveness of patellar taping in multiple applications over a longer period of time, so that both the short-term and long-term effects of patellar taping may be investigated.

CONCLUSIONS

The McConnell method of patellar taping has been a popular practice among athletic trainers and other health care professionals when treating patients with PFPS. However, the clinical evidence for the success of this intervention is still unclear. An insufficient number of randomized controlled trials, inconsistency of tape application techniques, and variance in measurement of specific outcome variables limit the strength of clinical efficacy and evidence.

We have attempted to present the current information regarding the efficacy of patellar taping on different outcome variables. Although the precise mechanisms are still unclear, patellar taping seems to significantly reduce perceived pain and improve function in patients with PFPS. Additionally, none of the reviewed studies demonstrated detrimental effects with patellar taping. Therefore, patellar taping may be a low-cost, noninvasive intervention to relieve symptoms in patients with PFPS. Regardless of the choice of therapeutic intervention, it is important to thoroughly understand the mechanisms and causes of the patient's patellofemoral pain. The clinician should remember that the patellofemoral joint is only one part of the dynamic lower extremity chain and that it is critical to identify the source of the problem and use appropriate techniques to correct that problem to ensure optimal results.

Therefore, it seems prudent to use a combination of various interventions based on the individual patient's symptoms and causes. Further research is needed to evaluate the effectiveness of patellar taping and possibly the mechanisms for treating patellofemoral pain. However, it appears that, based on the current literature, patellar taping may provide a useful tool to the clinician in treating PFPS and does not seem to exacerbate the symptoms.

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