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Myofascial Pain and Treatment

The effect of Kinesio-tape® on pain and vertical jump performance in active individuals with patellar tendinopathy

Kaori Tamura [a,*], Portia B. Resnick [b], Bruce P. Hamelin [c], Yukiya Oba [a], Ronald K. Hetzler [a], Christopher D. Stickley [a]

[a] Department of Kinesiology and Rehabilitation Science, University of Hawaii at Manoa, 1337 Lower Campus Road, PE/A Complex, Honolulu, HI, 96822, USA
[b] Department of Kinesiology, California State University, Long Beach, 1250 Bellflower Boulevard, Long Beach, CA, 90804, USA
[c] Department of Athletics, Florida Atlantic University, 777 Glades Rd, Boca Raton, FL, 33431, USA

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ABSTRACT

Background: Patellar tendinopathy is a common inflammatory condition in athletes who undergo large volumes of running and jumping. Kinesio-tape® (KT) is proposed to provide pain relief; however, its effect has not been examined on patellar tendinopathy.
Objective: To examine the effects of KT on pain modulation for active individuals with patellar tendinopathy during functional activities.
Methods: Thirteen symptomatic knees from seven college-aged females (6 bilateral; 1 unilateral) were included. Participants underwent three data collection sessions with KT, sham, and no tape (NT) in a randomized order. During the session, participants performed a maximum vertical jump, single-leg squats and isometric knee extension. The KT intervention was applied according to the KT manual and the sham utilized the same pattern without tension. Pain level was evaluated using the numeric pain scale before, during and after each activity. Function was assessed as maximum vertical jump height and maximum isometric strength. A separate repeated measures ANOVA was used to compare each dependent variable (pain level, vertical jump height, and isometric strength) among the conditions.
Results: Reported pain scores were significantly lower ($p = 0.05$) during the maximal vertical jump test for KT (3.38 ± 1.26) compared to NT (4.54 ± 2.22). Significantly lower jump heights were found under KT (17.73 ± 3.06in) during the maximum vertical jump test compared to sham (18.65 ± 2.17in, $p = 0.000$) and NT (18.18 ± 2.93in, $p = 0.008$).
Conclusions: The use of the KT tape with a tendon corrective strip and muscle facilitative strip was effective for decreasing pain associated with patellar tendinopathy during jump landing but led to decreased maximum jump height.
Clinical trial identifier: NCT04153877.

1. Introduction

Patellar tendinopathy is an inflammatory condition of the patellar tendon where it connects from the apex of the patella to the tibial tuberosity. This pathology is common in individuals who undergo large volumes of running or jumping and has an insidious onset caused by the knee-extensor mechanism used in these activities (Cook et al., 1997; Ferretti, 1986; Lian et al., 2005; Martens et al., 1982; Rudavsky and Cook, 2014; Witvrouw et al., 2001). Common complaints include anterior knee pain when running or jumping, with symptoms progressing to point tenderness along the patellar tendon or at its points of attachment, the apex of the patella and the tibial tuberosity (Cook et al., 1997; Martens et al., 1982; Witvrouw et al., 2001). If untreated, the pain itself can also progress to a point of debilitation for some individuals, lasting from months to years, necessitating withdrawal from sports participation. The development of the pathology is also influenced by a variety of intrinsic and extrinsic factors, requiring treatment and intervention to be highly individualized (Ferretti, 1986; Lian et al., 2005; Rudavsky and Cook, 2014).

* Corresponding author. Dept of Kinesiology and Rehabilitation Science, University of Hawaii, 1337 Lower Campus Road, Honolulu, HI, 96822, USA.
E-mail addresses: ktamura@hawaii.edu (K. Tamura), portia.resnick@csulb.edu (P.B. Resnick), bhamelin@fau.edu (B.P. Hamelin), yukiya@hawaii.edu (Y. Oba), hetzler@hawaii.edu (R.K. Hetzler), cstickle@hawaii.edu (C.D. Stickley).

