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Single-limb landing biomechanics are altered and patellar tendinopathy related pain is reduced with acute infrapatellar strap application

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Abstract

Background: Patellar tendinopathy, a common condition of the knee, is often treated with patellar tendon straps to control pain during dynamic activity. Little is known regarding their effect on pain, landing kinematics and kinetics with their application. The purpose of this study was to determine if patellar tendon straps influenced pain, kinematics at landing and ground reaction forces in individuals with patellar tendinopathy versus healthy controls.

Methods: 30 participants with patellar tendinopathy and 30 controls participated. They completed single-limb landings with and without patellar tendon straps while pain, three-dimensional kinematics and vertical ground reaction forces were measured. A multivariate analysis of variance was completed to determine the differences in strapping condition and group for the dependent variables.

Results: Individuals with patellar tendinopathy demonstrated a significant decrease in pain (no strap=37.1±22.1 mm, strap=28.0±18.5 mm). With the strap at landing all participants displayed less hip rotation (F=7.16, p=.01), knee adduction (F=10.20, p=.002), ankle inversion (F=4.60, p=.04), and peak vertical ground reaction force (F=7.30, p=.009).

Conclusion: Patellar tendon straps reduced pain in those with patellar tendinopathy. Additionally, with the strap, individuals landed in a more neutral alignment and decreased landing forces which could provide a benefit to those with patellar tendinopathy.

Key Terms:

Kinematics, Kinetics, Alignment, Jumper's Knee

Abbreviations:

MCID	Minimum clinically important difference
PTA	Patellar Tendon Abnormality

VAS	Visual Analogue Scale
VISA-P	Victorian Institute of Sport Assessment Scale-Patella
vGRF	Vertical Ground Reaction Force

1. Introduction

Patellar tendinopathy, colloquially known as "jumper's knee", is a common degenerative condition of the knee present in upwards of 45% of elite athletes [1-3]. Patellar tendinopathy often results in chronic pain and disability, with long-term symptoms causing frequent absences from physical activity [2]. Consequently, one study reported 53% of athletes ceasing their athletic career due to persistent tendinopathy related symptoms while the rest continued to participate despite their pain [4].

Associated with the pathogenesis of the condition, biomechanical changes during landing are also frequently observed in those with patellar tendinopathy [5]. More specifically, changes in frontal and sagittal plane biomechanics have been associated with increased loads on the medial portion of the patellar tendon which is consistent with the pathological degeneration of the tendon [5]. Furthermore, individuals with patellar tendinopathy tend to demonstrate a "stiffer" landing, observed via altered kinematics closer to maximum knee extension and larger ground reaction forces, compared to those who are healthy [5, 6].

To combat the symptoms associated with tendinopathy, many clinicians advocate the use of patellar tendon straps for pain control during sports activities. However, few studies to date have demonstrated the effectiveness of patellar tendon straps and mechanisms by which they assist in pain relief during dynamic activity [7-9]. However, several investigations have demonstrated differences in lower extremity three-dimensional landing patterns and mechanics in individuals with patellar tendinopathy during landing [5, 6, 10]. Accordingly, altering landing biomechanics through the use of a patellar tendon strap may assist in moderating pain in individuals with patellar tendinopathy. When wearing a patellar tendon strap, a compressive force is placed on the tendon, which may also manipulate patellar and lower extremity mechanics [8]. However, it is unknown what influence patellar tendon straps may have on three-dimensional kinematics and ground reaction forces during single-limb landings. Thus, mechanical changes with the use of a patellar tendon strap may assist in the pain relief reported in individuals with patellar tendinopathy.

Therefore the purpose of this study was to explore pain, initial landing kinematics and vertical ground reaction forces (vGRFs) during a single-leg landing task when wearing a patellar tendon strap in individuals with and without patellar tendinopathy. We hypothesized strapping would decrease pain in those with patellar tendinopathy, while landing kinematics and ground reaction forces would be altered during strapping conditions.

2. Methods

2.1 Participants

No published data on biomechanical properties of patellar tendon strapping in patellar tendinopathy participants were available to perform an accurately comparable *a-priori* power analysis. However, using data from a previous study [12] on the effectiveness of tendon strapping on pain control during single-limb vertical jump an *a-priori* power analysis was conducted using G*Power™ (Version 3.0.10 Kiel University, Germany). Using those data, with an α= 0.05, 1-β = 0.80 and achieved effect size d= 0.54, 23 individuals in the tendinopathy group would be necessary to find differences in pain with use of the strap.

