University of Nebraska at Omaha
DigitalCommons@UNO

Health and Kinesiology Faculty Publications

School of Health and Kinesiology

3-2017

Patellar tendon straps decrease pre-landing quadriceps activation in males with patellar tendinopathy

Adam B. Rosen
University of Nebraska at Omaha, arosen@unomaha.edu

Jupil Ko
Northern Arizona University, jupilko@gmail.com

Kathy J. Simpson
University of Georgia

Cathleen N. Brown
Oregon State University

Follow this and additional works at: https://digitalcommons.unomaha.edu/hperfacpub

Part of the Health and Physical Education Commons, and the Kinesiology Commons

Recommended Citation
Rosen, Adam B.; Ko, Jupil; Simpson, Kathy J.; and Brown, Cathleen N., "Patellar tendon straps decrease pre-landing quadriceps activation in males with patellar tendinopathy" (2017). *Health and Kinesiology Faculty Publications*. 34.
https://digitalcommons.unomaha.edu/hperfacpub/34

This Article is brought to you for free and open access by the School of Health and Kinesiology at DigitalCommons@UNO. It has been accepted for inclusion in Health and Kinesiology Faculty Publications by an authorized administrator of DigitalCommons@UNO. For more information, please contact unodigitalcommons@unomaha.edu.

Patellar Tendon Straps Decrease Pre-Landing Quadriceps Activation in Males with Patellar Tendinopathy

Abstract

Objective: To determine if patellar tendon straps altered quadriceps' muscle activity during a drop-jump landing in males with and without patellar tendinopathy.

Design: Case-control.

Settings: Biomechanics Research Laboratory.

Participants: Twenty recreationally-active males participated: ten (age=21.3±2.4 years, height=182.8±5.3cm, mass=81.7±8.6kg) with patellar tendinopathy; ten (age=22.0±1.6 years, height=185.7±4.5 cm, mass=82.2±9.8kg) were healthy with no history of tendinopathy.

Main Outcome Measures: Electromyography (EMG) data for the vastus medialis (VM), rectus femoris (RF), and vastus lateralis (VL) muscles were collected. Five 2-legged 40cm drop-jumps were performed wearing a patellar tendon strap and 5 with no-strap in a counterbalanced order. Root-mean square EMG (REMG) values of the VM, RF, and VL were averaged for a pre-landing and post-landing interval. Multiple mixed-model two-way ANOVAs were performed to determine the effect of tendinopathy and strapping condition on REMG values for each muscle.

Results: For the pre-landing interval, all participants displayed lesser VL EMG activation (0.44±0.19%, 0.53±0.27%, respectively; p=.007, d=0.39) in the no-strap compared with the strap condition.

Conclusions: When wearing a strap, all participants demonstrated lower VL activation prior to landing which may be helpful in reducing tensile stress at the tendon. These effects may be clinically important in modulating pain in those with patellar tendinopathy.

Introduction

Knee injuries are a frequent occurrence in high school sports accounting for approximately 15.2% of all injuries.[1] Additionally, 54% of recreational athletes have some degree of knee pain each year, with a significant percentage **(between 5-10%) coming** from a condition known as patellar tendinopathy more commonly known as jumpers' knee.[2,3] However, this condition is not limited to jumping sports such as basketball and volleyball, and most clinicians agree it can be broadened to any sporting activity which involves chronic overloading of the tendon through rapid repetitive movement.[4] Patellar tendinopathies are commonly diagnosed in physically active populations of all ages, with subsequent pain forcing many athletes to limit or discontinue athletic participation.[5,6] Although knee pain may affect females more than males, men appear to suffer from higher rates of patellar tendinopathy.[4,6]

Several factors have been shown to contribute to the symptoms associated with patellar tendinopathy. Those with patellar tendinopathy consistently demonstrate reduced flexibility in the quadriceps and hamstrings[7-9] and less strength in the quadriceps.[8] While strength and flexibility appear to be diminished in those with patellar tendinopathy, muscle activation strategies have yet to be reported in this clinical population. Several authors have reported alterations in muscular activation patterns in the vastus medialis and vastus lateralis in those with non-specific anterior knee pain during various movements and exercises,[10-13] but no study has focused specifically on patellar tendinopathy. This lack of understanding regarding the underlying pathology significantly hampers clinicians' ability to treat patellar tendinopathy.[14]

Many clinicians promote the use of patellar tendon straps during physical activity to alleviate pain and discomfort. But there is limited empirical evidence supporting their effectiveness.[15] One **recent study has shown a statistically and clinically meaningful**

reduction in pain with the use of the strap.[16] Theoretically, focal pressure is exerted on the tendon via the strap during movement, potentially reducing tensile forces transmitted through the tendon thus reducing pain.[17] This pressure may impact patellar dynamics and/or surrounding tissue.