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The efficacy of Kinesio-tape® (KT) in reducing pain has been reported on patients with various pathologic conditions including but not limited to shoulder impingement syndrome, acute whiplash injury, chronic low back pain, and plantar fasciitis (Kalron and Bar-Sela, 2013; Williams et al., 2012; Wu et al., 2015). Kinesio-tape® is an elastic, hypoallergenic, cotton-fiber tape with acrylic heat-activated backing and is widely used within sports. The elastic properties of KT allow it to stretch up to 140% of its original length along its longitudinal axis. The approximate weight and thickness of KT is designed to enhance a seamless feel to the body. When applied correctly, KT is proposed to offer a multitude of benefits depending on the dysfunction including reducing pain and inflammation by increasing the interstitial space, facilitating muscle function by modifying the recruitment activity patterns, improving joint function by facilitating realignment, and enhancing sensory function by improving joint position sense and kinesthetic awareness (Kase et al., 2003; McDuffie, 2013a). However, the physiologic basis behind KT techniques is considered weak and further research is warranted (Nunes et al., 2015).

Studies investigating the proposed benefits of KT on the knee joint have focused on general knee pathologies, such as patellofemoral pain syndrome (Aytar et al., 2011; Chen et al., 2008) and anterior knee pain (Campolo et al., 2013); the effect of KT on patellar tendinopathy has not been examined. Therefore, the purpose of this study is to examine the effects of KT on pain modulation for active individuals with patellar tendinopathy during functional activity. It was hypothesized that the application of KT would increase the functional outcome measures and decrease pain during functional testing.

2. Methods

2.1. Study design

This is an observational prospective cohort study with a repeated measures design to examine the effects of KT on participants' pain level during single-leg squats, maximum vertical jump test, and isometric knee extension. (Clinical Trial Identifier: NCT04153877).

2.2. Setting

The study was conducted in the university's athletic training research laboratory. All data were collected in the same facility by the same examiner.

2.3. Participants

A total of 13 knees with patellar tendinopathy, from seven active college-aged females (age 19.7 ± 0.9 y/o), were included in the study. Individuals with knee pain were recruited by the researcher from a pool of university's student athletes as well as from students enrolled in Kinesiology courses. An initial screening to confirm the inclusionary criteria of having the signs and symptoms of patellar tendinopathy was conducted by the same certified athletic trainer. Patellar tendinopathy in this study was defined as: (1) Anterior knee pain that increases with jumping and/or squatting; (2) pain with palpation at the tibial tuberosity, the patellar tendon, and/or at the apex of the patella; and (3) an insidious onset of this pain. Additional inclusionary criteria of participating in physical activity at least 3 days a week was used to ensure participants' ability to complete the testing required for data collection. Recruited individuals were then screened for the following exclusionary criteria: (1) injury from direct trauma to the anterior knee, (2) medical history of surgery at the knee joint within the past 6 months, (3) presence of any lower extremity injuries or non-orthopedic diseases and (4) suspected or confirmed pregnancy. The same certified athletic trainer conducted the physical examination to screen for the incursionary and exclusionary criteria, and diagnosed the patellar tendinopathy using the criteria described above; however, diagnostic imaging such as magnetic resonance imaging or ultrasound were not used. While pain level was not recorded during the initial screening, the presence of anterior knee pain was addressed under the inclusionary criteria. No other health related criteria were used for the initial screening. Participation in the study was voluntary and an informed consent was signed by each participant prior to study enrollment. The study was approved by the University of Hawaii Human Studies Program (CHS#23178).

2.4. Interventions

Kinesio Tex tape® (2-inch Kinesio Tex Gold, Kinesio Holding Corporation, Albuquerque, New Mexico, USA) was used for the KT and sham conditions (see Fig. 1). For the KT condition, the tape was applied in accordance with the KT instructional manual using a facilitative strip on the vastus medialis obliques (VMO) and a tendon corrective strip on the patellar tendon with appropriate tension. The participant flexed their knee to 30° for tape application. The tendon corrective I-strip was applied with the middle third of the KT tape stretched to 75–100% tension over the patellar tendon. The two outer thirds of the KT tape served as anchors and were laid with 0% tension along the lateral and medial aspects of the thigh moving superiorly towards the pelvis. A facilitative Y-strip was divided into thirds; the first third was designated as the tail and the remaining two-thirds were split longitudinally to create the Y-divisions. The KT tape representing tail of the Y was placed with 0% tension at the proximal origin of the VMO. Each KT tape strip of the Y-divisions was applied medially and laterally, respectively, around the VMO with 25–35% tension, ending with 0% tension at the anchors.

