Clinical Measures and Their Contribution to Dysfunction in Individuals With Patellar Tendinopathy

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ABSTRACT

Context: Patellar tendinopathy is prevalent in physically active populations and it affects their quality of living, performance of activity, and may contribute to the early cessation of their athletic careers. A number of previous studies have identified contributing factors for patellar tendinopathy however their contributions to self-reported dysfunction remain unclear. **Objective**: The purpose of this investigation was to determine if strength, flexibility, and various lower extremity static alignments contributed to self-reported function and influence the severity of patellar tendinopathy. **Design**: Cross sectional research design. **Setting**: University Laboratory. **Participants**: 30 participants with patellar tendinopathy volunteered for this study (age: 23.4±3.6 years, height: 1.8±0.1m, mass: 80.0±20.3kg, BMI: 25.7±4.3). **Main outcome measures**: Participants completed seven different patient-reported outcomes. Isometric knee extension and flexion strength, hamstring flexibility and alignment measures of rearfoot angle, navicular drop, tibial torsion, q angle, genu recurvatum, pelvic tilt, and leg length differences were assessed. Pearson's correlation coefficients were assessed to determine significantly correlated outcome variables with each of the patient-reported outcomes. The factors with the highest correlations were used to identify factors that contribute the most to pain and dysfunction using backward selection, linear regression models. **Results:** Correlation analysis found significant relationships between questionnaires and BMI (r=-0.35-0.46), normalized knee extension (r= 0.38-0.50) and flexion strength (r=-0.34-0.50), flexibility (r=0.32- -0.38, q angle (r=0.38-0.56) and pelvic tilt (r=-0.40). Regression models (R^2= 0.22-0.54) identified thigh musculature strength and supine q angle to have greatest predictability for severity in patient-reported outcomes. **Conclusions:**

These findings put an emphasis of bodyweight management, improving knee extensor and flexor strength, posterior flexibility in patellar tendinopathy patients.

INTRODUCTION

Patellar tendinopathy (PT) is a painful overuse condition of the patellar tendon accompanied by dysfunction typically with high-levels of physical activity.[1,2] PT affects up to 45% of athletes involved in jumping sports.[3] Clinically, its pathological process results in decreased load-bearing ability resulting from the failure of the collagen alignment or cross-link.[4] Thus, this pathological sequence has a significant impact on activities of daily living and the quality of life in patients presenting with symptoms of PT. The prolonged dysfunction associated with PT can result in a disruption of activities of daily living, reduction in physical activity, and early cessation of athletic careers which highlights the importance of determining the contributing factors associated with PT.[5]

PT is commonly characterized by persistent anterior knee pain concentrated on the patellar tendon, and occurs with activities that apply load on the tendon.[6,7] Although PT is frequent in athletics, contributing factors to PT remain unclear.[8] Both extrinsic and intrinsic factors have been proposed to contribute to the development of PT.[9] Representative extrinsic factors influencing PT are related to the environment, which includes hard training surfaces and increases in training frequency and volume.[9] Intrinsic factors for the development of PT are understood as tissue responses to external forces placed on the body and include knee joint and patellar mobility, lack of flexibility, leg length discrepancy, gender, and strength differences between agonist and antagonist muscles of the lower limb.[9]

However, considering the linked system of the lower limb, further alignment measures may be necessary to understand contributing factors to PT. Additionally, these studies fail to assess the progressive nature of PT, specifically, if those with more advanced symptoms have greater deficiencies compared to those with less severe symptoms of PT. Therefore, the purpose of this study was to comprehensively determine if strength, flexibility, and various lower extremity static alignments play a role in patellar tendinopathy patients and to determine if clinical measures influence the severity of patellar tendinopathy as indicated by patient-reported outcomes.

METHODS

Participants

Thirty, 19-40 year old subjects with patellar tendinopathy were recruited from the university and surrounding community. Participants completed University Institutional Review Board Approved documentation. Participants were included with the following criteria:[1,10] 1) Local tenderness in the patellar tendon region; 2) Pain aggravated with athletic movement; 3) Pain duration ≥ 3 months; 4) Victorian Institute of Sport Assessment of Patella (VISA-P) score ≤ 80; 5) Tegner activity scale ≥ 4; 5) Recreationally active; 6) Participating in physical activity despite symptoms. Exclusion Criteria included: 1) Previous patellar tendon surgery or patellar fracture; 2) Injection into the knee within 6 months; 3) Knee pain due to other pathology; 4) Current participation in rehabilitation program for knee pain.