Several researchers have attempted to identify the means by which these straps may influence the lower extremity.[17-20] Bohnsack and colleagues studied cadaveric specimens during isokinetic knee extension.[18] They demonstrated a decrease in infrapatellar fat pad pressure, a decrease in patellofemoral contact area, and a reduction in average and peak patellofemoral contact pressure.[18] They suggested patellar bracing altered patellar biomechanics characteristics through a "tensioning" of the patellar tendon and reducing patellofemoral contact pressure to relieve mild symptoms of anterior knee pain.[18] Lavagnino et al assessed patella-patellar tendon angles, patellar tendon length and created computational models designed to assess patellar tendon strain of strapping of 20 healthy male participants during a series of radiographs.[19] The authors found a decreased patellar tendon length, a decline in patellar-tendon angle with use of patellar tendon straps and a reduction in predicted tendon strain with use of patellar tendon straps.[19] This may be more contributory to a reduction in symptoms in those with patellar tendinopathies as opposed to an altering patello-femoral biomechanics. However, little is known about the straps' effect on the surrounding musculature during dynamic movement in those with patellar tendinopathy.

Therefore, the main purpose of this study were to determine if patellar tendon straps altered 1) pain levels, 2) pre-landing quadriceps' activation and 3) post-landing quadriceps' muscle activity during a drop-jump landing **differently in males with and without patellar**

tendinopathy. Secondary aims of this study was to determine if there were differences in quadriceps' activation between A) patellar tendinopathy and healthy participants and B) a strap and no-strap condition regardless of tendinopathy status. We hypothesized there would be less electromyographic amplitude in the quadriceps muscles in those with patellar tendinopathy with use of strap compared to controls.

Methods

Participants

This study was approved by the local human subjects institutional review board. Participants were recruited for a single test session from the university and community populations, via flyers, university physical activity classes, club sports athletes, university health center referrals and physician referrals from a local clinic. Participants were considered recreationally active if they participated in 90 minutes or more of physical activity per week and at a level of four or more on the Tegner scale.[21] The Tegner activity scale is a self-report questionnaire which identifies the highest level of competition and/or activity an individual performs regularly.[21] Ten participants reported current symptomatic pain consistent with patellar tendinopathy. Participants were accepted into the tendinopathy group if they reported all of the following: current pain located only in the patellar tendon, current pain in the tendon during physical activities such as jumping, squatting, etc., pain for at least the previous three months, performing their desired physical activity without limitations due to their pain, and less than or equal to 80 on the Victorian Institute of Sport Assessment Scale-Patella (VISA-P), indicating decreased function.[22] Ten control participants were age (±10%), height (±10%), and mass (±10%) matched to patellar tendinopathy participants. Control participants who had no history of patellar tendinopathy or other knee joint pathology, and scored greater than 90 on the VISA-P were enrolled into the study. Any participant was excluded if they reported any of the following: a previous lower extremity surgery or fracture, current enrollment in a physical therapy or rehabilitation program due to their knee pain, use of pain relievers or non-steroidal anti-inflammatory drugs in the past 24 hours to suppress their knee pain, current injury or chronic condition in the lower extremity, and a history of vestibular or balance disorder.

Participants first provided informed consent and completed a health history questionnaire, and VISA-P. For participants who suffered from bilateral tendinopathy, the more symptomatic limb, indicated by a lower VISA-P score, was used as the limb of interest. For the control participants the limbs were matched to the patellar tendinopathy participants. Participants' height, body mass, and anthropometric data were recorded.

Procedures

For electromyography, circular 1-3/8" diameter disposable pre-gelled Ag/AgCl electrodes (Biopac Systems, Inc., Goleta, CA) were placed on the subjects' limb of interest over their vastus medialis (VM), rectus femoris (RF) and vastus lateralis (VL) muscles.[23] Inter-electrode distance was approximately 2 cm, electrodes were arranged on the skin to ensure they were aligned in parallel with the muscle fibers.[23] To reduce impedance at the skin-electrode interface; the skin of each electrode site were shaved, abraded, and cleaned with isopropyl alcohol.[24] A single ground electrode was placed on the ipsilateral fibular head. A 16 – channel Myopac EMG system (Run Technologies, Inc., Mission Viejo, CA) was used for data collection. EMG data were sampled at 1200Hz using Vicon software (Motion Analysis Corp., Santa Rosa, CA). A single ended amplifier (impedance 1 MΩ) (gain 2000) with a common mode rejection ratio (CMRR) of 90db input, inferred voltage noise of 0.8 µV (rms), and 10 Hz to1000 Hz signal bandwidth was used. A MPRD-101 receiver with no filter further amplified the signal and had an output range -10 to +10 Volts. Two Bertec 4060-NC force platforms® (Bertec Corporation, Columbus, OH) affixed to the ground were used to denote ground contact, defined as >10N, collecting at 1200 Hz.

