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Effects of Taping on Pain and Function in Patellofemoral Pain Syndrome: A Randomized Controlled Trial

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Study Design: A randomized controlled trial.
Objectives: To investigate the effectiveness of daily patella taping and exercise on pain and function in individuals with patellofemoral pain syndrome.
Background: Patella taping and muscle-strengthening programs are commonly used to treat patellofemoral pain syndrome. There is, however, little evidence for the effectiveness of these approaches.
Methods and Measures: Twenty-four men and 6 women aged 17 to 25 years (mean ± SD, 18.7 ± 1.2 years) participated in the study. Subjects were randomly and exclusively assigned to 1 of 3 treatment groups: patella taping combined with a standardized exercise program, placebo patella taping and exercise program, or exercise program alone (n = 10 in each group). Taping was applied and exercises performed on a daily basis for 4 weeks. Outcome measures were visual analog scales for pain and the functional index questionnaire, recorded at weekly intervals by a therapist who was blinded to group allocation.
Results: Separate mixed-model ANOVAs, with repeated measures on time, indicated statistically significant improvements in pain and function over time for all groups ($P < .01$) and also significant differences between groups for all measures ($P < .01$). Separate independent samples *t* tests showed that the group receiving taping and exercises had better pain and function scores following treatment than the placebo taping-and-exercise group and the exercise-alone group. There were no significant differences between the placebo taping-and-exercise group and exercise-alone group at any time point.
Conclusions: These findings indicate that over a period of 4 weeks a combination of daily patella taping and exercises was successful in improving pain and function in individuals with patellofemoral pain syndrome. The combination of patella taping and exercise was superior to the use of exercise alone. *J Orthop Sports Phys Ther 2004;34:504-510.*

Key Words: *clinical trial, knee, patella*

Patellofemoral pain syndrome (PFPS) is characterized by diffuse pain at the front of the knee, which is exacerbated by activities that load the patellofemoral joint (for example, stair climbing, squatting, or prolonged sitting).[8,22,33] It thus impacts upon many aspects of daily life. PFPS is not confined to those engaged in sport,[19] having been reported as the most prevalent knee condition,[43] affecting up to a quarter of the population.[31] As such, it represents a common complaint presenting to medical and allied health professionals. Physical impairments associated with PFPS have been reported to include degradation of articular cartilage, pain, poor muscular control, patella malalignment, reduced flexibility of the hamstrings, gastrocnemius, iliotibial band, tensor fasciae latae, and biomechanical changes in the lower extremity.[19,33] This indicates that the etiology of PFPS is likely to be multifactorial.[8]

Physical therapy plays an important role in the conservative management of PFPS, with treatment frequently advocated for pain control and muscle strengthening.[18] One specific treatment regime, the McConnell approach, has been reported to have long-term success in alleviating the symptoms associated with PFPS.[30] The McConnell approach involves taping the patellofemoral joint with the aim of correcting abnormal patella alignment (tilt, glide, or rotation), and performing exercises that are purported to favor activation and strengthening of the vastus medialis obliquus (VMO).[8,22,30,31]

The available research evidence, however, would suggest that either taping does not change patella

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alignment[3,15] or that any change is short-lived.[27] Taping has, however, been reported to enhance the activity levels of VMO relative to vastus lateralis,[16,21,24,40] increase knee extensor moments,[35] and enhance proprioceptive acuity.[6,24] Pain relief may be elicited via the "pain gate."[3,17] The precise mechanisms by which taping might alter the symptoms of PFPS are not clearly understood, however. Crossley et al[8] suggested that future research should focus on the effects of patella taping compared with placebo tape, as this would begin to elucidate possible mechanisms of action.

