7-2017

Patellar Tendon Straps Decrease Pain and May Alter Lower Extremity Kinetics in Those With Patellar Tendinopathy During Jump Landing

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

Patellar tendon straps decrease pain and may alter lower extremity kinetics in those with patellar tendinopathy during jump landing

Key Points:

- Patellar tendinopathy participants had decreased pain with a strap while jumping.
- Anteriorly directed ground reaction forces in all participants were decreased while wearing the strap.
- Kinetic changes may influence pain reduction in individuals who wear a patellar tendon strap.

Key words: jumper’s knee, lower extremity biomechanics, bracing

ABSTRACT

Patellar tendinopathy is often managed with a patellar tendon strap however, their effectiveness is unsubstantiated. The purpose of this study was to determine if straps altered pain or lower extremity kinetics of individuals with patellar tendinopathy during landing. Thirty participants with patellar tendinopathy and thirty controls completed drop-jumps with and without patellar tendon straps. Wearing the strap, tendinopathy participants demonstrated significantly decreased pain and reduced knee adductor moment; all participants displayed significantly decreased anterior ground reaction force while wearing a strap. Patellar tendon strapping may reduce pain due to alterations in direction and magnitude of loading.

INTRODUCTION

Patellar tendinopathies account for approximately 10% of all clinical knee diagnoses in athletes.[1,2] Patellar tendinopathy occurs with chronic overloading of the quadriceps and/or patellar tendon, leading to degenerative changes within the tendon, potentially without histological signs of inflammation.[3-6] Consequently, excessive internal tensile loading may contribute to further degeneration and debilitating symptoms.[3,4] Therefore, any movement, especially when requiring eccentric quadriceps force, may cause pain.

To assist in pain relief, clinicians advocate use of a patellar tendon strap for pain reduction during physical activity.[7] However, there is a lack of evidence of the strap's efficacy and mechanisms by which strapping reduces patellar pain.[4,8-10] The patellar tendon strap is thought to exert compressive pressure on the damaged tendon and, via an unknown mechanism(s), alleviate internal tensile strain and loading created by quadriceps and tibial forces, thus reducing pain.[9]

These claims require further assessment to determine if the alterations are manifested in lower extremity mechanics. If, theoretically, compression occurs, the tendon may be pulled posteriorly, and, consequently, decreases the angle of pull and moment arm of the quadriceps force applied to the tibia.[7] Therefore, due to the linked kinetic chain of the lower extremity and the rectus femoris actions' on the hip and knee, it was anticipated that during landings, strapping would decrease knee and hip extensor moments of healthy or tendinopathy individuals.[11] Thus, these changes with the use of the strap may decrease the strain on the patellar tendon.[7]

Additionally, relative to healthy participants, to minimize pain, patellar tendinopathy participants were expected to display decreased hip and knee flexion moments during no-strap landings. Less knee and hip flexion motion exhibited by individuals with patellar tendinopathy may reduce tensile tendon strain, hence leading to decreased pain.[12] However, more erect landings in individuals with patellar tendinopathy have been associated with increased ground reaction forces (GRF) that cause unnecessary loading to the patellar tendon.[13] Increases in GRFs in any direction depending on the knee angle at contact may cause greater shearing or torsional effects on the lower extremity at landing.[14]

Exploring frontal and transverse plane mechanics at the knee may offer considerable insight into the effectiveness of strapping to compensate for moments produced in these planes.[17] Knee frontal and transverse moments are associated with patellar tendinopathy causation.[15] It is believed that higher transverse plane moments generated during jumping contribute to the development of patellar tendinopathy and pain by increasing torsional forces at the knee.[15] Correspondingly, tendons are particularly adept at transmitting tensile forces, however they appear ill-suited at dissipating shearing and torsional forces.[16] Therefore

Thus, the overall purpose of this study was to determine if patellar tendon straps reduced pain and altered ground reaction forces, peak knee and hip joint moments of individuals with and without patellar tendinopathy compared to a non-strapped condition during a drop-jump landing.

METHODS

Participants

This study was approved by the local Human Subjects Institutional Review Board. Recreationally active individuals volunteered to complete a single-test session (Table 1). Participants in the tendinopathy group had 1) pain completely within the patellar tendon and experienced pain during recreational activity during each of the last three months, 2) continued performance of their self-reported activity despite patellar tendinopathy pain, and 3) < 80 on the

Victorian Institute of Sport Assessment Scale-Patella (VISA-P), indicating decreased daily function.[18] Participants in the control group had no knee pain or history of tendinopathy.[18] They were pair-matched to corresponding patellar tendinopathy participants based on gender, age (±10% years), height (±10% cm), and mass (±10% kg). Participants were excluded if they had a history of lower extremity surgery or fracture or were enrolled in a rehabilitation or physical therapy program for knee pain at the time of entering the study.