Tension within the KT condition was standardized based on the Kinesio TexTape®'s inherent ability to stretch up to a maximum of 140% of its resting length. Therefore, to attain 100% tension on a specific portion of the tape, the tape must be stretched 40% further than its originally measured length. The tension was standardized as follows: seventy-five percent tension was reached at an increase of 30% of its original length, 50% tension at an increase of 20% its original length, and 25% tension at an increase of 10% its original length. For the sham condition, the tape was applied in an identical pattern on the involved extremity with zero stretch to evaluate the effect of the prescribed KT application method.

2.5. Procedure

Participants completed each test under three conditions: (1) no tape (NT); (2) Kinesio-tape® (KT); and (3) sham in a randomized order with each session separated by a minimum of three, but no more than seven days. For the participants with bilateral patellar tendinopathy undergoing testing of both knees during one session, the same condition was assigned for each knee. The data were collected one knee at a time, per each exercise during the session. Pain level was reported using the Numeric Pain Scale (NPS) ranging from zero to ten, with zero representing no pain, five as moderate pain and ten being unbearable pain. Participants were instructed to maintain their regular routine of exercise and treatment for the injury throughout the duration of the study.

At the beginning of each testing session, anthropometric data and baseline knee pain level were recorded. For the KT and sham conditions, the participant was blindfolded while the clinician applied the tape to the involved leg in accordance with the

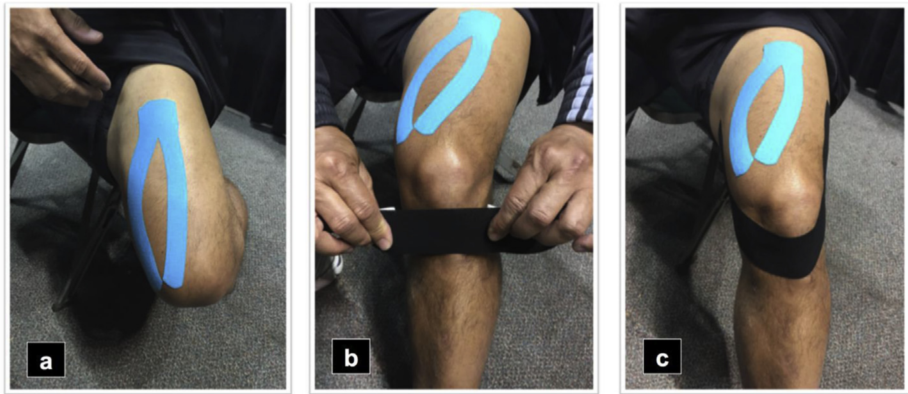

Fig. 1. Kinesio-tape® Application. Kinesio-tape® is applied to the left knee with: a) Facilitative Y-strip on Vastus Medialis Obliques, b) and c) Tendon Corrective Strip on Patellar Tendon.

condition of that day. The area of the involved leg to be taped was prepped by removing excess dirt and oils, and trimming hair if necessary, to ensure proper tape adhesion. The taping was applied by the same certified Kinesio taping practitioner. After the tape application, the blindfold was removed and the participant was instructed to perform a 5-min warm-up on a stationary bike at an intensity level of 64–74% of their maximal heart rate. Maximal heart rate was calculated from the maximal heart rate prediction equation (220-age); heart rate was monitored by a Polar heart rate monitor (Pacer T31, Polar Electro, Oy, Finland) (Heyward and Gibson, 2014). The researcher was not blinded from the testing condition.

The participant was then taken to the 20° slant board and instructed to perform a single-leg squat reaching at least 45° of knee flexion. A chair was placed behind the slant board as a safety measure to assist in catching the participant if falling backwards. Instructions for this test were delivered to the participant verbally and through physical demonstration by the researcher. Following a maximum of two familiarization trials, a five-repetition working trial was completed. After the trial, the participant verbally reported their level of pain at the knee.

Following 5 min of rest, the participant performed a maximum vertical jump test using a Vertec measurement system (Sports Imports, Hilliard, Ohio, USA). The participant was instructed to stand with feet shoulder width apart directly next to the Vertec, jump straight up as high as possible, and reach to touch their highest point on the Vertec. Participants were allowed to perform their normal jumping mechanics to reach their highest possible point, as long as they jumped from a standing position and did not use any type of drop-step or jump approach. After a maximum of two warm-up trials the participant was given 3 min of rest. The participant performed three working trials of the vertical jump with 1 min of rest between jumps; the highest jump height was used for data analysis. Pain level was recorded immediately after each jump. The pain level during the highest jump was used for data analysis.

