

Effects of Posterior X Taping on Movement Quality and Knee Pain Intensity during Forward-Step-Down in Patients with Patellofemoral Pain Syndrome

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Abstract

Excessive tibiofemoral rotation in weight-bearing position may be associated with patellofemoral pain syndrome (PFPS). A previous literature suggested that “posterior X taping” method is effective for correcting the reduction of hip adduction and tibiofemoral rotation in weight bearing position. The purpose of this study was to determine the effects of posterior X taping on the angles of hip adduction, tibiofemoral rotation, grades of the forward-step-down (FSD) performance test, and intensity of knee pain when descending stair in patients with PFPS. We recruited patients with PFPS. The knee pain intensity during FSD was measured using visual analogue scale system (100 mm) under both no-tape and tape conditions. A three-dimensional motion analysis system was used to assess the kinematics of lower limb joints during FSD. In addition, scoring system of FSD performance test was used to assess the movement deviation of the trunk and lower limb and one-leg balance. Participants with PFPS showed reduced pain intensity ($p = 0.001$) and improved scores on FSD performance test ($p = 0.002$) with posterior X taping compared to the no-tape condition during FSD. No significant alterations changes were noted in three dimensional angles of the hip, knee and ankle joints, especially hip adduction and tibiofemoral rotation between conditions. Posterior X taping decreases knee pain and improves the scores on FSD performance test for patients with PFPS.

Key words: Forward step down, patellofemoral pain syndrome, posterior X taping, tibiofemoral rotation.

Introduction

Patellofemoral pain syndrome (PFPS) is characterized by pain in/around the patella and caused by complex causes such as increased Q-angle in weight bearing position, genu valgum, patella malalignment, weakness of gluteus medius and gluteus maximus, degenerative changes in the patellofemoral joint in older adults and overactivity and acceleration of activity in young athletes and military person (Earl and Hoch, 2011; Rothermich et al., 2015). Patients with PFPS describe escalation of symptoms when going up/down stairs, running, jumping, or squatting, as these functional activities increase the compressive forces at the patellofemoral joint (Rothermich et al., 2015).

Valgus collapse of the knee during forward-step-down (FSD) test is related to diminished strength of hip abductor and external rotator, and is implicated in anterior cruciate ligament injury and patellofemoral joint dysfunction (Herman et al., 2016; Loudon et al., 2002). FSD test shows moderate to high intra-rater reliability (intraclass

correlation coefficient [ICC] = 0.94) when recording the number of FSD repetitions during 30 seconds and fair to good inter-rater reliability (ICC = 0.61) when scoring the movement deviation of pelvis, hip and knee during performing FSD in individuals with PFPS (Herman et al., 2016; Loudon et al., 2002). Although three-dimensional motion analysis system has been used to measure the center of mass during FSD as objective test postural stability (Lopes Ferreira et al., 2019), scoring system of FSD performance test is easy to measure the postural stability as inexpensive and time-saving test in clinics (Herman et al., 2016). FSD is also used as neuromuscular training, such as tactile feedback to the lateral knee or visual feedback using mirror to keep the knee over second toe and level pelvis during FSD for preventing hip adduction and contralateral pelvic drop in individuals with PFPS (Wouters et al., 2012).

Non-operative management for PFPS, including hip-focused and knee-focused exercises combined with taping/bracing, manual therapy, and pharmacology, has been considered the mainstay for first-line management (Collins et al., 2018). Among non-operative management, taping and bracing are easy to use, noninvasive and less time-consuming and decreased burden associated with treating knee pain by self-brace and self-tape than other methods, and it has immediate effects in reducing knee pain (Warden et al., 2008; Wilson et al., 2003). When comparing the brace, taping techniques have advantage that was the possibility of adjusting the tape in accordance to the individual's anatomy and symptoms (Podolsky and Kalichman, 2015). Patella medial glide taping is often used because traditional management of PFPS has focused on correcting patellar lateral tracking (Cowan et al., 2002). However, a poor correlation was demonstrated between patellar lateralization and radiographic signs in patients with PFPS (Wilson et al., 2003). Additionally, patella medial glide taping is less effective for reducing pain than patellar taping techniques using neutral and lateral gliding, which indicates that the mechanism of pain relief in patients with PFPS does not involve medialization of the patella (Wilson et al., 2003).

