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Distinguishing Quadriceps and Patellar Tendinopathy: Semantics or Significant?

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Introduction

You arrive at your clinic and check the schedule, in preparation for a day of patient care. An initial evaluation has been added to your first treatment slot with a referral from an orthopedist for “jumper’s knee”. “I’ve seen this before,” you think to yourself – “patellar tendinopathy, no question.” In preparation, you pull out your patellar tendon loading protocol and make some assumptions about how the patient will present, and how you might approach the shared decision-making for appropriate management. When you begin your assessment, to your surprise, the patient complains of pain in the quadriceps tendon, not in the patellar tendon. What do you do now?

Jumper’s knee is not synonymous with patellar tendinopathy.[4] The term includes patellar tendinopathy *and* quadriceps tendinopathy.[4] Patellar tendinopathy has been extensively researched while quadriceps tendinopathy has been largely ignored.[8,16,18,24] As a result, clinicians may have resorted to treating quadriceps tendinopathy with rehabilitation programs designed for patellar tendinopathy. Although the patellar and quadriceps tendons work in tandem as part of the extensor mechanism of the knee, they have distinct anatomy and functional roles. As a result, there are probable differences in risk factors, etiology, and response to treatment.

It is time to clinically separate patellar and quadriceps tendinopathy and design more specific rehabilitation programs. In this Viewpoint, we will (1) provide a rationale for distinguishing the two clinical entities – patellar tendinopathy and quadriceps tendinopathy – for treatment decision-making, and (2) identify areas of research priority in quadriceps tendinopathy.

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Anatomical and Biomechanical Differences

The patellar tendon attaches bone to bone, whereas the quadriceps tendon attaches muscle to bone (Figure 1). The patellar tendon connects two structures of similar stiffness, whereas the quadriceps tendon connects two structures with dramatically different stiffness. Tendon mechanical properties mimic their adjacent structures.[2] Tendon has greater extensibility (less stiffness) at the region closest to the muscle. Conversely, regions closer to the bone are less extensible (stiffer).

The adjustment of stiffness along a tendon allows for efficient and safe transmission of force, from compliant muscle to stiff bone.[2] When landing from a jump, the knee flexes to absorb the impact. Simultaneously, the quadriceps muscle contracts eccentrically to control knee flexion. The quadriceps tendon must act as a shock absorber, lengthening along with the quadriceps. Where materials of different stiffness join, there can be stress concentrations at their interface.[19] Consequently, if the tendon was overly stiff close to the muscle and unable to lengthen, then the quadriceps musculotendinous junction and muscle may be at increased risk of injury. Due to the difference in attachments sites, the patellar tendon is stiffer than the quadriceps tendon.[14]

There are differences in structure between the patellar and quadriceps tendons. The patellar tendon is a relatively linear structure, composed of a superficial and deep layer, running in parallel, without direct muscular attachments.[3] The superficial layer is a continuation of quadriceps tendon fibers from the rectus femoris.[1] Fibers of the deep layer begin at the most distal aspect of the patella and insert, along with the superficial fibers, at the tibial tuberosity.[1] In contrast, the quadriceps tendon is a more complex and variable structure, arising from four separate muscles. Typically, the quadriceps tendon has three layers, a superficial layer (rectus femoris), intermediate layer (vastus lateralis and medialis), and deep layer (vastus intermedius).[1] However, the number of layers and relative contribution of each muscle is highly variable.[25]

Interactions between these layers and the surrounding matrix may have implications for the pathogenesis, symptom and imaging presentation, or treatment of quadriceps tendinopathy,[20] but has not yet been considered in the literature. Each quadriceps muscle has a unique line of action subjecting the quadriceps tendon to non-uniform load and shear forces. The force transmitted through the patellar tendon is more uniform.[11,23]

Epidemiology of Patellar and Quadriceps Tendinopathy

Patellar tendinopathy presents as pain at the inferior pole of the patella. Up to 14% of recreational and 45% of elite jumping athletes experience symptoms at any given time.[9,10] Conversely, quadriceps tendinopathy presents as pain at the superior pole of the patella with symptoms most pronounced with deep knee flexion. The initial onset of symptoms is usually related to an acute incident involving high levels of eccentric quadriceps loading, such as occurs with knee flexion when landing from a rebound in basketball. However, symptoms are typically preceded by a period of excessive load.[5] Although few studies have examined the prevalence of quadriceps tendinopathy, the prevalence estimates range from 0.2% to 2%

in athletic populations.[9,21] Among athletes with extensor mechanism pain, up to one in four experience pain at the superior pole of the patella.[9,21]