Participants first performed three static, sub-maximal voluntary isometric contractions (SMVIC) of the quadriceps, hamstrings, and calf muscles for EMG normalization purposes. Submaximal isometric contractions were performed for 5 seconds using a 67 N (15 lb.) weight. For the knee extensors, the participant was seated with the knee flexed to 15°, the weight hung from the distal shank 25 cm from the knee joint center. **Similar methods have been shown to be a reliable to normalize EMG signals.[25,26]**

Participants then performed the following warm-up during a patellar tendon strap and no strap conditions. The patellar strap worn was a Universal Matt Strap™ (Hely & Weber, Santa Paula, CA). Strapping conditions were counterbalanced among the participants. Participants completed a five minute warm-up on a treadmill, including walking and running. Participants walked at speeds of 1.2 to 1.4 m/s (2.7 to 3.1 mph) for 1 minute, and the speed was then increased until the participants were at a natural running pace at a self-selected range between 2.5 to 3.5 m/s (5.6 to 7.8 mph).

Participants' maximum vertical jump height was collected in order to calculate their 50% max-vertical jump height. Participants performed three max-vertical jumps; their highest jump was recorded. The Vertec© jump trainer (Sports Imports, Columbus, OH) was then set to 50-55% of their maximum vertical jump height. Participants then completed a two-legged drop landing from a 40cm box, followed immediately by a 50-55% max-vertical jump, landing with one foot on each force plate.[27] Participants performed 5 control trials with no strap and 5 trials fitted with a patellar tendon strap. The order of control and strapping conditions was counterbalanced. Pain was assessed after each condition using a 100 mm visual analogue scales (VAS) for knee pain (“no pain” and “very severe pain” were anchors).[28] The participant was given approximately 1 minute of rest after each jumping trial and 2 minutes after each condition to avoid fatigue.

Statistical Analyses

Collected EMG raw data were analyzed via Matlab 7.0 (Mathworks, Inc., Natick, MA, USA) with a custom written program. Raw EMG signals of each muscle were first corrected for signal drift by subtracting a baseline trial. The adjusted data were then band-pass filtered using a 4th order Butterworth filter with cutoff frequencies of 10 and 500 Hz.[29] Root-mean-square (REMG) (t = 50 ms, equivalent to 3.17 Hz low-pass filter) was then calculated with the processed EMG data.[24] REMG values were normalized to the 50% SMVIC of each individual muscle during the aforementioned procedures. For the drop-jump, we extracted data from two intervals of interest, 250ms prior to ground contact to initial contact (pre-landing) and from ground contact to 250 ms post-landing (post-landing) for the EMG variables. Dependent variables of interest were the pre-landing and post-landing REMG of VM, RF and VL.

All statistical analyses were performed using IBM SPSS software (Version 21.0, IBM, Inc., Armonk, NY). Demographic data, the VISA-P and visual analogue scales for pain were first assessed for differences between control and patellar tendinopathy groups utilizing independent samples *t*-tests ($p<.05$). Multiple mixed model 2 (between subjects: patellar tendinopathy vs. control) x 2 (within subjects: strap vs. no strap) analyses of variance (ANOVAs) were performed to determine statistical significance of the effect of the tendinopathy status and bracing condition on each dependent variable. **If interactions were not-significant, follow-up one-way ANOVA's were assessed for differences between conditions and groups, separately. If an assumption of normality (Shapiro-Wilk) was violated, a non-parametric Friedman's ANOVA was used to assess differences.**[30] We were interested in pre and post-landing EMG data separately. Because three separate mixed-model ANOVA's were performed for each a Bonferroni correction was used to control for multiple comparisons, with statistical significance therefore set to $p<.017$ for these tests. Cohen's *d* effect sizes were also calculated for each of the comparisons. **Effect sizes were interpreted as .1=small, .3=moderate and .5= large effects, .8= very large.**[31]

Results

Twenty male recreationally active individuals completed this study. The groups were not significantly different in age, height or mass. The results of this study indicate the patellar tendinopathy group ($p<.001$) had significantly lower VISA-P scores compared to controls (Table 1). Pain between strapping conditions was decreased in the strapping condition but not significantly ($p=.14$). **Two dependent variables violated the assumption of normality, post-RF and post-VL.** There were no significant interactions (all *p*'s > .017) in REMG measures between groups and strapping conditions (Table 2, 3). For the pre-landing interval, all participants during the strap compared to the no-strap condition displayed significantly lower VL REMG (Figure 1). This was supported by a small-moderate effect ($d=.39$). Although not statistically significant, participants trended towards having less RF EMG prior to landing in the strap condition ($p=.05$). No statistically significant differences were noted between control and patellar tendinopathy participants, however, regardless of strapping condition tendinopathy participants trended towards higher VM REMG post-landing compared to controls, this was also indicated by a very large effect size (0.96) (Figure 2).

Table 1. Demographic Data (Mean ± Standard Deviation).