Excessive tibiofemoral rotation in weight-bearing position may be associated with pain of PFPS rather than only patellar lateralization because excessive tibiofemoral rotation, especially from 20° to 30° of medial femoral rotation relative to tibia, results in an increase in patellofemoral contact pressure on the lateral facets of the patella (Lee et al., 2003). Previous studies demonstrated the effects of femoral rotational taping on reduction of knee pain and

tibiofemoral rotation during single-leg squat and the star excursion balance test in individuals with PFPS, resulting in successful pain reduction and a change in patellar kinematics, but failed to alter tibiofemoral rotation (Song et al., 2015; 2017). Another literature suggested that “posterior X taping” method is effective for correcting the reduction of hip adduction and tibiofemoral rotation in weight bearing position, thus leading to pain relief (Sahrmann, 2011). A strip of posterior X taping was applied in a spiral fashion, starting from the proximal lateral thigh and ending at the distal medial tibia to assist in reducing tibiofemoral rotation and hip adduction. Another strip of posterior X taping was applied symmetry, starting from the proximal medial thigh and ending at the distal lateral tibia to prevent knee hyperextension (Sahrmann, 2011). A recent study demonstrated the posterior X taping in patients with knee osteoarthritis on the improvements in self-reported pain (11 point-numerical rating scale, 2.5 reduction), self-reported difficulty (5-point Likert scale, 1 reduction), and self-reported stability (5-point Likert scale, 2 reduction) during stair down test (Park and Kim, 2018). Previous study suggested the possible causes of knee pain reduction with posterior X taping might be decreased tibiofemoral rotation internally and externally and varus/valgus movement, and decreased fear and avoidance of weight-bearing activities, although kinematic changes in hip and knee joints were not assessed (Park and Kim, 2018).

No study has been investigated the effects of posterior X taping on the reduction of hip adduction and tibiofemoral rotation using three-dimensional (3D) assessments, leading to reduction of knee pain intensity in patients with PFPS. Hence, we investigated the effects of posterior X taping on the 3D angles of the lower limb (hip adduction and tibiofemoral rotation in particular), FSD performance test scores, and intensity of knee pain during FSD in patients with PFPS. We hypothesized that posterior X taping may reduce maximal excursion of hip adduction and tibiofemoral rotation in 3D assessments, improve the FSD performance test scores, and decrease the knee pain intensity during FSD.

Methods

Subjects

A one-group pre-post test design was conducted in laboratory setting. We conducted an a priori power analysis using G-Power 3.0.1 software, and the sample size calculations were based on a clinical minimal difference of 20 mm on a 100 mm VAS (Crossley et al., 2004). Assuming a standard deviation of 20 mm, a power of 0.80, two tailed α value of 0.05, and effect size of 1.58, we required 10 subjects.

Sixteen participants with PFPS were included in the study from the university if they had experienced knee pain during at least two of the following activities: prolonged sitting, climbing up and down stairs, squatting, running, kneeling, jumping, deep knee flexion, and isometric contraction of quadriceps muscle (Song et al., 2017). Additional inclusion criteria were gradual onset of symptoms unrelated to a traumatic accident, a pain score of at least 30

on a 100 mm visual analog scale (VAS) during the previous week, and pain lasting for >2 months.

Participants were excluded from the study if they had a history of knee osteoarthritis by radiographic features and clinical symptomology; a history of dislocation or subluxation of the knee joint; history of surgery for repair of the meniscus, knee ligament, and knee joint; physiotherapy of the knee within the previous 6 months; steroid injection or oral medication within the previous 6 months; any neurological deficit; or allergy to tape. Before entry into the study, participants were informed about its objectives as well as the experimental and safety procedures. Each participant provided written informed consent. This study was approved by the Institutional Review Board of Jeonju University.



Figure 1. Forward step down with posterior X taping.