Quadriceps muscle weakness, resulting in malalignment of the patella, may play a key role.[10,13] Decreased quadriceps peak torque has been identified in patients with PFPS[11] and general strengthening exercises have, therefore, been advocated as a possible intervention.[1,4,8,21] Other authors have identified weakness of VMO as being particularly important.[5] It is thought that VMO counterbalances vastus lateralis and that VMO insufficiency may, therefore, be a major cause of patellar malalignment.[14,21,31,39] VMO strengthening has, therefore, become a cornerstone of PFPS treatment,[1,4,16,22,26,30] although the evidence for being able to selectively activate VMO is ambiguous.[23,32,44] It remains unclear whether a general quadriceps-strengthening regime or one specific to VMO would be most effective at improving pain and function in patients with PFPS.

A number of studies have been conducted to investigate the effects of patella taping and exercise in this patient population. Some studies for example have found that patella taping and exercises decreased pain and improved function.[14,22,30] It has also been shown that patella taping immediately decreases pain associated with PFPS, but that the direction of taping was not important (medial, neutral, and lateral).[42] A comprehensive stretching and exercise program, used in conjunction with taping, has been shown to be significantly better in reducing pain and improving function at 4 weeks when compared with exercise alone.[19]

The systematic reviews in this area, however, indicate that the research evidence is generally of poor quality. A Cochrane review of the effectiveness of different orthotic devices (including patella taping) for the treatment of PFPS[9] concluded that, due to the weak evidence available, it was not possible to provide recommendations for treatment. The authors called for high-quality trials to be conducted to further investigate the effects of orthotic devices in the treatment of PFPS. Another review looked at the effects of exercise therapy for PFPS and concluded that there was limited evidence to suggest that exercise reduced pain when compared with no exercise.[20] The effects on function were conflicting, but there was strong evidence that weight-bearing and non–weight-bearing exercises were equally effective.[20] These reviews highlight the lack of clear evidence for the effectiveness of these interventions for the treatment of PFPS.

The purpose of this study was therefore to investigate the effectiveness of patella taping and exercise on pain and function in individuals with PFPS. Incorporation of placebo taping into the experimental design was used to provide some insight into possible mechanisms of action of this intervention.[8]

METHODS

Ethical approval for the study was received from Queen Margaret University College and the Defense Medical Services Research Committee. The study was conducted at the Army Training Regiment Bassingbourn between January and March 2002. The study population was army recruits referred for physiotherapy by the Unit Medical Officer with a diagnosis of acute PFPS. A physiotherapist (therapist 1) assessed 30 consecutive referrals to confirm a diagnosis of PFPS and to screen for inclusion and exclusion criteria. Inclusion criteria were 2 from the following 4: pain on ascending and/or descending stairs, squatting, sitting for extended periods of time, or associated with an increase in physical activity. In addition, subjects were aged 17 to 25 years (reflecting the age of recruits), men and women, and able to give informed consent. Exclusion criteria were a history of subluxation or dislocation of the patella, anterior or posterior cruciate ligament insufficiency, previous knee surgery or meniscal damage, or any other underlying musculoskeletal problems that would have prevented the subject from performing the exercises. All 30 subjects screened (24 men and 6 women with a mean [±SD] age of 18.7 ± 1.2 years) entered and completed the study. All subjects gave signed, informed consent and were then randomly assigned to 1 of 3 treatment groups: patella taping and a standardized exercise program (detailed below), placebo taping and the exercise program, or exercises alone. A block randomization process was used, where subjects randomly chose 1 of 3 labeled envelopes to determine their group allocation. The next subject chose 1 of the remaining 2 envelopes and the third subject was then assigned to the remaining group before the process was repeated. This ensured that there were even numbers of subjects in each group. All subjects remained in the group to which they were originally assigned. All subjects were placed on restricted duties (similar for all individuals) throughout the treatment period.