	Control n=10	Patellar Tendinopathy n=10
Age (years)	22.0 ± 1.6	21.3 ± 2.4
Mass (kg)	82.2 ± 9.8	81.7 ± 8.6
Height (cm)	185.7 ± 4.5	182.8 ± 5.3
VISA-P	100 ± 0.0*	64.3 ± 8.7*
50% Maximum Vertical Jump Height (cm)	24.9 ± 4.8	29.4 ± 6.1
No Strap Visual Analogue Scale for Pain (mm)	0.0 ± 0.0	27.6 ± 23.8
Strapping Condition Visual Analogue Scale for Pain (mm)	0.0 ± 0.0	21.5 ± 18.8

* indicates significant difference between groups (p<.05)

Table 2. Mean, Standard Deviations and Effect Sizes **(**main effects for strapping and condition**)** for Average Root-Mean-Square, Pre-Landing (250 ms pre-initial contact) Electromyographic Activity of the Vastus Medialis, Rectus Femoris, and Vastus Lateralis Muscles in the Control vs. Patellar Tendinopathy (PT) Groups within No-Strap and Strapping Conditions.

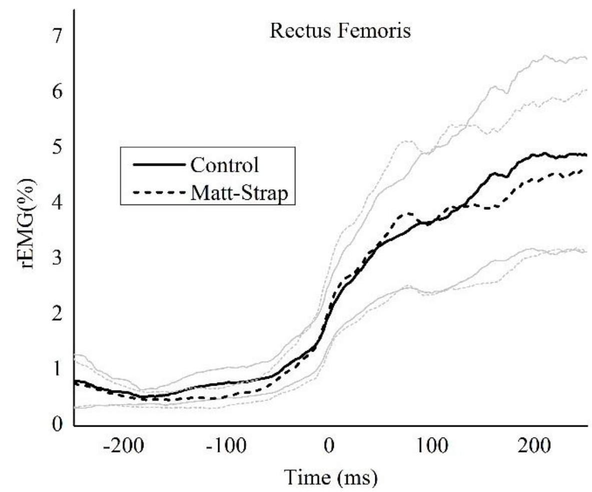
			Pre-Landing	
	Strapping condition	PT Status	Mean ± SD (%)	F, p, **power (1-β),** Cohen's D
Vastus Medialis	No-Strap	Con	0.58 ± 0.38	3.36, .08, .41, 0.28
		PT	0.78 ± 0.31	
		Total	0.68 ± 0.35	
	Strap	Con	0.54 ± 0.34	
		PT	0.64 ± 0.23	
		Total	0.59 ± 0.29	
	Total	Con	0.56 ± 0.36	1.28, .27, .89, 0.47
		PT	0.71 ± 0.27	
Rectus Femoris	No-Strap	Con	0.79 ± 0.54	4.31, .05, .50, 0.20
		PT	0.88 ± 0.53	
		Total	0.83 ± 0.53	
	Strap	Con	0.66 ± 0.43	
		PT	0.80 ± 0.52	
		Total	0.73 ± 0.47	
	Total	Con	0.72 ± 0.48	0.30, .59, .08, 0.24
		PT	0.84 ± 0.53	
Vastus Lateralis	No-Strap	Con	0.50 ± 0.24	8.86, .007, .80, 0.39
		PT	0.57 ± 0.30	
		Total	0.53 ± 0.27*	
	Strap	Con	0.42 ± 0.22	
		PT	0.45 ± 0.17	
		Total	0.44 ± 0.19*	
	Total	Con	0.46 ± 0.23	0.21, .66, .07, 0.21
		PT	0.51 ± 0.24	

* denotes significant ($p \leq .017$) difference between no-strap and strapping conditions.

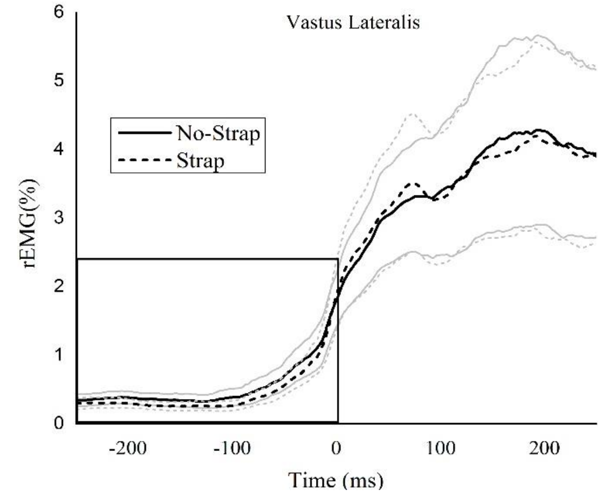
Table 3. Mean, Standard Deviations and Effect Sizes **(**main effects for strapping and condition) for Average Root-Mean-Square, Post-Landing (250 ms post-contact) Electromyographic Activity of the Vastus Medialis, Rectus Femoris, and Vastus Lateralis Muscles in the Control vs. Patellar Tendinopathy (PT) Groups within No-Strap and Strapping Conditions.