Posterior X taping

Non-elastic tape of 3.75 cm width (Leukotape; BSN Medical, Hamburg, Germany) was applied to participant's leg by an experienced physical therapist. Knee stiffness was lowest at 20° of knee flexion than 0° and 65° of knee flexion, and 20° of knee flexion was used for valgus-varus stress testing as loose-packed position according to the international knee documentation committee objective guidelines for medial compartment opening (Mangaleshkar et al., 1998; Laprade et al., 2010; Reed et al., 2000). Thus, we decided to apply the tape to the tested knee in sitting position with the knee flexed to 20° to reduce the genu valgus during FSD. Two strips of tape strips were same length as that determined by the individual's body size. The origin and insertion of two strips were middle of anterior thigh (half distance between the knee and the iliac spine) and middle of anterior tibia (half distance between the knee and ankle). A strip of tape was applied in a spiral fashion, starting from the proximal-lateral thigh around posterior knee to the distal-medial tibia for reduction of femoral medial rotation and tibial lateral rotation. Another strip was applied, starting from the proximal-medial thigh around posterior knee to the distal-lateral tibia for symmetry or preventing knee hyperextension. The strips of tape formed an “X” around the posterior knee (Figure 1) (Sahrmann, 2011). We applied two strips of tape with moderate tension and no discomfort (Chen et al., 2018). During performing FSD, we reapplied tape if it became loose. The participant was asked to report any adverse symptoms with application of the tape, and the investigator checked the skin condition after removing the tape.

Forward step down

If participants complained of bilateral PFPS, the tested leg was chosen as the side with the knee showing the greatest symptoms for each participant during FSD with and without posterior X taping conditions. Participant stand shoulder width apart with arms folded across the chest, and toe with the front end of the step. We determined the step height as 20-cm regardless of leg length based on previous studies which were used during performing step down test (Herman et al., 2016; Lopes Ferreira et al., 2019) and a previous study demonstrated no significant difference in intensity of knee pain between the three step heights (8, 14, and 20 cm) in patients with PFPS (McClinton et al., 2007). The participant was asked to flex the knee of the tested side until the heel of the non-tested limb touched the floor while keeping the trunk straight without putting weight on the heel, and then return to the starting position (Figure 2). The participant was asked to perform FSD three times for familiarization and to serve as a warm-up before testing. After a 5 min rest, the participant was asked to perform FSD seven times; we used 3D motion capture and video-recording to grade the FSD performance based on the middle five trials. The order of two conditions (with and without posterior X taping) was randomized using random-number generator. After recording under the first condition, the participant was given a rest period of approximately 15–30 minutes to allow for pain levels to return to baseline prior to performance of the next condition (Campolo et al., 2013). The procedure was then repeated under second condition.

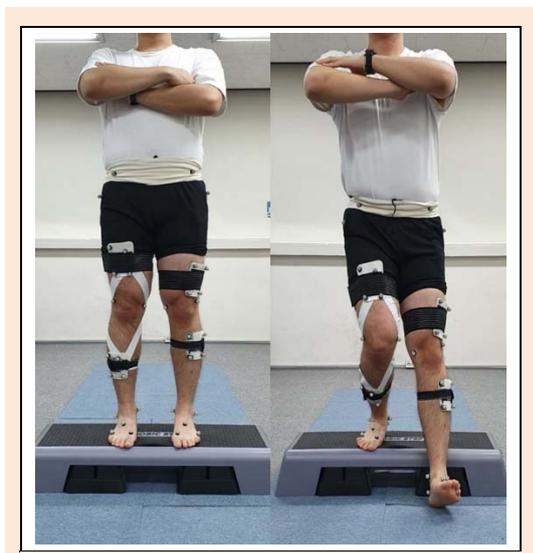


Figure 2. Forward step down with posterior X taping.

Outcome measures

Intensity of knee pain with and without taping

Participants were asked to rate their perceived pain (VAS) while performing FSD with and without posterior X taping. A VAS translator application (VAS Translator (VAS Tool) for iPad: TaF Media, Amsterdam, Netherlands) on a tablet PC (iPad, Apple Inc, Cupertino, CA, USA) was used to measure and record the pain level (0 = no pain; 100 = maximum pain). Each participant was asked to mark a 100 mm line on the monitor of the tablet PC to indicate the intensity

of knee pain during FSD. Assessment of VAS using a tablet PC is more easy to collect electronic data and user friendly by a sliding scale or by tapping a number on the tablet screen than using paper (intraclass coefficient, ICC = 0.97) (Bird et al., 2016).

Table 1. Marker locations at anatomical points.