Research protocol

Participants completed several questionnaires including, the Tegner activity scale, VISA-P questionnaire, the lower extremity functional scale (LEFS), anterior knee pain scale (AKPS), knee outcome survey activities of daily living scale (ADLS), lysholm score (LS) and visual analog scale (VAS). Pain level with a VAS was asked for the worst pain during physical activity.

Strength

Strength measurements were performed with a Biodex isokinetic dynamometer (Biodex Multi-joint system 4, Biodex Medical Inc. NY, USA). Participants performed three maximal isometric exertions alternating between knee extension and knee flexion. The average peak knee extensor and flexor torque were recorded with three maximal isometric tests at 60° knee flexion (5 second duration with 20 second rest).[1] Average peak torque (Nm) was recorded and normalized with body mass (Nm.kg-1).

Flexibility

First a sit-and-reach test which tested the flexibility of posterior structures was completed.[1] Hamstring length was then measured with supine active knee extension (Figure 1).[1] The angle between femur and tibia was measured with a goniometer.

Alignment

For the rearfoot angle, the participant was standing and asked to bear weight equally between both limbs. Rearfoot angle was assessed via goniometry, with the axis aligned to the distal insertion of the Achilles tendon on the calcaneus, the stationary arm aligned to a point 1/3 up the posterior leg that bisected the leg, and the moveable arm bisecting the posterior calcaneal tuberosity.[11] The navicular drop (ND) test was measured with the subject standing using a height gauge (Figure 2).[12] The height of the navicular tuberosity was measured while the participant held subtalar neutral, the participant stood in a normal posture with 50:50 weight bearing and the navicular height was re-measured. The height difference of asymptomatic navicular height subtracted from symptomatic navicular height was used. Tibial torsion (TT) was measured supine as the angle between the imaginary vertical line and a bimalleolar axis was measured.[12]

Supine q-angle (Sup Q) and standing q-angle (Stan Q) used the landmarks of the anterior-superior iliac spine, patellar center, and tibial tuberosity.[13] Genu recurvatum (GR) was assessed supine with the distal tibia supported on a bolster, and the angle formed by the femoral head, lateral epicondyle, and lateral malleolus was recorded.[12] Pelvic tilt angle (PTA) was measured standing. A line was drawn with anterior superior iliac spine and posterior superior iliac spine was used and the angle between the line and horizontal plane was measured.[12] Leg length was assessed as the length from anterior superior iliac spine to the medial malleolus. Length of both legs were measured and the length of the asymptomatic leg was subtracted from the length of the symptomatic leg (LLD).[1]

Reliability

Prior to data collection, the reliability of the tester was measured to ensure consistency. The rater assessed 10 individuals in each of the reported alignment measurements. After the initial measurement, the participants were measured again and the single rater was blinded to the previous assessment. Each measurement was performed 3 times and the mean value was used in statistical analysis. Intraclass correlation coefficients (ICC (2,k)) and standard error of the mean (SEM) were used to assess the test-retest intrarater reliability. The rater demonstrated good to excellent reliability (r=.77-.99, Table 1) across each of the measurements.

Statistical analysis

All statistical analyses were conducted using IBM SPSS software (Version 20.0, IBM, Inc., Armonk, NY). Pearson's product moment correlations were first performed between each individual patient-reported outcome and measurement. The measurements with the greatest significant correlations with each questionnaire were then used to identify factors that contribute the most to pain and dysfunction associated with PT. This was completed using a backward selection, linear regression to determine the most parsimonious, multifactorial model to predict each of the pain and function scales. Models were chosen based on the least amount of predictors and statistical significance. Additionally, to ensure the assumption of multicollinearity was not violated the variance inflation factor (VIF) and tolerance were inspected. The significance level was set a-priori to $\leq .05$ for all statistical tests.

RESULTS

Table 2 displays the descriptive demographic, questionnaire and dependent variable measurements averaged across all participants. All included participants reported unilateral knee pain although there was no limitation with bilateral or unilateral knee pain.