	Post-Landing			
	Strapping condition	PT Status	Mean ± SD (%)	F, p, **power (1-β),** Cohen's D
Vastus Medialis	No-Strap	Con	2.86 ± 1.67	0.02, .89, .05, 0.01
		PT	4.53 ± 1.68	
		Total	3.73 ± 1.68	
	Strap	Con	2.84 ± 1.79	
		PT	4.50 ± 1.85	
		Total	3.71 ± 1.96	
	Total	Con	2.85 ± 1.73	4.46, .05, .51, 0.96
		PT	4.52 ± 1.76	
Rectus Femoris	No-Strap	Con	3.71± 2.61	0.28, .60, .08, 0.04
		PT	4.17 ± 3.14	
		Total	3.94 ± 2.83	
	Strap	Con	3.87 ± 2.91	
		PT	3.80 ± 2.75	
		Total	3.84 ± 2.75	
	Total	Con	3.79 ± 2.76	0.02, .88, .05, 0.07
		PT	3.99 ± 2.95	
Vastus Lateralis	No-Strap	Con	3.37 ± 2.44	0.02, .89, .05, 0.01
		PT	4.71 ± 2.04	
		Total	3.54 ± 2.20	
	Strap	Con	3.22 ± 2.17	
		PT	3.82 ± 2.31	
		Total	3.52 ± 2.20	
	Total	Con	3.30 ± 2.31	0.22, .65, .07, 0.21
		PT	3.77 ± 2.17	

Figure 1. Strapping condition averaged (with 95% confidence interval) time-dependent muscle activation patterns for the Rectus Femoris (1a) and Vastus Lateralis (1b) across all participants.



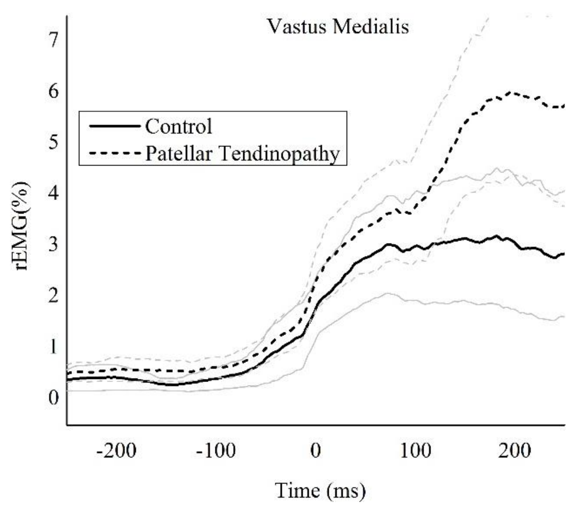
1a



1b

*Gray lines are 95% confidence interval.
†Boxed area indicates statistical significance ($p<.05$).

Figure 2. Group averaged (with 95% confidence interval) time-dependent muscle activation patterns for the Vastus Medialis across all participants in the no-strap condition.



*Gray lines are 95% confidence interval.

Discussion

The results of this study indicated patellar tendon strapping **altered VL and possibly RF activation in all participants during jump landing,** which partially supported original hypotheses. The lower activation prior to landing while wearing a strap may be helpful in reducing tensile stress at the tendon. These differences are considered small, but may be clinically relevant based on the **small-moderate effect sizes** in controlling symptoms associated with tendinopathy.

Despite the statistical insignificance, there was an approximate 25% reduction in pain in the tendinopathy group with the use of the strap. **A previous study found a similar percent decreases in pain.[16] The investigators had tendinopathy participants perform various activities with nothing, a strap, sports tape and placebo conditions.[16] For absolute change we found a decrease of approximately 6mm across all participants, whereas the previous investigation found a decrease between 1-11.5mm depending on the movement.[16] In addition, in our study several participants saw no or small decreases in pain, however 30% of participants saw large decreases (>10mm) with the strap. These larger changes would be considered a clinically meaningful reduction in pain.[32,33]** Therefore clinicians may want to take an individualized approach to strapping and provide treatment to those who may benefit the most.

A reduction in quadriceps activation with the strap could assist in a lessening in pain reported in individuals who wear the strap during activity through muscle inhibition. To the authors' knowledge no previous studies have assessed the effects of tendon strapping on muscle activation strategies in those with current symptomatic tendinopathy. However, there has been previous work completed on a similar population with patella-femoral pain. Gulling and colleagues[34] found bracing produced decreases in muscle activation during an isokinetic exercise compared to a non-bracing condition in those with patella-femoral pain. They believed this lower muscle activation may reduce pain at the joint through reducing the tension of the VM and the VL.[34] Similarly, this may be occurring with the patellar tendon strap in patients with patellar tendinopathy. Optimizing muscle stiffness and tension during landing will allow the patient to successfully complete movements while reducing the strain on tendons. Although, pre-activating and tensioning muscles to maintain joint stiffness for dynamic restraint during movement is particularly important in conditions affecting joint stability[29, 35, 36], these particular individuals are not suffering from joint instability. Therefore the reduction in muscle activation observed in the VL may contribute to lessening pain through inhibition of the musculature thereby reducing tension and stiffness through the patellar tendon.