Segments	Marker locations at anatomical points
Pelvis	Anterior superior iliac spine Posterior superior iliac spine
Thigh	Greater trochanter Lateral side of the thigh using a cluster consisting of four markers Medial and lateral epicondyle of the femur
Shank	Lateral surface of the shank using a cluster consisting of four markers Medial malleolus of distal tibia and lateral malleolus of distal fibula
Foot	Middle point of the midfoot 1st and 5th metatarsal head Medial and lateral sides of the calcaneus

3D motion analysis

A 3D motion-analysis system (Vicon MX System; Oxford Metrics, Oxford, UK) was used to measure the 3D kinematics of the lower limb during FSD with and without tape. The sampling rate was 100 Hz. Reflective markers were secured by double sided tape to the skin or tight pants. To ensure no unwanted motion of markers, bandages were wrapped around the waist, thigh and shank. Forty reflective markers were attached to the following anatomical landmarks using the calibrated anatomical system technique (Table 1) (Figure 2) (Cappozzo et al., 1995). From the coordinate data obtained from the markers, two segments were created that included the thigh and shank. The attitude of each segment was determined from the principal axis using the point cluster technique, which provides a minimally invasive estimation of the knee motion and reduce the noise resulting from skin deformation. Previous studies have established the validity of the point cluster technique (Alexander and Andriacchi, 2001; Andriacchi et al., 1998). Joint angles of hip, knee and ankle in sagittal, frontal and transverse planes were collected as participants performed the FSD test at a self-selected speed. Raw kinematic data were exported to visual 3D software (C-Motion Inc., Germantown, MD) and then filtered using fourth-order Butterworth filters with a cut-off frequency of 6 Hz. Previous studies analyzed the frontal plane knee angles at maximum knee flexion during single leg drop jump and single limb squat (Russell et al., 2006; Schmidt et al., 2019), because there was significantly negative correlation between knee pain and knee internal rotation at peak knee flexion (Schmidt et al., 2019). Thus, the kinematic data were analyzed at the maximum knee flexion angle during FSD by tester A (physical therapist), who was blinded to scoring data of FSD test. The kinematic data of the lower extremity were calculated based on the Cardan sequence of XYZ (Grood and Suntay, 1983). The relative angles of hip, knee and ankle were calculated using global coordinates oriented to the pelvis. The angle of hip adduction and internal rotation were calculated between pelvis and femur in

frontal and transverse plane. The angle of tibiofemoral rotation was calculated between the femur and tibia in the transverse plane.

Table 2. Scoring criteria of forward step down performance test.

Criterion	Interpretation for failed movement
Arm	Failure to keeping the arm folded across the chest
Trunk	Trunk leaning in any direction
Pelvis	Pelvic movement in horizontal plane
Knee	Valgus collapse (tibial tuberosity medial to medial border of foot)
Steady stance	Stepping down on nontested limb, or the foot wavered from side to side

Scoring of forward step down test

To grade the FSD test, a video file was recorded during FSD using a digital video recorder (Canon EOS 760D) coincident with the recording of 3D motion data with and without application of tape. A camera was placed 3 m directly in front of and facing the participant. Tester B (physical therapist), who had undergone a 1-month training session on the methods for FSD test grading, analyzed the recorded video file. Tester B was blinded to VAS and 3D kinematic data. FSD performance was considered “good” if the participant could perform FSD smoothly while maintaining balance without using the arms, maintain trunk and pelvic posture without deviations, maintain a steady unilateral stance, and avoid hip adduction and knee valgus for all five FSD trials (Table 2). FSD performance was rated as “poor” if the participant did not meet all of the requirements for at least 1 criterion for all five FSD trials. Participants who could not be clearly rated as good or poor were rated as “moderate” (Herman et al., 2016). FSD performance was rated as “good” = 0, “moderate” = 1, “poor” = 2. Previous studies have indicated fair to good inter-rater reliability of grading of FSD tests by a broad cohort of physical therapists (Herman et al., 2016), and high intra-rater reliability (Loudon et al., 2002). A tester showed high intra-rater reliability (ICC = 0.96) to evaluate FSD test grading in this study.

Table 3. Comparison of hip, knee and ankle joint at the maximum knee flexion angle with and without posterior X taping.