This sample size was recruited based on an a-priori power analysis using G*Power™ (Kiel University, Germany). Although previous literature in this area is limited, one study by Bisseling and colleagues investigated kinetics during drop jumps among three groups of participants: controls, previous history of tendinopathy and recent history of tendinopathy.[19] We used the *t*-test family to assess differences in the previous results, with α=.05, 1-β=.80 and Cohen's *d* effect size = 0.81. Based on this data twenty-five control participants and twenty-five with a previous history of patellar tendinopathy during a drop jump were found to be necessary to identify differences in vertical ground reaction forces. Therefore a sample size of 60 (30 controls and 30 patellar tendinopathy) was concluded to be appropriate to account for potential dropouts and unforeseeable data issues. As no studies to date have identified differences in kinetics during strapping conditions between control and patellar tendinopathy participants, this was the best available literature comparison to perform an apriori power analysis.

Procedures

Participants provided consent and completed a laboratory health history and physical activity questionnaire, VISA-P, and "baseline" 100 mm visual analogue scales (VAS) for knee pain, with "no pain" and "very severe pain" as anchors.[20] Retro-reflective markers were attached to sixteen anatomical landmarks of the pelvis and lower extremity for later use with a kinematic model used in the Plug-In-Gait software (Workstation, v5.2.4, OMG Plc., London, UK).[21,22] To determine vertical jump height for the test task, the participant completed three maximum-vertical jumps (Vertec Jump Trainer™; Sports Imports, Columbus, OH).

Participants completed a two-legged drop landing off a 40cm box, with each foot landing onto one of two force platforms (1200 Hz; Bertec 4060-NC®; Bertec Corporation, Columbus, OH, Figure 1), followed by a vertical jump (50-55% maximum height). Marker locations were recorded via a 7-camera motion capture system (120 Hz, Vicon-MX40, Vicon, Oxford, UK). Participants performed five trials for each of the no-strap and strap conditions (Universal Matt Strap™; Hely & Weber, Santa Paula, CA, Figure 2) in a counterbalanced order. Participants completed the VAS after completing no-strap and strap conditions and were blinded to previous scores. There were ≈15 minutes between the VAS declarations.

Data Reduction and Analysis

Standard inverse dynamics (Vicon Workstation™ software) were used to calculate joint moments for the knee joint (all planes) and hip joint (sagittal plane) for the vertical jump contact phase (touchdown to take-off).[11, 23] Dependent variables of interest included peak magnitudes for hip sagittal plane joint moments, knee sagittal, frontal and transverse plane joint moments, (scaled to body mass: $Nm \bullet kg^{-1}$) and antero-posterior GRF (normalized to body weight [BW]).

Statistical significance was set at $p \leq .05$. Independent samples *t*-tests were applied to test for differences in demographic data and VISA-P scores between control and tendinopathy groups. Baseline and test VAS pain scores were compared using Friedman's analysis of variance.[24] A two factor, mixed-model (2 tendinopathy groups x 2 no-strap and strap conditions [within-subjects factor]) multivariate analysis of variance (MANOVA) was performed that included all dependent kinetic variables. If a significant interaction or main effect was detected, univariate analysis of variance test was applied. Cohen's *d* effect size was calculated and interpreted as .1-.3=small, .3-.5=moderate and >.5= large effects.[25]

RESULTS

Patellar tendinopathy participants had more pain (p <.001) prior to testing and in the strapping and no-strap trials compared to the control participants. Tendinopathy participants reported less pain at baseline (p=.05) and for the strapped compared to the non-strapped condition.

The MANOVA exhibited no interaction between strap and tendinopathy conditions (p=.34, 1-β=.52), but strapping was significant (p=.05, 1-β=.84). Only one kinetic variable reached univariate significance. Decreased peak anterior GRF (p=.01, 1-β=.75, d=0.28: moderate effect; Table 2) occurred when participants wore the strap. Compared to no-strap, while wearing the strap, tendinopathy participants tended to have a decrease in peak knee adduction moment (p=.08, 1-β=.41, d: -0.44 to -0.51; Table 3). Qualitatively, they tended to display ≈15% greater peak hip flexor moment compared to controls, regardless of strapping condition (p=.36, 1-β=.52, d=0.39; Table 4).