Additionally, the strap may be effective at reducing activation during both static and dynamic movements. Straub and Cipriani[20] assessed the influence of patellar tendon bracing on the quadriceps muscle activation during a body-weight squat. The investigators found no differences in peak or mean muscle activation.[20] However, with the strap participants displayed delayed VL muscle onset timing.[20] The authors believed this timing change was a positive effect due to changes in muscle firing imbalances associated with patellar mal-tracking conditions. Although we did not measure muscle timing variables, it is interesting to note the previous study did not find differences in average muscle activity, whereas our study displayed decreases in average muscle activity in the VL and possibly the RF across the pre-landing phase with the strap. The differences between the results may be accounted for by the movement performed. The previous study assessed the muscle activation with the strap during a bodyweight squat, a fairly static maneuver, while we made our observations during a drop-jump landing. This is encouraging as the patellar-tendon strap may be effective at modulating muscle activation strategies in both static and dynamic movement.

Previous speculation regarding the working mechanism of the straps to reduce pain range from biomechanical changes to proprioceptive influences.[17-20] We believed the pressure exerted on the tendon by the strap would change the biomechanical properties of the knee joint thus altering the angle of pull of the quadriceps force applied to the tibia.[19] This change would likely have an influence on all quadriceps activation but we only observed a statistically significant difference in the pre-landing VL with the strap. However, this is probably due to a lack of statistical power as both the RF (p=.05, 1-β= .50) and VM (p=.08, 1-β=.41) observations were trending, yet underpowered.

Another interesting and potentially impactful finding is those with patellar tendinopathy trended towards demonstrating greater VM activation post-landing compared to controls regardless of strapping according to the effect size difference. This greater activation suggests the presence of an altered quadriceps activation strategy in males with patellar tendinopathy, which has not been demonstrated previously. Increases in the symptomatic limbs' quadriceps activation during isometric contractions has been noted in individuals with unilateral patellofemoral pain syndrome.[37] Doxey et al[37] believed the symptomatic limb was inefficient during torque production due to the increases in quadriceps activation**. Likewise, males with patellar tendinopathy may be inefficient in their activation patterns during dynamic movement, creating unnecessary tension in their quadriceps. Correspondingly, recent studies have found those with patellar tendinopathy have decreased knee range of motion during landing compared to their healthy counterparts.[27, 38] It was believed those with PT use a different strategy due to the pain which pain may also influence the VM activation.**

Another plausible explanation for this greater VM activity is as a response to the injured tendon. During the landing the quadriceps must eccentrically contract to control the landing. As the tendon becomes stiffer it is theorized the tendon may be more efficient at force transfer and thus could be the reason for the observable increase in activation.[39]

The increased activation of the quadriceps post-landing regardless of strapping condition may also suggest the strap is not completely effective at limiting the higher amplitude quadriceps activation found post-landing. This perhaps could be a reason why individuals demonstrate decreased, but not completely eliminated, pain throughout activity while wearing patellar straps. Clinicians need to use additional treatments during activity to limit the pain and dysfunction associated with patellar tendinopathy or be cognizant that the strap may not completely eliminate pain.

The authors acknowledge a few limitations from the current study. First, we did not assess the participants with an imaging tool such as diagnostic ultrasound to verify self-reported data **and thus a definitive clinical diagnosis was not obtained.** Although this would have made for a stronger design, several previous investigations assessing those with patellar tendinopathy have used similar inclusion and exclusion criteria and we are confident this is an accurate portrayal of their condition.[40-42] In addition, although we have detected some differences in EMG across conditions and participants, this study may have been slightly underpowered to detect all potential alterations present. Further studies likely warrant adding more participants to achieve greater statistical power. We also assessed the effects of patellar tendon straps over a single acute test period. Habituation with the strap may provide different results and the long-term effectiveness of patellar tendon straps warrants further investigation. Based on the current data it becomes exceedingly difficult to speculate and determine where this activation alteration is being accommodated. This is certainly a limitation of the current study which requires further investigation for definitive analysis. **Additionally, standardizing the pressure of the strap is difficult. However, a single investigator performed all strapping applications on participants, and the investigator attempted to consistently instruct individuals that the strap should be "snug but comfortable".** Lastly, this study was performed on college-aged males, and may not be highly generalizable to females or older or younger participants. Future research is necessary to observe changes with patellar straps in different populations and identify the mechanisms behind the observed change of quadriceps activation.