Sample Size Calculations

Sample size was calculated on the basis of the mean (±SD) visual analogue scale (VAS) pain scores (7.4 ± 0.4 cm) over the previous 24 hours reported by

subjects during pilot work (n = 3). An assumption was made that the study should detect a 10% change at a significance level of 0.05 and 90% power. These criteria lead to an estimated minimum sample size of 10 in each group.[28]

Patella Taping

A second physiotherapist (therapist 2), who was aware of group allocation, applied adhesive tape to the affected knee of subjects in the taping group and placebo taping group. The taping techniques used were those detailed by McConnell[30] to correct specific patella malalignments (tilt, glide, or rotation) identified by the therapist. Undertape was first applied, taking care not to place any tension on the skin. One strip of corrective tape was then applied as deemed appropriate by therapist 2. There is a lack of consensus in the literature regarding the reliability of therapists in assessing the specific components of tilt, glide, and rotation of the patella, which taping is purported to alter.[16,25,34,41] The present study, therefore, took the pragmatic approach of investigating current clinical practice. Therapist 2 had 5 years experience in the assessment and treatment of PFPS using the McConnell approach. For placebo taping, tape was placed across the surface of the patella without patella alignment correction. The exercise control group did not have any tape applied. Taping was applied daily, with the subject positioned in long sitting with back support. All subjects attended the physiotherapy department at 08:00 hours each day for the application of tape and performance of exercises, and were advised to remove the tape at the end of the day.

Exercises

Therapist 2 supervised the standardized exercise program performed by subjects in all experimental groups. Exercises were performed on a daily basis immediately following the application of tape (the control exercise group only performed the exercises). The performance of all exercises was completed wearing standard-issue military clothing and training shoes. The program was designed to enhance VMO activation and was graduated so that subjects only progressed to the next exercise when 3 sets of 10 repetitions of the previous exercise could be performed without pain. Non–weight-bearing isometric, inner-range isotonic (from approximately 10° flexion to full extension), and straight leg raise quadriceps exercises were included. A variety of weight-bearing exercises were also completed.[31,32] These included isometric quadriceps contractions in sitting (knees at 90° flexion), bilateral quarter squats (in standing), and unilateral quarter squats (all with a rolled towel between the knees). Further progressions included unilateral quarter-squats (without a rolled towel), controlled step-downs (backwards, sideways, and forwards), and hip external rotation exercises (standing with the lateral aspect of the affected leg against the wall, hip and knee flexed to 90°, and pushing the leg into the wall). Thirty repetitions of each exercise were completed except for the final exercise, where only 10 repetitions were performed (with a 20-second hold). Stretches for the quadriceps, hamstrings, gastrocnemius, and iliotibial band were also included (20-second hold, 4 repetitions). No home exercise program was given because the treatment program detailed above was undertaken on a daily basis.

Outcome Measures

Another physiotherapist (therapist 3), who was blinded to group allocation, took all outcome measures. Subjects wore tracksuit bottoms to hide the presence of tape during assessment. Outcome measures were taken on initial assessment and then at weekly intervals for 4 weeks (total of 5 measures). All subjects attended a session for assessment of outcome measures at a standardized time of the day (13:30 hours).

Pain intensity was assessed using a VAS. To enhance the usefulness of information gained on pain intensity, 3 measures were used: average pain over the previous 24 hours, and pain on performance of an aggravating activity (stepping down from a standard 8-in [20.3-cm] gym bench[3,38,45]), both without tape and then with the tape applied (for the taping and placebo taping groups). The exercise-alone group repeated the step test twice (as for the other 2 groups), but did not have tape applied. The VAS has been reported as being capable of detecting statistically significant changes in small samples of patients with PFPS.[2,7] A 10-cm horizontal line was employed, as this has been shown to produce a more uniform distribution than a vertical line,[36] with anchor words of ''no pain'' and ''worst pain possible.''[36]

Finally, a functional index questionnaire (FIQ) was completed. The FIQ, adapted by Chesworth et al,[7] was used in the current investigation. This questionnaire assesses patients' reports of their ability to perform 8 different activities using a 3-point rating scale: ''no problem'' (scored 2), ''can do with problem'' (scored 1), and ''unable to do'' (scored 0). A summative score is produced, the maximum being 16 (able to do all activities without any problem), which has been reported to approximate to an interval scale.[37] The activities assessed were ''walking as far as a mile,'' ''climbing up 2 flights of stairs,'' ''squatting,'' ''kneeling,'' ''sitting for long periods with your knees bent in 1 position,'' ''climbing up 4 flights of stairs,'' ''running a short distance (100 m),'' and ''walking a short distance (about quarter mile).'' The final 2 activities were adapted very slightly from those used by Chesworth et al[7] to suit British patients (a quarter-

TABLE 1. Descriptive statistics (mean ± SD) for the 3 groups participating in the study. Each group contained 8 men and 2 women.