After another 5 min of rest, the participant performed an isometric knee extension strength test. A MicroFet2 Hand Held Dynamometer (HHD) (Hoggan Health Industries Inc., West Jordan, UT) was used to measure force output at the knee during extension (Andrews et al., 1996; Bohannon, 1997; Kim et al., 2014). The HHD was held in place with a strap at an 80% distance from the knee segment to standardize lever arms amongst individuals of varying heights. Data were collected from a seated position with hips and knees flexed to 90°, verified using a goniometer. Participants were instructed to exert maximal pressure and to sustain pressure for 3 s upon the command "Go" and to cease upon the command "Stop".

Table 1
Numeric pain scale scores (0–10) during functional activities under three conditions.

	Condition (Mean ± SD)		
	KT	Sham	NT
Single-Leg Squat	3.92 ± 2.4	4.54 ± 2.7	4.23 ± 2.4
Max Vertical Jump	3.38 ± 1.3*	3.92 ± 2.1	4.54 ± 2.2
Isometric Knee Extension	3.51 ± 1.8	4.40 ± 2.4	4.05 ± 1.6

Pain was significantly lower following the maximum vertical jump under the KT condition compared to the NT condition. No other significant differences were found.
Note: KT=Kinesio-tape®, NT=No Tape* indicates significant difference compared to NT at $P \le .05$.

Following a submaximal familiarization trial, maximal trials were recorded on the involved side with a minimum of 90 s rest between trials. If the first two trials differed by more than 10% a third trial was performed; mean torque of two or three trials was used for the data analysis. Any trials with obvious attempts to rotate the trunk and use adjacent muscles were discarded and re-tested. Pain level was recorded immediately after the completion of each trial; mean pain score was used for data analysis. All participants underwent the functional testing tasks in the same order, maintained for all testing sessions to standardize the fatigue level. However, the order of testing condition (KT, Sham and NT) was randomized to control for learning effects and possible changes in injury severity.

2.6. Statistical analysis

One-way analysis of variance (ANOVA) was used to compare the baseline pain level for each condition. Repeated measures ANOVA with post hoc pairwise comparisons were used to compare each outcome among conditions (KT, sham, and NT). The outcomes were pain level for each functional task, isometric knee extension strength obtained via HHD and maximum vertical jump height obtained via Vertec. Significance level was set at $P \le .05$.

3. Results

The one-way ANOVA comparing the baseline pain level at each condition indicated no significant difference, suggesting that pain level did not change over the data collection period. Reported pain scores were significantly lower ($P = 0.05$) during the maximum vertical jump test for the KT condition (3.38 ± 1.26) compared to the NT condition (4.54 ± 2.22); there was no significant difference between the sham and NT conditions ($P = 0.392$) (see Table 1). No

Table 2
Maximum vertical jump height and maximal isometric knee extension torque under three conditions.

	Condition (Mean ± SD)		
	KT	Sham	NT
Jump Height (inches)	17.73 ± 3.07*	18.65 ± 2.17	18.81 ± 2.93
Torque (N*m)	36.32 ± 23.69	40.54 ± 37.09	39.51 ± 34.66

The maximum vertical jump height was significantly lower for the KT condition compared to the Sham and NT conditions. There was no significant difference for mean torque.
Note: KT=Kinesio-tape®, NT=No Tape.
*indicates significant difference compared to NT at $P \leq .05$

significant difference was found between conditions for reported pain score during the single-leg squat test ($P = 0.67$) or the knee extensor strength test ($P = 0.34$). Significantly lower jump heights were found under KT condition (17.73 ± 3.06 in) during the maximum vertical jump test compared to the sham (18.65 ± 2.17 in, $P = 0.000$) and NT conditions (18.81 ± 2.93 in, $P = 0.008$) (see Table 2). No statistical significance was observed for the isometric knee extensor strength between conditions (see Table 2).