BMI (r=-.35, p=.03), normalized knee extension (r=.50 p=.003), normalized knee flexion (r=.43, p=.009), Sup Q (r=.56, p=.001), and Stan Q (r=.54, p=.001) had significant, moderate to large correlations with the AKPS. Higher values of the AKPS indicate less pain and better function of the lower limb. Only PTA (r=-.40 p=.02) had a moderate correlation with the LEFS questionnaire. Higher LEFS score indicate better function of the lower extremity. BMI (r=.46 p=.005), NKE (r=-.50 p=.002), NKF (r=-.34 p=.03), SR (r=-.38 p=.02), AKE (r=-.38 p=.02), and Sup Q (r=-.38 p=.02) had a statistically significant moderate to large relationships with VAS. Greater ADLS score, which means better function of daily living, was moderately related to greater NKE (r=.47 p=.004), SR (r=.32 p=.04), and Sup Q (r=.42 p=.01). Only strength measures of NKE (r=.47 p=.004) and NKF (r=.44 p=.008) had significant, moderate correlations with the VISA-P which is specific to PT and higher scores mean better function. Lastly, the NKE (r=.50 p=.002), NKF (r=.36 p=.002), Sup Q (r=.49 p=.003), Stan Q (r=.38 p=.02) had significant moderate correlations with LS and with higher NKE values indicating better function of the knee (Table 3).

Backwards regression models revealed several items with significant predictability for the patient-reported outcomes. For the AKPS, NKF and Sup Q explained approximately 54% of the variability (r=.73, R^2=.54, $F_{(2,27)}$=15.62, p<.01, Table 4). PT explained 21% variability of LEFS (r=.46, R^2=.21, $F_{(1,28)}$=5.19, p=.03, Table 4). While, BMI and NKE explained 43% of variability of the VAS (r=.66, R^2=.43, $F_{(2,27)}$=10.33, p<.01, Table 4). NKE and Sup Q explained 30% and 47% variability of both ADLS (r=.55, R^2=.30, $F_{(2,27)}$=5.89, p=.008, Table 4) and LS (r=.68, R^2=.47, $F_{(2,27)}$=11.82, p<.01, Table 4). Lastly, only NKE explained 22% variability of VISA-P (r=.47, R^2=.22, $F_{(1,28)}$=8.04, p=.008, Table 4). Each of the models had VIF's less than 1 and no greater than 10, while their tolerance were between 1 and .2.

DISCUSSION

The purpose of this study was to comprehensively assess strength, flexibility, and various lower extremity static alignments and their role in patellar tendinopathy patient self-report pain and function as well as to determine if clinical measures influenced the severity of patellar tendinopathy. The results demonstrate that strength measures played the largest role while several alignment measures, also affected lower extremity pain, function and severity in those with PT.

Strength

AKPS, VAS, ADLS, VISA-P, LS had significant correlations with normalized knee extension and besides the ADLS, normalized knee flexion was also significant with each of the self-report questionnaires. All outcomes indicate that participants demonstrated better function and less pain with more strength. Crossley et al performed a study measuring normalized knee extension on PT patients and found a significant correlation with their function and strength.[1] Since the most significant factor for dynamic patellar stabilization is strength of the quadriceps muscles, results of this study is in line with previous literature.[14] However, it is difficult to distinguish if pain causes the muscular weakness or if muscle weakness is causing dysfunction with this correlation analysis.

Furthermore, the significant correlation of normalized knee flexion and questionnaires indicates that hamstring muscle function should not be overlooked in these patients. This hamstring weakness may have been caused by refraining from vigorous activity with weight bearing or modifying their activities due to the pain.[15] Previous literature that studied chronic knee pain concentrates on hamstring tightness but not hamstring weakness.[14] Similarly, this study indicates clinicians should not only focus on the quadriceps but should also target hamstring strengthening exercises when developing a patellar tendinopathy rehabilitation plan.

Flexibility

SR was significantly correlated with the VAS and ADLS and the AKE was correlated with the VAS. The results demonstrate that better flexibility is related to less pain and better function. Murphy et al performed a systematic review on risk factors for lower extremity injuries finding that muscle tightness is a risk factor for various types of injuries.[16] Previous literature has shown quadriceps flexibility has a high positive correlation with VISA-P score but not hamstring flexibility.[17] In contrast, other research found no significant correlations between flexibility and PT symptom but found a valid predictability with AKE.[1] Although there is conflicting results from previous studies, the current investigation found hamstring flexibility is related to the severity of symptoms in individuals with PT.

Alignment

In general, Sup Q showed the greatest correlation among alignment measures performed in this study. AKPS, VAS, ADLS and LS showed moderate to strong correlations indicating that greater q angle is related to better function and less pain. While no studies to the authors' knowledge have previously assessed q-angle and PT, this outcome is contrary to another study that found q-angle is not statistically associated with anterior knee pain.[18] Pelvic tilt also demonstrated a moderate strength of correlation with LEFS. The correlational coefficient indicated that less anterior pelvic tilt is related to better function of the lower extremity.