Joint	Motion	No taping (°)	Taping (°)	Mean differences ^a (95% CI)	F	p
Hip	Flexion	50.90 ± 11.00	49.44 ± 10.00	1.46 ± 7.85 (-2.3 to 5.64)	.74	.47
	Adduction	11.55 ± 6.16	10.66 ± 6.10	.90 ± 3.97 (-1.22 to 3.01)	.90	.38
	Internal rotation	8.12 ± 7.69	5.34 ± 8.72	2.78 ± 6.05 (-.45 to 6.00)	1.84	.09
Knee	Flexion	83.87 ± 7.43	84.84 ± 6.10	-.97 ± 6.49 (-4.43 to 2.49)	-.60	.56
	Adduction	9.59 ± 6.05	7.27 ± 7.92	2.32 ± 6.78 (-1.29 to 5.93)	1.37	.19
	Internal rotation	3.15 ± 4.58	4.64 ± 5.95	-1.49 ± 4.88 (-4.09 to 1.11)	-1.22	.24
Ankle	Dorsiflexion	114.59 ± 7.36	114.09 ± 7.67	.50 ± 3.95 (-1.60 to 2.61)	.51	.62
	Inversion	-18.62 ± 8.42	-18.47 ± 6.38	-.15 ± 4.94 (-2.78 to 2.49)	-.12	.91
	Internal rotation	-7.62 ± 4.19	-8.23 ± 3.92	.61 ± 3.88 (-1.46 to 2.68)	.63	.54

^aMean ± standard deviation

Discussion

Posterior X taping applied to patients with PFPS reduced the intensity of knee pain during FSD and improved total scores on FSD performance test. However, it failed to change the kinematics of the hip, knee, and ankle joints

Statistical analysis

The Kolmogorov-Smirnov test was performed to confirm the normal distribution of dependent variables. Data of knee pain intensity and angle of hip, knee, ankle were found to be normally distributed (Z value, .09 to .19; P value, .11 to .20), whereas data of FSD test were found to be non-normal distributed (ranges of Z value, from .22 to .40; P value, from 0.01 to 0.03). To compare the differences in pain intensity and angles of the hip, knee, and ankle joints, especially hip adduction, hip internal rotation and tibiofemoral rotation during FSD with and without taping, 1-way repeated analysis of variance was used. The marginal homogeneity test was used to compare the ordinal FSD test scores with and without taping. Analyses were performed using SPSS software (ver. 20.0; SPSS Inc., Chicago, IL) with the α level set at 0.05.

Results

Sixteen participants with PFPS, non-active adults (3 men, 13 women; age mean ± SD, 38.0 ± 16.26 years; height 1.65 ± 1.23 m, mass 62.0 ± 9.4 kg) were deemed acceptable for inclusion in the analyses. There was a significant reduction in knee pain intensity during FSD with taping (mean ± SD, 18.81 ± 9.73 mm) compared to without taping (mean ± SD, 47.25 ± 12.96 mm) (mean differences = 28.43 mm; 95% CIs [22.73-34.14 mm]; F = 10.63; P = 0.001). The angles of the hip, knee, and ankle joints showed no significant differences between taping conditions in maximal angle of knee flexion during FSD (Table 3) (Figure 3). The FSD test scores showed significant improvement with taping compared to without taping (p = 0.001) (Table 4).

Table 4. Comparison of scores of forward step down test with and without posterior X taping.

Score	No tape (N, %)	Tape (N, %)	p
Good	1 (6.3)	10 (62.5)	.001*
Moderate	6 (37.5)	6 (37.5)	
Poor	9 (56.3)	0 (0)	

* Marginal homogeneity test

during FSD, such as reduction of hip adduction and tibiofemoral rotation. Based on these findings, we recommend posterior X taping to control knee pain during FSD in management of patients with PFPS. However, the pain-inhibition effects may not be due to correction of lower limb kinematics.