4. Discussion

In the current study, pain associated with patellar tendinopathy significantly decreased under the KT condition compared to the control condition during the maximal vertical jump test. The KT effect on pain has been inconclusive among previous studies, possibly due to the difference in selected pathologies causing pain. Thelen, Dauber, and Stoneman (2008) examined the effect of KT compared to a sham KT condition (incorrectly applied KT) for participants with shoulder impingement or rotator cuff tendinitis. In this randomized, double-blind study KT was no more efficacious than sham taping as pain decreased in both KT and sham groups. Aytar et al. (2011) examined the KT effect on pain associated with patellofemoral pain syndrome during functional movement utilizing a randomized, double-blind method with a placebo condition consisting of an inelastic tape applied in a similar manner, and reported both KT and placebo tapes did not decrease pain scores. Conversely, Shakeri et al. (2013) conducted a randomized, double-blind placebo controlled study and reported significantly decreased nocturnal pain associated with shoulder impingement syndrome in both KT and placebo (incorrectly applied KT) groups, and significantly decreased functional pain only in the KT group. These authors explained that the pain control effects seen in both KT and placebo conditions may be attributed to gate control theory.

Our study results indicating decreased pain during vertical jump test was unique to the KT condition as there was no sham effect. However, the KT effect on pain was seen only during the maximal vertical jump test and was not seen during the single-leg squat test or the knee extensor strength test. These results suggest that the effects of KT tape on pain may not be fully explained by gate control. The use of a patellar tendon strap is one of the most common methods to reduce patellar tendon pain during activity. Rosen, Ko, and Brown (2017) reported that the infrapatellar tendon strap reduced pain associated with patellar tendinopathy during single leg landing. Lavagnino, Arnoczky, Dodds, and Elvin (2011) found that application of a patellar tendon strap reduced the average and maximum localized tendon strain at the site of application, increased the patella-patellar tendon angle and decreased the patellar tendon length. Since the tendon corrective I-strip was applied over the patellar tendon in a fashion similar to an infrapatellar tendon strap with 100% tension, it is possible that the pain reduction effect found in this study is associated with the mechanism similar to the infrapatellar strap. This could also explain why sham tape did not have the same effect as the I-strip was applied with no tension. Lavagnino, Arnoczky, Elvin, and Dodds (2008) also reported that the patellar tendon undergoes its highest strain at 60° of knee flexion during a simulated jump landing. It is plausible that the non-weight bearing position of the isometric knee extension strength test and the slower loading on the extensor mechanism during the single-leg squat did not elicit enough patellar tendon strain for the KT tape to be effective.

Interestingly, the vertical jump height was negatively influenced by KT as indicated by significantly decreased jump height compared to the sham and NT conditions. This is in contrast to previous studies reporting that KT application did not inhibit or facilitate participant performance during maximum vertical jump testing (Aktas and Baltaci, 2011; de Hoyo et al., 2013; Kümmel et al., 2011; Nakajima and Baldridge, 2013). This may be due to the difference in taping procedures used for these studies; two studies used muscle facilitative Y-strip on quadriceps muscle, one study used a combination of muscle facilitative Y-strip on quadriceps muscle and a mechanical correction Y-strip on the patella, and one study used taping methods for a lateral ankle sprain, on healthy participants (Aktas and Baltaci, 2011; de Hoyo et al., 2013; Kümmel et al., 2011; Nakajima and Baldridge, 2013). These different taping procedures are theorized to elicit unique effects on pain and muscle function. Muscle facilitation procedures are the preferred method to improve function when a muscle is weak from chronic injury or while undergoing rehabilitation. This is accomplished by pulling the tape distally from the proximal origin of the target muscle with 15–35% tension (Kase et al., 2003), which results in the tape recoiling toward the proximal attachment supporting the muscle contraction in parallel. Although evidence supporting the KT's muscle facilitation effect is limited, Wong et al. reported a significantly shorter time to the knee extension peak torque with muscle facilitation technique and explained that the tactile input and stimulation of cutaneous mechanoreceptors might alter the firing time of the motor neurons (Wong et al., 2012). On the other hand, mechanical correction techniques are used to provide a positional hold around a joint, which is accomplished by applying KT with 50–75% tension with a “downward and inward” pressure on the target tissue while the joint is at a desired resting position. The previous studies that utilized these KT methods did not show significant improvement in vertical jump performance; however, they did not show decreases in vertical jump height either. The KT methods used for the present study were a muscle facilitative Y-strip at the VMO, and a tendon corrective I-strip at the site of the patellar tendon as these were determined to be the most appropriate application method for patellar tendinopathy. The tendon corrective I-strip method for patellar tendinopathy involves applying the tape horizontally with 75%–100% tension over the patellar tendon to dissipate stress. The tape applied perpendicular to the tendon is theorized to enhance proprioceptive signals through the cutaneous receptors providing feedback to avoid painful movements (McDuffie, 2013b). This is accomplished by KT's limited ability to stretch perpendicular to its length, restricting the stretch of the skin over the patellar tendon along its longitudinal axis. These proposed effects of tendon corrective methods might have influenced the normal range of motion during the vertical jump by avoiding the painful range, altering the stretch-reflex mechanism at the patellar tendon, resulting in decreased jump heights. In addition, it is important to note that these previous studies utilized healthy participants while this study's participants were suffering from patellar tendinopathy symptoms at the time of data collection.