Conclusion

It appears patellar tendon strapping alters pre-landing quadriceps muscle activation, specifically in the VL and potentially the RF muscles. The decreased activation, prior to landing, may diminish tensile stress placed on the tendon during dynamic movements leading to feeling some reductions in pain. Individuals with patellar tendinopathy also demonstrated increased VM activation post-landing, suggesting increased tension on the patellar tendinopathy during the drop-jump landing. This increase in VM muscle activation may be perpetuating symptoms in individuals with patellar tendinopathy. Straps appear to have some influence on muscle activity around the knee during landing in an acute situation, and may have some utility for treatment. Future studies should determine the clinical utility in various, habituated populations.

Funding: The authors received no research funding and have no financial affiliation or involvement with any commercial organization that has a direct financial interest for this study.

References

1. Ingram JG, Fields SK, Yard EE, Comstock RD. Epidemiology of knee injuries among boys and girls in US high school athletics. *Am J Sports Med.* 2008;36(6):1116-1122.
2. Calmbach WL, Hutchens M. Evaluation of patients presenting with knee pain: Part I. History, physical examination, radiographs, and laboratory tests. *Am Fam Physician.* 2003;68(5):907-912.
3. Foss KDB, Myer GD, Chen SS, Hewett TE. Expected Prevalence From the Differential Diagnosis of Anterior Knee Pain in Adolescent Female Athletes During Preparticipation Screening. *J Athl Train*. 2012;47(5):519-524..
4. Cook JL, Khan KM, Harcourt PR, Grant M, Young DA, Bonar SF. A cross sectional study of 100 athletes with jumper's knee managed conservatively and surgically. The Victorian Institute of Sport Tendon Study Group. *Br J Sports Med.* 1997;31(4):332-336.
5. Foss KDB, Myer GD, Chen SS, Hewett TE. Expected Prevalence From the Differential Diagnosis of Anterior Knee Pain in Adolescent Female Athletes During Preparticipation Screening. *J Athl Train.* 2012;47(5):519-524.
6. **Ito E, Iwamoto J, Azuma K, Matsumoto H. Sex-specific differences in injury types among basketball players. *Open Access J Sports Med*. 2015;6:1-6.**
7. Cook JL, Kiss ZS, Khan KM, Purdam CR, Webster KE. Anthropometry, physical performance, and ultrasound patellar tendon abnormality in elite junior basketball players: a cross-sectional study. *Br J Sports Med.* 2004;38(2):206-209.
8. **Crossley KM, Thancanamootoo K, Metcalf BR, Cook JL, Purdam CR, Warden SJ. Clinical features of patellar tendinopathy and their implications for rehabilitation. *J Orthop Res*. 2007;25(9):1164-1175.**

9. Witvrouw E, Bellemans J, Lysens R, Danneels L, Cambier D. Intrinsic risk factors for the development of patellar tendinitis in an athletic population. A two-year prospective study. *Am J Sports Med.* 2001;29(2):190-195.

10. Felicio LR, Baffa Ado P, Liporacci RF, Saad MC, De Oliveira AS, Bevilaqua-Grossi D. Analysis of patellar stabilizers muscles and patellar kinematics in anterior knee pain subjects. *J Electromyogr Kinesiol.* 2011;21(1):148-153.

11. Cesarelli M, Bifulco P, Bracale M. Quadriceps muscles activation in anterior knee pain during isokinetic exercise. *Med Eng Phys.* 1999;21(6-7):469-478.

12. Boling MC, Bolgla LA, Mattacola CG, Uhl TL, Hosey RG. Outcomes of a weight-bearing rehabilitation program for patients diagnosed with patellofemoral pain syndrome. *Arch Phys Med Rehab.* 2006;87(11):1428-1435.

13. Cavazzuti L, Merlo A, Orlandi F, Campanini I. Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. *Gait Posture.* 2010;32(3):290-295.

14. Cannell LJ, Taunton JE, Clement DB, Smith C, Khan KM. A randomised clinical trial of the efficacy of drop squats or leg extension/leg curl exercises to treat clinically diagnosed jumper's knee in athletes: pilot study. *Br J Sports Med.* 2001;35(1):60-64.

15. Beam JM. *Orthopedic Taping, Wrapping, Bracing, and Padding.* Philadelphia, PA: F.A. Davis Company; 2012.

16. de Vries A, Zwerver J, Diercks R, Tak I, van Berkel S, van Cingel R, van der Worp H, van den Akker-Scheek I. Effect of patellar strap and sports tape on pain in patellar tendinopathy: A randomized controlled trial. *Scand J Med Sci Sport.* 2015. [Epub ahead of print]

17. Lavagnino M, Arnoczky SP, Dodds J, Elvin N. Infrapatellar Straps Decrease Patellar Tendon Strain at the Site of the Jumper's Knee Lesion: A Computational Analysis Based on Radiographic Measurements. *Sports Health.* 2011;3(3):296-302.