There were some alignment measures that were not correlated to the pain and function of PT. Leg length difference was not a significant predictor for PT with one previous study and similarly was not significantly correlated with any of the questionnaires or scales used in this study.[1] Also, while static rearfoot angle is a good predictor of plantar fasciitis, navicular drop test for medial tibial stresss syndrome, tibial torsion and genu recurvatum for anterior cruciate ligament injury[19-21] there may not be a relation to those with PT. Thus, PT may have several unique characteristics when compared to other pathologies influencing its severity and dysfunction reported in patients.

Predictability

Several regression models indicated strength, flexibility and alignment measures were able to predict the severity of symptoms as indicated by the patient-reported outcomes. The regression model with the AKPS included normalized knee flexion and Sup Q. Previously, a greater q angle has not been shown to be a potential contributor to PT.[22] However, increased Q angles biomechanically have a relationship with the pulling angle of the patella and has been shown to have a relationship with a patellofemoral pain.[23] One alternative study measured the effects of hamstring coactivation on normal joint function and pain alleviation with knee osteoarthritis which implies the importance of the hamstring function.[24] Therefore, normalized knee flexion and Sup Q may play a role in the level of anterior knee pain symptoms of PT.

The LEFS is the only survey which includes items associated with activities of daily living and its model was the only one that included PTA. PTA has not been studied in individuals with PT but has been assessed in those with patellofemoral pain and osteoarthritis.[25,26] As a coupled system, anterior pelvic tilt has a relationship with femoral internal rotation which can cause a valgus collapse of the knee and result in faulty mechanisms of patellar pull.[27] Moreover, according to a study that measured the effect of pelvic tilt on standing posture, populations with deviated pelvic orientation had a tendency to have a problematic knee, hip and spine orientation which denotes its importance in this model.[28]

For the VAS modeling, BMI and normalized knee extension demonstrated significant predictability. Similar to the arthrogenic muscle inhibition, strength deficits could be exhibited due to pain induced muscle inhibition.[29] Obesity or high BMI has also shown to be a risk factor in recent literature and it is found to be a predicting factor for the pain level of PT which emphasizes the importance of body mass.[30,31] BMI and quadriceps strength appear to be valid predictors of PT related pain and may be necessary to manage in individuals with PT.

Both the ADLS and LS measures function of lower extremity demonstrated the same predictors (NKE and Sup Q) while the VISA-P had NKE as a sole predictor. In the literature, patients with PT have demonstrated isometric knee extension strength deficits when compared to a control population.[1] This emphasizes the importance of maintaining quadriceps muscle activation and strength in individuals with PT.[1,32] The effectiveness of quadriceps strengthening exercises on PT symptom alleviation support this as well.[33]

CONCLUSION

PT is a multifactorial chronic injury and is difficult to assess, manage and treat. Therefore, prevention and early detection is crucial to assist in management of symptoms and severity of PT. In addition, the current study may provide some insight for clinicians to more effectively manage the symptoms of those with more severe bouts of PT. Based on the results, during rehabilitation for PT, clinicians should target thigh musculature strengthening and provide effective interventions to prevent or minimize biomechanical shifts that could be caused by the q-angle. There is some evidence in the literature supporting the effectiveness of eccentric or isometric knee extensor strengthening on the realignment of patellar tendon structure and pain alleviation.[33-35] Therefore, it is recommended to incorporate these concepts when rehabilitating individuals with PT. Additionally, although this research was not targeting athletes specifically, adding quantified strength measurement and supine q-angle measurement into the pre-participation examination is recommended in sports medicine clinical settings to identify athletes that may be prone to PT.

Limitations of this study include an absence of a control group to compare their mean values of each measurement. Ankle mobility, hip alignment, body composition, patellar position, and patellar laxity were not included in this research study and could potentially have a correlation to the symptoms and should be observed in future work.

In conclusion, strength deficits in the quadriceps and hamstrings, lack of flexibility, pelvic tilt and supine q angle demonstrated the greatest relationship with PT symptoms and self-reported dysfunction. Additionally, the results of the current study signify that the severity of PT can be predicted mainly by thigh musculature strength and supine q-angle measurements. This should provide healthcare providers better ability to treat dysfunction and pain associated with PT. Moreover, since BMI showed a negative correlation and flexibility measures showed a positive correlation, managing bodyweight and increasing posterior structural flexibility should still be included in the management and potentially prevention of PT. Future studies may want to target more anthropometric data of PT patients such as hip alignments, patellar position, patellar laxity, and lean body mass.

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