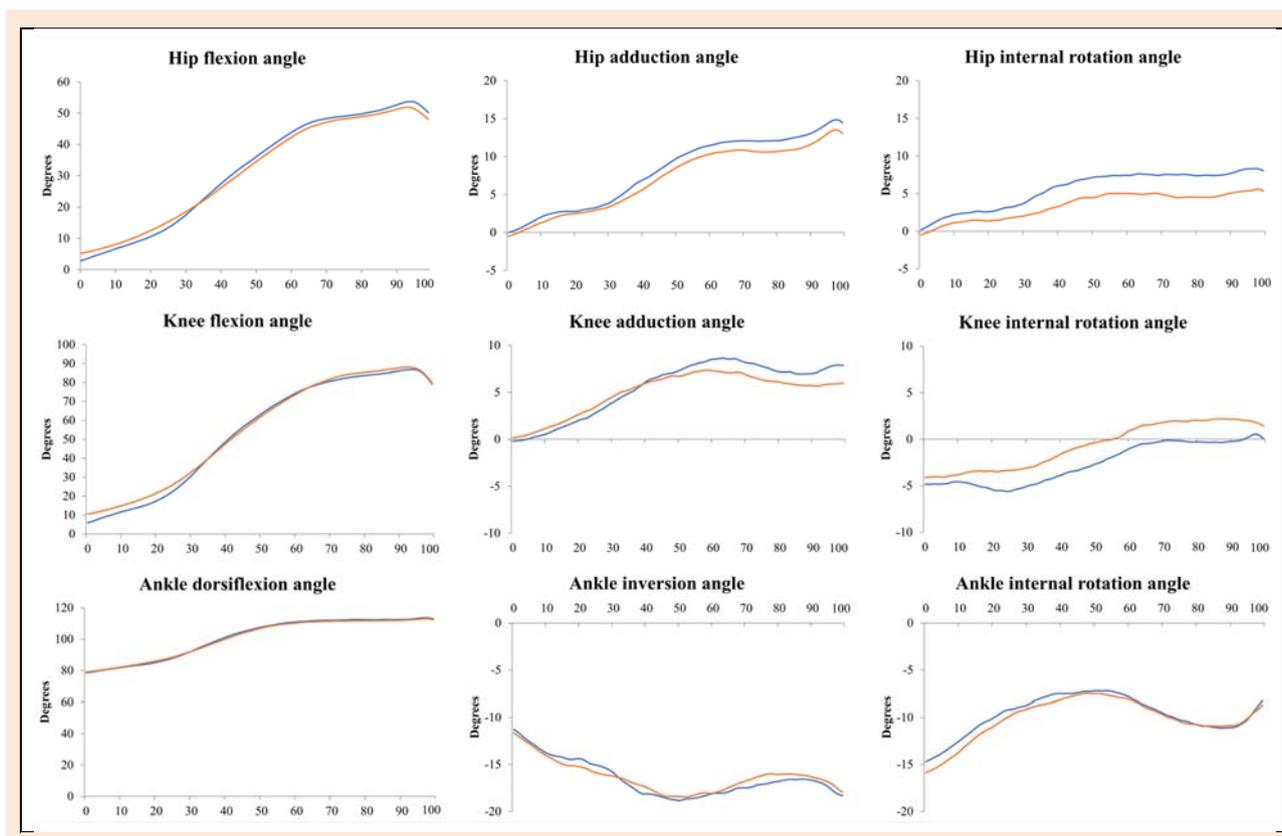


Figure 3. Mean time series data during forward step down for angles of hip, knee and ankle joint in posterior X tape condition (red line) and no-tape condition (blue line).

Posterior X taping condition was more effective to improvement of knee pain and total scores on FSD performance test than no-tape condition. Scoring system of FSD performance test was used to assess the movement deviation of the arm, trunk, pelvis, knee and steady stance (Herman et al., 2016). When comparing no-tape condition, posterior X taping reduced movement deviations significantly; 56.2% increase of good score and 56.3% decrease of poor score (Table 4). Total scores on FSD performance test can be graded when the overall pattern of the arm strategy, trunk alignment, pelvis plane, knee position, and steady balance is evaluated, rather than in segments (Herman et al., 2016). A previous study suggested that PFPS patients could compensate using ipsilateral trunk leaning rather than hip adduction, because ipsilateral trunk leaning could shift the center of mass over the center of the hip joint during the step-down task (Souza and Powers, 2009). Patients with PFPS subconsciously select an appropriate movement pattern to reduce knee pain during stair descent (Bolglia et al., 2008). Thus, inhibition of compensatory movement patterns during FSD resulted significant improvement of total scores of FSD test in patients with PFPS.