Variable	Taping and Exercise	Placebo Taping and Exercise	Exercise Alone
Age (y)	18.8 ± 1.3	18.6 ± 1.1	18.7 ± 1.4
Height (cm)	171.3 ± 10.1	172.0 ± 10.0	172.5 ± 11.2
Mass (kg)	69.2 ± 6.8	69.4 ± 6.1	69.4 ± 5.9

TABLE 2. Reported pain (mean ± SD) during previous 24 hours, using a 10-cm visual analog scale with anchor words of "no pain" and "worst pain possible."

Time Period	Taping and Exercise	Placebo Taping and Exercise	Exercise Alone
Initial	7.5 ± 1.0	7.5 ± 0.8	7.5 ± 0.8
Week 1	4.4 ± 0.7	5.6 ± 1.2	5.0 ± 1.4
Week 2	2.4 ± 0.7*	4.1 ± 1.2	3.9 ± 1.3
Week 3	0.8 ± 0.4*	2.3 ± 1.2	3.1 ± 1.0
Week 4	0.0 ± 0.0*	0.9 ± 0.7	1.8 ± 0.9

* Significantly lower than placebo taping-and-exercise and exercise-alone groups ($P < .01$).

mile equals approximately 402.3 m). The previous version contained clarification statements in the brackets of "about the length of a football field" and "about a city block," respectively. The FIQ has been shown to be a valid measure, being capable of detecting clinical changes[7,18,29] and possessing a high internal consistency.[18,37] Its reliability has also been demonstrated.[18,29]

Data Analysis

Separate 1-way ANOVAs were performed to compare age, mass, and height among groups. Separate mixed-model ANOVAs, with repeated measures on time, were used to investigate changes over time, between groups, and any interaction effects for the 24-hour VAS, pain on the step test, and the FIQ data. The degrees of freedom were corrected using Huynh-Feldt epsilon, if Mauchly's sphericity test proved statistically significant. Statistical significance was set at $\alpha = .05$. Any statistically significant differences observed between groups were investigated further using independent samples t tests, with Bonferroni corrections for multiple testing (α adjusted to .01).

RESULTS

Descriptive statistics for each experimental group are contained in Table 1. There were no statistically significant differences among groups for any variable (age: F = 0.061, $df = 2$, $P = .941$; height: F = 0.033, $df = 2$, $P = .967$; mass: F = 0.003, $df = 2$, $P = .997$). The experimental groups were therefore comparable, at least on these factors.

24-Hour Pain Scores

VAS scores for the average pain over the previous 24 hours are reported in Table 2. There was a progressive decrease in pain from initial assessment to week 4 for all groups. Subjects in the taping group were pain free at week 4. A mixed-model ANOVA, with repeated measures on time, performed on these data found statistically significant changes over time (F = 623.105, $df = 3.977$, $P < .001$). There were also statistically significant differences between experimental groups (F = 6.214, $df = 2$, $P = .006$) and interaction effects (F = 9.093, $df = 7.953$, $P < .001$). Group differences were analyzed further using independent samples t tests. The group receiving the combination of taping and standardized exercises had significantly lower VAS ratings than both the placebo taping-and-exercise group and the exercise-alone group at weeks 2, 3, and 4 ($P < .01$). There were no differences between the 3 groups for the initial or week 1 recordings ($P > .01$). There were also no statistically significant differences between the placebo taping-and-exercise and the exercise-alone groups at any time point ($P > .01$).