18. Bohnsack M, Halcour A, Klages P, et al. The influence of patellar bracing on patellar and knee load-distribution and kinematics: an experimental cadaver study. *Knee Surg Sport Tr A.* 2008;16(2):135-141.

19. Lavagnino M, Arnoczky SP, Elvin N, Dodds J. Patellar tendon strain is increased at the site of the jumper's knee lesion during knee flexion and tendon loading: results and cadaveric testing of a computational model. *Am J Sports Med.* 2008;36(11):2110-2118.

20. Straub RK, Cipriani DJ. Influence of infrapatellar and suprapatellar straps on quadriceps muscle activity and onset timing during the body-weight squat. *J Strength Cond Res.* 2012;26(7):1827-1837.

21. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat R.* 1985(198):43-49.

22. Visentini PJ, Khan KM, Cook JL, Kiss ZS, Harcourt PR, Wark JD. The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). Victorian Institute of Sport Tendon Study Group. *J Sci Med Sport.* 1998;1(1):22-28.

23. Perotto A, Delagi EF. *Anatomical guide for the electromyographer: the limbs and trunk.* 3rd ed. Springfield, Ill., USA: Charles C. Thomas, 1994.

24. Kamen G GD. *Essentials of Electromyography*. Champaign, IL: Human Kinetics; 2010.

25. Finucane SD, Rafeei T, Kues J, Lamb RL, Mayhew TP. Reproducibility of electromyographic recordings of submaximal concentric and eccentric muscle contractions in humans. *Electroen Clin Neuro.* 1998;109(4):290-296.

26. Yang JF, Winter DA. Electromyography reliability in maximal and submaximal isometric contractions. *Arch Phys Med Rehab.* 1983;64(9):417-420.

27. Rosen AB, Ko J, Simpson KJ, Kim S-H, Brown CN. Lower Extremity Kinematics During a Drop Jump in Individuals With Patellar Tendinopathy. *Orthop J Sports Med.* 2015;3(3).

28. Huskisson EC. Measurement of pain. *Lancet.* 1974;2(7889):1127-1131.

29. Rosen A, Swanik C, Thomas S, Glutting J, Knight C, Kaminski TW. Differences in lateral drop jumps from an unknown height among individuals with functional ankle instability. *J Athl Train.* 2013;48(6):773-781.

30. Field A. Discovering statistics using SPSS (3rd ed.): London: Sage; 2010. 555-567.

31. Cohen J. Statistical Power Analysis. Curr Dir Psychol Sci. 1992;1(3):98-101).

32. Lauche R, Langhorst J, Dobos GJ, Cramer H. Clinically meaningful differences in pain, disability and quality of life for chronic nonspecific neck pain - a reanalysis of 4 randomized controlled trials of cupping therapy. *Complement Ther Med*. 2013; 21(4):342-347. 27.

33. Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. *Eur J Pain*. 2004; 8(4):283-291.)

34. Gulling LK, Lephart SM, Stone DA, Irrgang JJ, Pincivero DM. The effects of patellar bracing on quadriceps EMG activity during isokinetic exercise. *Isokinet Exerc Sci.* 1996;6(2):133-138.

35. Sinkjaer T, Toft E, Andreassen S, Hornemann BC. Muscle stiffness in human ankle dorsiflexors: intrinsic and reflex components. Journal of neurophysiology. 1988;60(3):1110-1121.

36. Swanik CB, Lephart SM, Giraldo JL, Demont RG, Fu FH. Reactive muscle firing of anterior cruciate ligament-injured females during functional activities. J Athl Train. 1999;34(2):121-129.

37. Doxey G, Eisenman P. The Influence of Patellofemoral Pain on Electromyographic Activity during Submaximal Isometric Contractions. *J Orthop Sports Phys Ther.* 1987;9(6):211-216.

38. Van der Worp H, de Poel HJ, Diercks RL, van den Akker-Scheek I, Zwerver J. Jumper's knee or lander's knee? A systematic review of the relation between jump biomechanics and patellar tendinopathy. *Int J Sports Med*. 2014;35(8):714-722.

39. Zhang ZJ, Ng GY, Lee WC, Fu SN. Changes in Morphological and Elastic Properties of Patellar Tendon in Athletes with Unilateral Patellar Tendinopathy and Their Relationships with Pain and Functional Disability. *PLoS ONE*. 2014;9(10):e108337.

40. Bisseling RW, Hof AL, Bredeweg SW, Zwerver J, Mulder T. Relationship between landing strategy and patellar tendinopathy in volleyball. *Br J Sports Med.* 2007;41(7):e8.

41. Fietzer AL, Chang YJ, Kulig K. Dancers with patellar tendinopathy exhibit higher vertical and braking ground reaction forces during landing. *J Sports Sci.* 2012;30(11):1157-1163.

42. Siegmund JA, Huxel KC, Swanik CB. Compensatory mechanisms in basketball players with jumper's knee. *J Sport Rehabil.* 2008;17(4):359-371.