Treatment of Patellar and Quadriceps Tendinopathy: Similarities and Differences

Clinicians and patients are challenged by a lack of scientific evidence to help them make quality decisions when managing quadriceps tendinopathy.[16] In the absence of evidence, understanding the anatomy and biomechanics of the quadriceps tendon can help the clinician tailor a treatment program for quadriceps tendinopathy. In this section we highlight the common principles for treating patellar and quadriceps tendinopathy, and provide suggestions for how the clinician might tailor a program for quadriceps tendinopathy (Table 1).

Key principles: activity modification and graduated loading

All tendinopathies, including patellar and quadriceps tendinopathies, are overuse injuries resulting from tendon overload with inadequate recovery.[5] The primary symptom is load-dependent tendon pain, where greater loads result in a higher degree of pain, during or immediately after activity. Therefore, these injuries may benefit from activity modification.

In addition to pain, tendinopathies are accompanied by changes in tendon structure (tendinosis) and mechanical properties. Thus, tendinopathies benefit from controlled tendon loading programs to reduce pain, promote remodeling and restore mechanical properties. However, these similarities do not mean that the treatment strategies can be identical for patellar and quadriceps tendinopathy.

Preferentially loading the quadriceps tendon

The patellar tendon and quadriceps tendon are not loaded equally throughout knee motion. The quadriceps tendon experiences greater loads than the patellar tendon as the knee moves further into flexion.[12] This relationship is due to an increasing mechanical advantage of the patellar tendon and greater passive tension in the quadriceps muscle as it approaches end-range. This may explain why pain in quadriceps tendinopathy is most pronounced in activities that involve deep knee flexion. Graduated loading programs for quadriceps tendinopathy should include appropriate loading in deep knee flexion. However, bony abnormalities are common and some patients may experience excess compression from the patella. In highly symptomatic cases, the patient may not tolerate loading in deep knee flexion in the early phases of treatment.

The load generated by the four quadriceps muscles causes nonuniform load through the quadriceps tendon. Some areas of the tendon are stress-shielded, and areas close to the patella may be compressed. Areas of lower stress, and areas of increased compression may be more susceptible to injury. Therefore, additional modifications may be needed, based on the patient's response, to avoid compression and stress-shielding when loading the tendon across the region of injury.[11] Based on the multidirectional nature of the quadriceps line of action, tibial rotation may preferentially load or unload specific regions. Combining hip

extension with deep knee flexion loading may increase forces in the superficial layer of the tendon.

Pain as a guide for clinical decision making

Mild to moderate pain is typically acceptable in patellar tendinopathy treatment protocols. There is no reason to believe this should not be the case for quadriceps tendinopathy. Pain may be a good clinical guide to appropriate tendon loading.[17] Because of the complex structure of the quadriceps tendon, it is possible for force transfer to occur without force transmission through the pathological region of the tendon. There may be injury-induced alterations in quadriceps muscle function that unload the pathological region.[13] Therefore, provoking pain during tendon loading may help clinicians identify positions where force is transmitted through the appropriate part of the tendon. We suggest that pain should not exceed 5 out of 10 on the numeric pain rating scale (0 = no pain, 10 = worst pain imaginable) during or immediately after treatment (Figure 2).[15] Symptoms should subside to baseline levels by the following morning and not increase from week to week. Pain thresholds may need to be modified based on the irritability of the patient.

Addressing altered muscle function

Changes in corticospinal excitability to the quadriceps muscle in patients with patellar tendinopathy may alter muscle activation.[13] In pilot studies, many individuals with patellar tendinopathy had reduced voluntary activation of the quadriceps. Therefore, we expect that there may be changes in quadriceps muscle function among patients with quadriceps tendinopathy. However, these changes may pose additional problems in quadriceps tendinopathy that are not present in patellar tendinopathy. In patellar tendinopathy, the force from the quadriceps is ultimately transferred through the patella to the patellar tendon, even if this force is diminished. In quadriceps tendinopathy, changes in relative activation of the four muscles may underload or stress shield the pathological area. Neuromuscular electrical stimulation or functional electrical stimulation may help offset these changes, augmenting quadriceps activation and ensuring adequate loading of all regions of the tendon.