DISCUSSION

The purpose of this study was to determine whether patellar tendon straps acutely reduced pain and altered peak joint moments and/or ground reaction forces during a drop-jump landing of participants with patellar tendinopathy versus healthy controls. Patellar tendon straps reduced self-reported pain in those with patellar tendinopathy. Both groups demonstrated moderately decreased anterior GRF during strap wear. Predictions of reduced knee and hip joint moments due to strap wear were not supported; nor were predictions of comparisons between the tendinopathy and control group.

Strapping may have a beneficial acute effect on pain. As hypothesized, pain experienced by the tendinopathy participants decreased approximately 25% (VAS: mean difference= 6.7 mm, no-strap VAS=28.0) when wearing the strap. Although knee pain was not ameliorated entirely when wearing the patellar strap, the 7mm average decrease is clinically significant, relative to the 8mm minimum clinically important difference (MCID) and 15 to 25% reduction reported for studies of similar construct.[26,27]

Reduced anterior ground reaction forces may play a role in the pain reduction observed. Unanticipated, and for reasons unknown, both groups experienced moderately decreased anterior-GRF when wearing the strap. Decreased landing anterior-posterior GRF may reduce shearing or torsional effects on the lower extremity and patellar tendon loading. [14, 28, 29] Therefore, this may be a positive benefit of strapping but will need to be confirmed.

Our prediction that peak knee and hip moments would decrease during strap landings was not supported, as no significant effects were detected. However, potentially relevant was the tendency (p=.08, with moderate to large effect sizes *d*: -0.44 to -0.51) of reduced knee adductor moments during strap compared to no-strap landings of the patellar tendinopathy group. This is supported by previous observations of reduced frontal plane moments with use of a patello-femoral brace or taping during a step-down exercise.[30,31] Investigators have surmised that this is due to enhanced proprioception via the brace/tape stimulating cutaneous structures near the patellar tendon and knee tendons.[30, 31] However, enhanced proprioception is difficult to prove, and the benefits are likely limited in nature.

Sagittal knee and hip joint moments were not affected by strap condition for several potential reasons. First, the strap may not influence knee moments as evidenced by the relative lack of significance and effect size in the data. Perhaps there is not enough compressive force provided by the strap to effectively pull the tendon posteriorly towards the center of rotation to change the quadriceps moment arm length. Second, no differences in knee joint moments with the strap may be beneficial in that more patellar tendon force would be necessary to produce the same joint moment, possibly putting more strain on the tendon. If the moment arm did change, then the quadriceps force through the patellar tendon force could have increased proportionally. Hypothetically, if assumed all else equal (which may or not occur), then patellar tendon force could then be estimated by dividing the knee joint moment by the patellar tendon arm.[32] The estimated patellar tendon moment arm at 30° of knee flexion is approximately 4.5cm.[32] Then if the strap pulled the tendon posteriorly 1 cm, the patellar tendon forces would correspondingly increase by approximately 20%.

As this was a comparative study of acute effects of strapping, and no patellar forces or angle of pull were estimated, there are limitations. Neither long-term consequences nor mechanisms explaining the decrease in pain via landing kinetics can be demonstrated with these data. No sham treatment was applied, so a placebo effect may have also been present. Additionally, inter-participant variability in landing technique may have resulted in lack of statistical significance for the kinetic variables, as evidenced by the large standard deviations across participants.[33,34] Based on the potential relevance of the strap effects on kinetics, it may also be important to observe kinematic alterations. However, it appears based on a posteriori observations, there were no statistical differences in kinematics with strapping (Table 5). Although no differences in kinematics were observed between participants during strapping, we did detect differences between groups for this same movement task, reported in a previous investigation.[12] Participants with tendinopathy also had varying levels of dysfunction and disability thus may use different landing strategies to prevent pain upon landing.[35] Finally, we used a sample of convenience from a recreationally-active, college-student population, 18-35 years old; thus the results may not be generalizable to other populations.