Step Test Pain Scores

Mean VAS scores with and without patella taping are presented in Tables 3 and 4. Statistical analysis was performed for the without-tape VAS data using a mixed-model ANOVA with repeated measures on time. Data showed significant changes over time (F = 617.304, $df = 3.519$, $P < .001$). There were also statistically significant differences among groups (F = 8.712, $df = 2$, $P = .001$) and interaction effects (F = 7.626, $df = 7.037$, $P < .001$). Group differences were investigated further using independent samples t tests. The taping-and-exercise group had significantly lower VAS ratings than the placebo taping-and-exercise group at weeks 1, 2, 3, and 4, and the exercise-alone group at weeks 2, 3, and 4 ($P < .01$). There were no statistically significant differences be-

tween the placebo taping-and-exercise and the exercise-alone groups at any time point ($P>.01$).

Statistical analysis was also performed on the step test with-tape VAS data using a mixed-model ANOVA with repeated measures on time. Significant changes were found over time (F = 426.251, df = 3.188, $P<.001$), among groups (F = 39.040, df = 2, $P<.001$), and for interaction effects (F = 13.361, df = 6.377, $P<.001$). Group differences were investigated further using independent samples t tests. The taping-and-exercise group had significantly lower VAS ratings than the placebo taping-and-exercise group and the exercise-alone group at all time periods ($P<.01$). There were no statistically significant differences between the placebo taping-and-exercise and exercise-alone groups at any time point ($P>.01$).

Functional Index Questionnaire Scores

The mean FIQ scores are presented in Table 5. A mixed-model ANOVA, with repeated measures on time, performed on these data showed statistically significant changes over time (F = 421.462, df = 3.175, $P<.001$), among groups (F = 23.762, df = 2, $P<.001$), and interaction effects (F = 11.020, df = 6.350, $P<.001$). Independent samples t tests were used to further investigate group differences. The taping-and-exercise group had significantly better FIQ scores than the placebo taping-and-exercise group at weeks 2, 3, and 4, and the exercise-alone group at weeks 1, 2, 3, and 4 (P = .01). There were no significant differences in FIQ scores between the placebo taping-and-exercise and the exercise-alone groups at any time point ($P>.01$).

DISCUSSION

The present study showed that a combination of daily patella taping and exercises was superior to a regime of placebo taping and exercises or exercises alone in improving pain and function in patients with PFPS. Although all 3 experimental groups improved

TABLE 3. Reported pain (mean ± SD) on performing a step test without tape (using a 10-cm visual analog scale with anchor words of "no pain" and "worst pain possible").

Time Period	Taping and Exercise	Placebo Taping and Exercise	Exercise Alone
Initial	7.4 ± 1.0	7.5 ± 0.6	7.4 ± 0.8
Week 1	4.3 ± 0.6*	5.7 ± 1.2	5.0 ± 1.2
Week 2	2.4 ± 0.7†	4.1 ± 1.3	3.8 ± 1.2
Week 3	0.7 ± 0.5†	2.5 ± 1.2	2.9 ± 1.0
Week 4	0.0 ± 0.0†	1.2 ± 0.5	1.7 ± 0.9

* Significantly lower than placebo taping-and-exercise group ($P<.01$).
† Significantly lower than placebo taping-and-exercise and exercise-alone groups ($P<.01$).

TABLE 4. Reported pain (mean ± SD) on performing a step test with tape (using a 10-cm visual analog scale with anchor words of "no pain" and "worst pain possible"). The exercise-alone group acted as a control and did not have any tape applied.

Time Period	Taping and Exercise	Placebo Taping and Exercise	Exercise Alone
Initial	3.6 ± 0.4*	7.6 ± 1.2	7.9 ± 1.0
Week 1	2.3 ± 0.4*	5.1 ± 1.2	5.5 ± 1.4
Week 2	1.3 ± 0.4*	3.6 ± 1.1	3.8 ± 1.5
Week 3	0.4 ± 0.4*	2.0 ± 1.0	2.7 ± 1.1
Week 4	0.0 ± 0.0*	1.1 ± 0.5	1.4 ± 0.7

* Significantly lower than placebo taping-and-exercise and exercise-alone groups ($P<.01$).