Restoration of mechanical properties

The mechanical properties of tendon are altered by tendinopathy, and performance is impaired.[7,22] One aim of treatment for tendon injuries is to restore mechanical properties, although the clinical goals may be different. The mechanical properties of healthy patellar and quadriceps tendons differ, and may also respond differently to injury. We have observed in patients with unilateral quadriceps tendinopathy (using sonoelastography – a non-invasive method of measuring mechanical properties in-vivo) that symptomatic quadriceps tendons have lower stiffness in the pathological region than the uninjured limb.[6] In contrast, in patellar tendinopathy, *increased* stiffness correlates with symptom severity.[26]

Summary

There are differences in anatomy, function and response to injury that warrant clinical distinction of patellar tendinopathy and quadriceps tendinopathy. To help clinicians and

patients with quadriceps tendinopathy make quality decisions, we suggest future research must focus on 3 key areas:

1. Investigating the etiology and characteristics of patellar tendinopathy, addressing what regions or layers of the tendon are most commonly involved. Alterations to exercises that preferentially load the most common areas of pathology should be identified and tested.
2. Developing quadriceps tendinopathy-specific outcome measures, including measures of symptom severity and tendon mechanical properties, to provide a more complete picture of tendon health.
3. Conducting clinical trials to ascertain the efficacy of current and proposed treatments so clinicians can design and implement effective, tailored treatment programs.

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Key Points:

- Patellar and quadriceps tendinopathies are often grouped under the umbrella diagnosis of Jumper's Knee.
- Although the patellar and quadriceps tendons work in tandem as part of the extensor mechanism, they have distinct anatomy and functional roles.
- Quadriceps tendon loading should be performed in deep knee flexion and additional alterations may be necessary to preferentially load the pathological region.
- Recognition and research of quadriceps tendinopathy as a distinct diagnosis is needed to improve patient outcomes.