Conclusion

The clinical implications of this study are that individuals with existing patellar tendinopathy report decrease knee pain during jump landings when wearing the patellar tendon strap. The reduced anterior-GRF for all participants and decreased knee adductor moment for patellar tendinopathy participants with use of the strap may be related to pain reduction. At present, whether these findings reflect underlying mechanical mechanisms or other factors that cause reduced patellar tendon loading are unknown. Future work is necessary to determine if wearing the strap during landings consistently leads to decreased peak anterior-ground reaction force and knee adductor moment; and if so, whether each of these findings reflects different causational effects that would reduce patellar tendon loading, e.g., reduced shear loading or more axial-directed patellar tendon force, respectively. Conversely, the lack of strap effect on knee extensor joint moments may also have clinical relevance. If there are no clinically-meaningful strap effects for sagittal plane joint moments, then perhaps the strap is not creating abnormal moments that could increase risk of other injuries. A proposed secondary benefit of strap wear, if knee adductor moments decrease, may be less medial-side tibio-femoral compressive force.

Future research should identify the long-term effectiveness of patellar tendon strapping, the loading on the patellar tendon and other relevant tissues, and the mechanisms by which pain reduction occurs to support strapping for patients with patellar tendinopathy.

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. 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.
3. 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.
4. Khan KM, Maffulli N, Coleman BD, Cook JL, Taunton JE. Patellar tendinopathy: Some aspects of basic science and clinical management. *Br J Sports Med.* 1998;32(4):346-355.
5. Khan KM, Cook JL, Kannus P, Maffulli N, Bonar SF. Time to abandon the "tendinitis" myth. *Brit Med J.* 2002;324(7338):626-627.
6. Duri ZA, Aichroth PM. Patellar tendonitis: Clinical and literature review. *Knee Surg Sport Tr A.* 1995;3(2):95-100.
7. 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.
8. 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.

9. 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.

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

11. Winter DA. *Kinetics: Forces and Moments of Force. Biomechanics and Motor Control of Human Movement*. Hoboken, NJ: John Wiley & Sons, Inc.; 2009:107-138.

12. 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):1-8.

13. 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.

14. Wang LI. The lower extremity biomechanics of single- and double-leg stop-jump tasks. *J Sports Sci Med.* 2011;10(1):151-156.

15. Richards DP, Ajemian SV, Wiley JP, Zernicke RF. Knee joint dynamics predict patellar tendinitis in elite volleyball players. *Am J Sports Med.* 1996; 24(5):676-683.

16. Vogel KG. What happens when tendons bend and twist? Proteoglycans. *J Musculoskelet Neuronal Interact.* 2004;4(2):202-203.

17. Williams DS, Zambardino JA, Banning VA. Transverse-plane mechanics at the knee and tibia in runners with and without a history of achilles tendonopathy. *J Orthop Sports Phys Ther*. 2008;38(12):761-767.

18. Visenti PJ. The VISA score: An index of severity of symptoms in patients with jumper's knee (patellar tendinosis). *J Sci Med Sport.* 1998;1(1):22-28.

19. 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.

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

21. Davis RB, Ounpuu S, Tyburski D, Gage JR. A gait analysis data-collection and reduction technique. *Hum Movement Sci.* 1991;10(5):575-587.

22. Kadaba MP, Ramakrishnan HK, Wootten ME. Measurement of lower extremity kinematics during level walking. *J Orthop Res.* 1990;8(3):383-392.

23. Greenwood DT. *Principles of dynamics.* Englewood Cliffs, NJ, Prentice-Hall; 1965; 380-393.

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

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

26. 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. 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.

28. Edwards S, Steele JR, McGhee DE, Beattie S, Purdam C, Cook JL. Landing strategies of athletes with an asymptomatic patellar tendon abnormality. *Med Sci Sports Exerc*. 2010;42(11):2072-2080.

29. Simpson KJ, Pettit M. Jump distance of dance landings influencing internal joint forces: II. Shear forces. *Med Sci Sports Exerc*. 1997;29(7):928-936.

30. Selfe J, Richards J, Thewlis D, Kilmurray S. The biomechanics of step descent under different treatment modalities used in patellofemoral pain. *Gait Posture.* 2008;27(2):258-263.

31. Callaghan MJ, Selfe J, McHenry A, Oldham JA. Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. *Manual Ther.* 2008; 13(3):192-199.

32. Nisell R. Mechanics of the knee. A study of joint and muscle load with clinical applications. *Acta Orthop*. 1985;216: 1-42.

33. Cruz A, Bell D, McGrath M, Blackburn T, Padua D, Herman D. The effects of three jump landing tasks on kinetic and kinematic measures: implications for ACL injury research. *Res in Sports Med*. 2013;21(4):330-342.

34. James CR, Dufek JS, Bates BT. Effects of injury proneness and task difficulty on joint kinetic variability. *Med Sci Sports Exerc*. 2000;32(11):1833-1844.

35. 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.