TABLE 5. Mean (±SD) functional index questionnaire (FIQ) scores (normal function is 16/16).

Time Period	Taping and Exercise	Placebo Taping and Exercise	Exercise Alone
Initial	7.6 ± 1.0	7.8 ± 0.8	7.7 ± 0.8
Week 1	11.3 ± 1.2*	10.3 ± 1.1	10.0 ± 0.8
Week 2	14.0 ± 0.8†	11.6 ± 1.0	11.3 ± 0.8
Week 3	15.5 ± 0.7†	12.5 ± 1.3	12.7 ± 0.9
Week 4	16.0 ± 0.0†	13.5 ± 1.1	13.5 ± 1.0

* Significantly better than exercise-alone group ($P<.01$).
† Significantly better than placebo taping-and-exercise and exercise-alone groups ($P<.01$).

over the 4-week study period, all subjects in the taping-and-exercise group were pain free with full function, whilst subjects in the other groups had residual problems. These findings are similar to those of other investigators using similar taping techniques and provide further evidence for the effectiveness of such interventions.[3,16] The results indicate that patella taping offers a treatment component that is greater than placebo. It is not possible to identify the precise mechanisms of action, but this observation is important for future mechanisms-based investigations.

These results indicate that patella taping acts as more than simply a placebo over the course of a 4-week treatment program. Taping was also shown to have immediate effects that were greater than placebo (Tables 3 and 4, and ANOVA results). Some authors have claimed that, with the patella correctly taped, there should be at least a 50% reduction in pain when performing a step test.[16,30] The pain experienced on performing a step test decreased by an average of 47% with the application of active patella taping in the present study, compared to only 10% with placebo tape. There was a 2% decrease in pain in the control group when repeating the step test without taping. This compares very favorably with the reductions in pain reported by other investigators.[3,16,42]

Favorable outcomes in the current investigation were based on improvements in pain (24-hour and step test VAS with and without tape) and function (FIQ). The results indicated statistically significant reductions in pain and improvements in function in all groups, although the taping-and-exercise group displayed significantly better results than the placebo taping-and-exercise and the exercise-alone groups. The progressive improvements in pain and function in the placebo taping-and-exercise and exercise-alone groups suggests that the beneficial effects of intervention in the present investigation cannot be attributed to taping alone. Other contributing factors may have been a reduction in physical activity, the exercise program itself, and natural progression of the condition. Other authors have reported similar findings of improvements in pain and function in the absence of taping.[1,25,39] Finestone et al[12] demonstrated a high rate of recovery of recent onset retropatellar pain even when physical activity is maintained. The significant additional effect of patella taping in the present investigation cannot be disregarded, however.

It should be noted that the present study was conducted on military recruits who were able to attend physiotherapy on a daily basis for the application of tape and to conduct the exercise program. Although it may be more difficult to recreate these conditions in other clinical situations, the results suggest that a structured daily exercise program is an important component of treatment. Future studies should investigate whether these results may be replicated with a home exercise program. It would also be interesting to investigate whether strategies such as daily self-application of patella tape may be as successful as that applied by a therapist in the present investigation. There was also a limited age range and the study sample had a majority of men. The external validity of the findings should, therefore, be considered within these limitations. Outcomes were taken over a 4-week period in the present investigation, so it is not possible to comment on the long-term success of treatment. Within these constraints, however, the results provide important information for clinical practice, supporting the combination of patella taping and exercise for the short-term treatment of patients with PFPS.

CONCLUSION

The combination of daily patella taping with a 4-week exercise program has been shown to be more effective than placebo taping and exercise or exercise alone in reducing pain and improving function in patients with PFPS. Although patella taping clearly provided additional benefits to patients in the present investigation, it is not possible to identify the precise mechanisms of these effects.

It is recommended that in the clinical management of PFPS, patella taping should be used in conjunction with muscle-strengthening techniques to enhance the speed of recovery. It would be useful to determine the long-term effectiveness of such interventions in future studies.

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