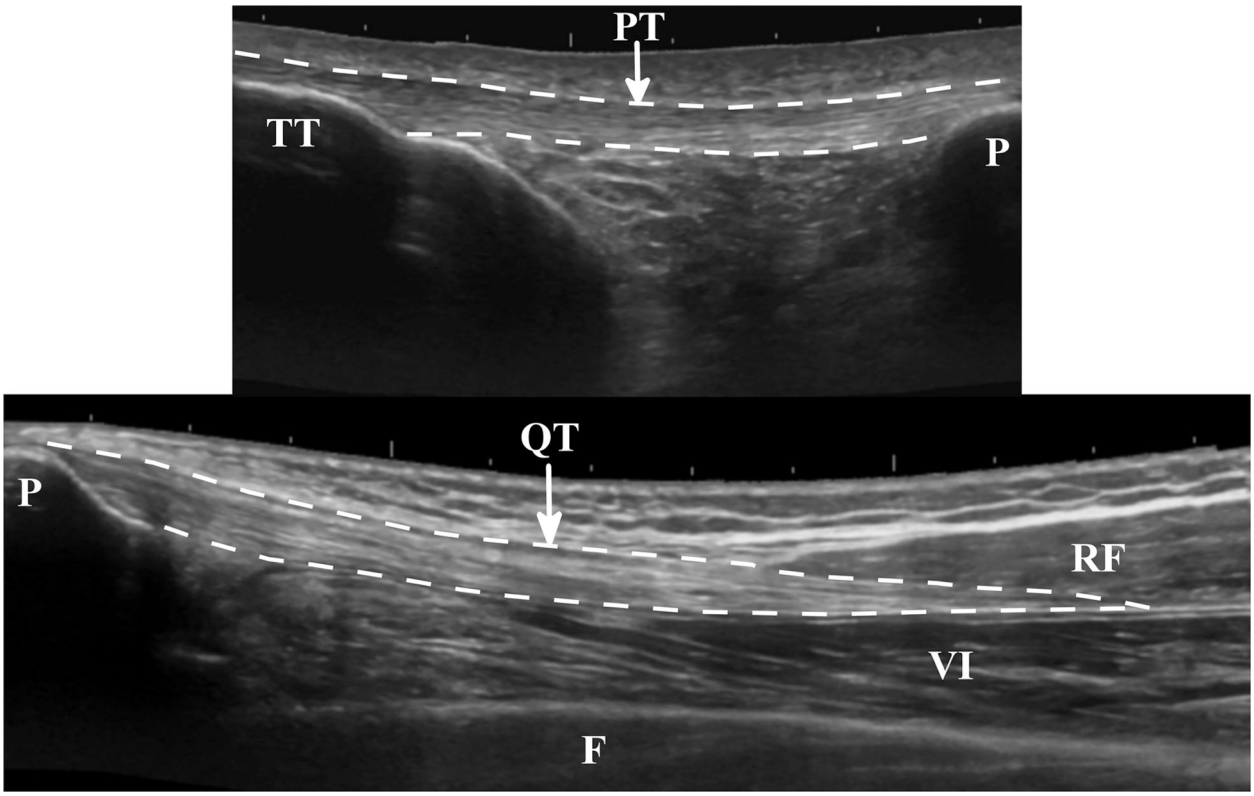

FIGURE 1.

Longitudinal ultrasound images of uninjured patellar and quadriceps tendons. PT = patellar tendon; TT = tibial tuberosity; P = patella; QT = quadriceps tendon, RF = rectus femoris; VI = vastus intermedius; F = femur.

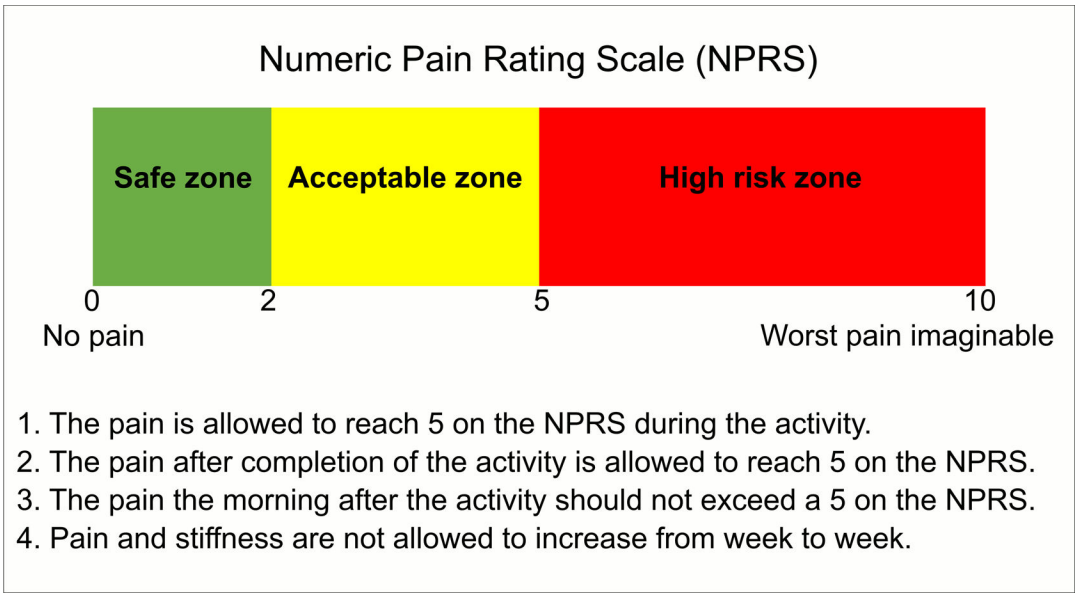

FIGURE 2.
The pain-monitoring model. Abbreviation: NPRS, numeric pain-rating scale.

TABLE 1.

Key principles of quadriceps tendinopathy treatment

Key Principles
• Controlled tendon loading is the central tenant of treatment.
• Activity modification may be necessary to prevent worsening of symptoms and to allow adequate time for the tendon to recover.
• Loading in end-range knee flexion may maximize load in the quadriceps tendon but caution should be used in the presence of bony abnormalities.
• The addition of tibial rotation and/or hip extension with loading exercise may preferentially load different regions of the quadriceps tendon.
• Mild to moderate pain during loading is not detrimental and may help target loading to the pathological region of the tendon.
• Electrical stimulation may be beneficial in restoring quadriceps muscle function and ensuring adequate load across the tendon.