Neither KT nor sham conditions influenced knee extensor strength in the current study. In contrast, Slupik et al. (2007) found an increase in bioelectrical activity and torque at the knee using the same muscle facilitative KT method on vastus medialis without the tendon corrective I-strip. That study reported a significant increase in bioelectrical activity and peak torque, measured using EMG, at 24 and 72 h post KT application, which decreased back to the baseline level after 96 h of KT application; no changes were indicated immediately after (10 min) KT application (Slupik et al., 2007). These results may indicate that greater amounts of time after tape application is needed to elicit the effects of fascial manipulation and muscle facilitation. Research by Schleip (2003) has shown that in order to make any significant deformation in areas of fascial or muscle restriction, a significant amount of force or time is needed. As the muscle facilitation method does not exert an extensive amount of force on target tissues, the extent of time after application may be a noteworthy factor for taping outcomes. It is also possible that the tendon corrective I-strip used in this study had an inhibitory effect, supported by decreased vertical jump height, countering the muscle facilitative Y-strip effect. The influence of time after KT application as well as the effect of the tendon corrective I-strip on knee extensor strength in patients with patellar tendinopathy warrants further investigation.

4.1. Limitations

Limitations of this study include diagnosis criteria, inclusion of the participant with bilateral patellar tendinopathy, participants' previous experience with KT, and small sample size. With our diagnosis criteria and procedure, we were unable to differentiate Sinding-Larsen-Johansson syndrome, Osgood-Schlatter disease, chondromalacia patellae and pre/infrapatellar bursitis. Given that our participants were all female with the mean age of 19.7 ± 0.9 y/o, it is less likely that their patellar tendon pain was due to epiphyseal injuries which are commonly seen in adolescents ranging from 10 to 14 years of age (Draghi et al., 2008); however, it is possible that participants' knee pain was associated with the aforementioned conditions. The participants with bilateral knee pain were included in the study and each leg was treated individually to increase our sample size. Although the same tape condition was assigned for both knees and the functional tests were conducted separately for the single-leg squat test and the knee extensor strength test, it was impossible to isolate one leg during the vertical jump test. Although the pain level was taken separately for each leg, it is possible that the pain perception was influenced differently for those with bilateral knee pain. This study did not identify participants who had previous experience with KT, which could influence the subjective data such as pain outcome. Lastly, A Priori analysis indicated a total sample size of 28 in order to detect a medium effect size. The sample size of 13 knees could be too small to detect medium effect. The Post hoc analyses indicated small effect sizes for all non-significant findings (η_p^2range: 0.081 to 0.164), while large ($\eta_p^2 = 0.762$) and medium ($\eta_p^2 = 0.290$) effect sizes were indicated for the vertical jump height and pain during vertical jump, respectively.

5. Conclusion

In conclusion, KT tape with a muscle facilitative Y strip on the VMO and a tendon corrective I-strip on the patellar tendon was found to be effective for decreasing pain associated with patellar tendinopathy during vertical jump activity. The specific KT tape method used in the current study negatively influenced the jump performance decreasing the maximum jump height. The study findings seem to be specific to the type of injury, activity, and KT method used for this injury. Further studies should investigate the mechanism of KT effects in decreasing pain and decreased vertical jump height in participants with patellar tendinopathy.

6. Clinical relevance

- The knee pain during vertical jump activity associated with patellar tendinopathy was decreased with the application of KT tape using a muscle facilitative Y strip on the VMO and a tendon corrective I-strip on the patellar tendon.
- Although the knee pain was decreased, the application of KT tape also resulted in decreased maximum jump height.
- The application of KT tape did not affect the pain level during the single-leg squat test and the knee extensor strength test.
- The application of KT tape did not affect the knee extensor strength.
- Clinicians may choose to use KT tape for patient population with patellar tendinopathy that regularly experience repeated bouts of jumping activities as long as the vertical jump height is not the main performance outcome.

Declarations of interest

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