Sixty physically active individuals were recruited from the local community to participate in this study, which was approved by the local human subjects review board. Thirty participants with patellar tendinopathy were recruited if they expressed pain only in their patellar tendon, pain throughout their preferred sporting activity for a minimum of the previous 3-months, no limitations in their physical activity due to their pain or were enrolled in a rehabilitation treatment protocol, and Score ≤ 80 on the Victorian Institute of Sport Assessment Scale-Patella (VISA-P) indicating decreased function and the presence of patellar tendinopathy [6, 12, 13]. The VISA-P is an 8-item questionnaire designed specifically for patellar tendinopathy patients and has a maximum score of 100. It has demonstrated excellent test-retest and interrater reliability [13].

Thirty, gender, age, height, and weight, matched participants were recruited for the control group. Control participants had no history of any knee joint injury. All participants were excluded if they had a prior lower extremity surgery or fracture, current signs and symptoms of a lower extremity joint injury, current pregnancy, or a previous diagnosis of a vestibular or balance disorder. Although imaging was not used to definitively identify the presence of patellar tendinopathy, an athletic trainer with 10 years clinical experience evaluated each participant for inclusion criteria. In addition, previous biomechanical research studies assessing PT participants have used similar criteria [10, 12]. As this was part of larger study, portions of data from this cohort of participants have been previously published [10, 14].

2.2 Procedures

Participants initially provided informed consent, then completed health history questionnaires to assess inclusion and exclusion criteria. Sixteen retro-reflective markers were attached based on the kinematic models of Davis et al [15] and Kadaba et al [16] to landmarks of the pelvis and lower limbs used in the Plug-In-Gait software (Workstation, v5.2.4, OMG Plc., London, UK).

Participants' maximal vertical jump height was assessed using a Vertec© jump trainer (Sports Imports, Columbus, OH). The jump trainer was then set to 50% of the maximum as a target height. Participants raised one arm to reach the target height after jumping off 2-legs at a distance 70 cm from a force platform (Figure 1) [17, 18]. Participants then landed on a single-limb on the force plate (1200 Hz; Bertec 4060-NC®; Bertec Corporation, Columbus, OH), stabilizing and balancing for 10 seconds. Participants performed five trials for each in a no-strap and strap condition (Universal Matt Strap™; Hely & Weber, Santa Paula, CA). Between each trial, participants had approximately a minute rest period. Strapping conditions were counterbalanced; half of the participants across both groups performed the no-strap condition first while the other half performed the strap condition first. This ensured the same amount of participants in each group were distributed across the testing order equally to wash out the potential effect of fatigue or pain on the strapping conditions. Participants completed a 100 mm visual analogue scale (VAS) for pain with "no pain" and "very severe pain" as anchors after completing each strap condition [19]. Participants were blinded to previous scores.

2.3 Data Reduction and Analysis

Marker trajectories were recorded with a 7-camera motion capture system (120 Hz, mean residual error= ≤0.5 mm, Vicon-MX40, Vicon, Oxford, UK). Kinematic and kinetic data were processed through the Vicon Workstation software (Workstation, Oxford Metrics LTD., Oxford, UK), with spatial locations of the retro-reflective markers transformed into three-dimensional coordinates. Segmental positions and joint angles (cardan) of the lower extremity defined the joint angles following the recommendations from the International Society of Biomechanics [20, 21]. These kinematic models demonstrate good to excellent, test-retest and interrater reliability (22). Ground-contact was determined with >10N via the force platform. Three-dimensional hip, knee and ankle joint angles at initial ground contact were extracted as dependent variables of interest and averaged over the first three trials with complete kinematic information over each condition. Initial ground contact joint angles were used due to the nature of the type of landing maneuver performed [23]. Much of the previous research on patellar tendinopathy landing mechanics have focused on double-limb landings of stop-jumps and countermovement [5, 6] As the participants were asked to perform a forward 50% maximum vertical jump, land on a single limb and then balance, it was believed kinematics at initial-contact provided the most robust information. Peak vertical ground reaction forces normalized to body weight (vGRF) were also calculated.