Sahrmann (2011) suggested that posterior X taping may reduce excessive tibiofemoral rotation, leading to reduced knee pain. However, based on our results, posterior X taping did not reduce hip adduction and tibiofemoral rotation but successfully alleviated knee pain during FSD. Previous studies applied femoral rotational taping to correct excessive tibiofemoral rotation during single-leg squat and the star excursion balance test in individuals with

PFPS, resulting in successful pain reduction, but failed to alter tibiofemoral rotation (Song et al., 2015; Song et al., 2017). Previous studies and our results could not explain the clear mechanism of pain reduction by taping because tape could not change significant tibiofemoral rotation (Sahrmann, 2011; Song et al., 2015; Song et al., 2017). Clinicians can apply the posterior X taping to control the knee pain during FSD with less expectation of kinematic changes of hip, knee and ankle in patients with PFPS.

Posterior X taping in our study resulted in an immediate reduction in knee pain of about 28.43 mm on the VAS during FSD, compared to no-tape condition. VAS change of 20 mm was necessary for clinical significance, so the level of pain reduction in our study was clinically significant (Crossley et al., 2004). There are possible reasons for pain reduction by taping based on results of previous studies. First, the tape stretches the skin, which can activate subcutaneous mechanoreceptors and inhibit pain transmission to the brain, thus reducing pain (Chen et al., 2018; Lim and Tay, 2015). Posterior X taping has a greater contact area of the thigh and tibia diagonally compared to patellar taping (Osorio et al., 2013; Wilson et al., 2003), so greater numbers of subcutaneous mechanoreceptors around the thigh and tibia/fibula may be stimulated during FSD, leading to more pain relief. Second, it is also possible that the application of taping has a psychological effect that results in reduction of knee pain (Lim and Tay, 2015; Song et al., 2015). A previous systemic review on PFPS patients indicated a linear correlation between pain level and psychological factors such as catastrophizing and fear of movement (Maclachlan et al., 2017). Posterior X taping for

patients with knee osteoarthritis can reduce difficulties by changing confidence and reducing fear of movement during functional activities (Park and Kim, 2018). Our results also showed similar reduction in knee pain (VAS, 28.43 mm) in line with a previous study (Park and Kim, 2018). Although experimental design of this study was one-group pretest-posttest design without comparative group using other taping methods, we speculated that psychological expectations and activation of subcutaneous mechanoreceptors may have given rise to pain reduction in our study. In this study, it was difficult to explain the mechanism of knee pain reduction by taping. Further study should incorporate the addition of a control group or comparator group using other types of taping to reduce threats to the internal validity of data and explain the clear mechanism of knee pain reduction by taping.

This study had limitations. First, we measured angle of the lower limb only without taking into consideration the angle of the spine. Further studies are required to investigate the angle of trunk plus lower limb during FSD in patients with PFPS. Second, few males were included in this study, so these findings cannot be generalized to all patients with PFPS. Third, we investigated the immediate effects of posterior X taping on knee pain. Further studies are required to determine the long-term effects. In addition, studies are required to examine the long-term effects of a combination of posterior X taping and exercise on pain reduction. The long-term effects of exercise plus taping interventions are controversial. A previous study indicated that a combination of patellar taping and exercise was superior to exercise alone for reduction of knee pain and improvement of knee function in patients with PFPS (Whittingham et al., 2004). By contrast, other studies have shown no benefits with regard to pain reduction when adding kinesiotaping to exercise therapy over a period of 4 or 6 weeks in patients with PFPS, compared to exercise alone (Akbas et al., 2011; Ghourbanpour et al., 2018). Lastly, this study was lack of the control group, future study would be required to confirm the present findings with comparative taping or sham taping group.

Conclusion

We investigated the effects of non-elastic tape attached to both the upper and lower legs diagonally, which is referred to as posterior X taping, on knee pain, FSD performance, and rotational angle of the lower limbs, especially hip adduction and tibiofemoral rotation during FSD in participants with PFPS. Posterior X taping decreased knee pain intensity and improved the FSD test scores in participants with PFPS. The mechanism underlying the pain reduction associated with taping is still unclear, as we did not find any significant changes in lower limb kinematics during FSD with posterior X taping compared to without taping. Our results suggest that posterior X taping may be an effective and rapid intervention to alleviate knee pain immediately during functional tasks such as step-down maneuvers in patients with PFPS.

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Key points

- Posterior X taping can reduce knee pain intensity during forward-step-down (FSD).
- Posterior X taping is effective to improve scores on the FSD performance test.
- The pain-inhibition effects by taping may not be due to correction of tibiofemoral kinematics.

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