2.4 Statistical Analysis

All statistical analyses were performed using IBM Statistical Package for the Social Sciences software (Version 23.0, IBM, Inc., Armonk, NY). Demographic data and questionnaires were initially inspected for differences utilizing independent samples t-tests. A paired-sample *t*-test was used to assess differences in pain among the patellar tendinopathy group. A mixed-model, multivariate analysis of variance (MANOVA) was used to determine statistical significance between control and patellar tendinopathy groups (between subjects) and strapping conditions (repeated-measures). If significant differences were found among multivariate statistics, univariate tests of significance (analysis of variance) were then inspected for differences. All statistical significance levels were set *a*-priori at .05.

3. Results

No significant differences were observed among demographic data across participant groups (Table 1). Significantly less pain (t=3.84, p<.01) was observed between strapping (28.0 ± 18.5 mm) and no-strap conditions (37.1 ± 22.1 mm) in the patellar tendinopathy participants.

The MANOVA revealed no interaction effect between strapping and tendinopathy group (*F*=.98, *p*=.48) and no main effect for tendinopathy (*F*=0.52, *p*=.86). However, a significant main effect for strapping was present (*F*=3.20, *p*=.004). Furthermore, univariate tests revealed significant differences in the hip transverse plane (*F*=7.16, *p*=.01, Table 2), knee frontal plane (*F*=10.20, *p*=.002), ankle frontal plane (*F*=4.60, *p*=.04) and peak vGRF (no-strap=4.40 ± 0.79, strap=4.26 ± .80, *F*=7.30, *p*=.009, Table 3) across all participants in the strapping condition. Specifically, with the strap, participants displayed more neutral hip rotation, knee adduction and ankle inversion as well as lower vGRF.

4. Discussion

The purpose of this study was to determine if pain, three-dimensional landing kinematics and vGRFs were altered when participants with and without patellar tendinopathy wore a patellar tendon strap during a single-limb landing. Based on the results, it appears strapping acutely modifies pain and biomechanical landing characteristics.

4.1 Pain

Strapping had a beneficial effect on pain during a single-limb landing which appears to be statistically and potentially clinically significant. We found an approximate 25% reduction in pain during a single-limb landing with an average decrease of 9 mm on the VAS's. This result is in agreement with previous studies which also found similar decreases pain with strapping in individuals with patellar tendinopathy [12, 14]. While the pain reduction may be considered small, the reduction observed falls in line with studies of similar construct regarding the minimum clinically important difference (MCID) and the percent decrease in pain. Previous literature on MCID's has focused on emergency room visits, and reductions in pain following various treatments appeared to range from between 8-30mm [24-26]. Due to the relatively low baseline response and pain during the non-strapped trials, the threshold for change for a typical MCID for VAS pain may not be appropriate in this task and may underestimate the pain response in our participants [27]. Despite this, one-third of tendinopathy participants demonstrated relatively large pain decreases (>15mm). For clinicians this suggests an individualistic approach to strapping may provide more benefit.

4.2 Kinematics

Strapping influenced landing kinematics at initial contact in the single leg landing compared to the no-strap condition. While wearing the strap, all participants landed with less hip internal rotation, knee adduction and ankle inversion, indicating a potentially more neutral landing. As individuals with patellar tendinopathy tend to demonstrate both excessive muscular tension and a load-avoidance strategy during landing movements, any assistance in decreasing tendon tension may provide symptomatic relief [5, 28]. Furthermore, kinematic changes in individuals with patellar tendon abnormality (PTA), a predisposing condition to tendinopathy have been observed during landing [29]. Those with PTA have demonstrated greater hip flexion, hip abduction, knee flexion and knee abduction compared to controls during a stop-jump task [29]. This positioning would put the quadriceps and the patellar tendon in an elongated position, potentially adding strain to an already damaged tendon. Therefore, with the lower extremity in a more neutral frontal and transverse plane positioning with use of the strap, the musculotendinous fibers may also be more aligned, ultimately reducing tendon tension in symptomatic patients.

Few studies have reported the influences of patellar tendon straps on biomechanical parameters. Previously, many of the studies to assess the biomechanical differences with strapping are cadaveric, radiographic and electromyographic examinations [7-9]. In a cadaveric study, authors found decreased infrapatellar fat pad pressure, patellofemoral contact area and pressure with the addition of the patellar tendon brace [7]. However, utilizing cadaver specimens may not appropriately account for all internal and external forces placed on the limb during landing [29]. In a radiographic study, the investigators reported a decrease in patellar tendon length as well as a decline in patellar-tendon angle with use of patellar tendon straps [8]. The authors believed this may have led to decreased strain at the site of injury with the use of the straps. While these findings may be contributory to a reduction in patellar tendinopathy symptoms, the patellar tendon angle and length were measured at a single time period, 60° of flexion, not during dynamic movement [8]. In another study on muscle activation strategies while wearing a strap during a squat, investigators found an alteration in quadriceps muscle timing, specifically in the vastus lateralis [9]. The authors thought this was a beneficial finding due to muscular imbalances associated with mal-tracking conditions, but nothing specific was mentioned related to patellar tendinopathy [9]. Comparatively, the alteration in patellar dynamics and muscle activation suggest a potential to impact sagittal plane dynamics. The results of the current study do not necessarily support the previous findings, but provide evidence for small changes in alignment in the frontal and transverse plane. Assessing patellar tendon strap effectiveness in human subjects during dynamic activities such as landing remains paramount, as many of those who suffer from patellar tendinopathy continue to perform their normal recreational activity in spite of the pain.

4.2 Ground Reaction Forces

There was a significant main effect for strapping, where all participants experienced decreases in vGRFs with the strap compared to the no-strap condition. Although no previous studies have identified differences in GRFs with patellar tendon strapping, previous studies on knee taping and bracing do support our results. One study on patellar taping found decreases in peak vGRFs during fast paced walking compared to no tape [32]. Another on healthy participants using a custom fitted functional knee brace during 70 cm single limb drop landings reported decreases in peak vGRFs compared to non-braced conditions [33]. Although the findings in our study were significant, similar to the previous studies differences, they were relatively small. This is indicated by a relatively small mean difference (*Cohen's d*=0.18*)* and therefore may not be clinically relevant. However, if the decreased vGRFs noted are consistently compounded over time during physical activity, such as basketball, it could have significant implications on lower extremity loading and tissue quality of the lower extremity. Considering training volume and excessive sport participation are believed to be primary extrinsic factors related to tendinopathy development [34, 35], even small decreases in vGRFs could provide a significant benefit to individuals with tendinopathy.

4.3 Limitations

The authors must acknowledge several limitations. As this was an observational study, a double-blinded randomized control trial combined with a sham treatment for strapping would likely be a better design to assess the strapping effectiveness. Similarly, because this was an observational study, it is difficult to determine and speculate on the mechanism by which patellar tendon straps both decrease pain and influence landing characteristics. Due to this and the non-inclusion of a sham treatment it is also plausible a psychological and placebo effect was present. In addition, we had relatively functional patients, characterized by the low to moderate pain levels reported, and patients with more severe tendinopathy may portray different responses to patellar tendon strapping. Imaging such as diagnostic ultrasound to definitively diagnose tendinopathy was not completed. Despite this, we are confident in our inclusion criteria and previous work has used similar constructs [10, 12, 23]. Another possible limitation is the use of a 50% maximum jump height as opposed to a maximum jump height. The relatively small changes observed may potentially be attributed to this discrepancy and perhaps a maximum vertical jump may have elicited greater changes in kinematics and vGRFs. Future studies may want to incorporate maximum vertical jumps or other dynamic maneuvers which may elicit different biomechanical responses. Additionally, as this study only observed kinematics at initial landing, it would may be beneficial to identify possible changes during the entire landing phase with use of a strap. Thus, additional investigations may want to observe these variables to potentially provide more insight into the effectiveness of strapping during a single-limb landing. Lastly, there was fairly large variability in the landing patterns across individual participants, and although statistically significant most of the effects were interpreted as small, therefore limiting the overall impact of the findings. However, this variability appears consistent with previous research studies [10, 23], and further investigations may want to perform advanced, non-linear analyses to identify more subtle changes in biomechanical data.

5. Conclusions

The major results of this study indicate patellar tendon straps are effective at reducing pain acutely in individuals with patellar tendinopathy and they alter landing characteristics during a single-limb landing. As some individuals reported greater decreases in pain with the strap, clinicians may want to take an individualistic approach to strapping. Participants landed in a more neutral alignment and changing biomechanical alignment could potentially assist in reducing strain to the tendon. While wearing the strap individuals also demonstrated decreased vGRFs, which could provide benefits for individuals participating in high volumes of practice or training. Future studies may want to determine the effectiveness with more robust designs, advanced symptoms and for longer periods.

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