STRAIN PATTERNS IN THE PATELLAR TENDON

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Introduction:
Many chronic tendon problems, such as patellar tendinitis are considered to result from repetitive tensile loading. In patellar tendinitis the injury usually occurs at the central and posterior side of the patella near the bony insertion at the inferior pole of the patella (1). Previous in vitro studies of the supraspinatus tendon insertion (2) have shown that in addition to tensile strains being present, compressive strains also exist. Based on these observations, we have hypothesized that tensile strains across the patellar tendon are also non-uniform and tensile strains in the area, usually affected by tendinitis, are actually less compared to usually non-affected regions. The objective of this study was to characterize how patellar tendon strains change as a function of knee flexion angle and location within the tendon.

Methods:
Eight fresh-frozen human knee specimens were dissected to allow access to the anterior and posterior aspects of the patellar tendon. The dissection involved the removal of skin, muscle and the infra-patellar fat pad. Two differential variable reluctance transducers (DVRT, Microstrain Inc., Burlington, VT) were inserted, one at the anterior side and one at the posterior side of the patellar tendon. The displacements on both sides as well as the joint angle were continuously measured as the knee was moved from full extension to 60 degrees of flexion. Joint angle was measured by an electrogoniometer. The quadriceps tendon was loaded with a 26N force as a DC servomotor was utilized to flex the knee at a constant angular velocity of approximately 5 degrees per second. Displacement measurements were repeated up to 5 times and repeated for 3 different locations within the tendon: A (central proximal), B (lateral proximal) and C (central distal). Measurements at the central distal location were also conducted at a faster flexion rate of approximately 40 degrees per second to assess the effect of the rate of flexion on the measured displacements. To assess the relative extent of the anterior and posterior bundle of the tendon (location A) being strained with an increase in load at full extension, strain changes were monitored in the tendon as the load was increased from 13N to 58N.

Displacement and joint angle signals were sampled at 20 Hz and processed using Labview Software (National Instruments Inc., Austin, TX) and a PC data acquisition system. Displacement signals were converted to strains utilizing full extension as a zero-strain reference. The approximate gauge length of the DVRT at zero strain was 10mm. Strains were plotted as a function of joint angle utilizing a joint angle increment of 5 degrees. The average, minimum, and maximum strain were calculated for the complete joint flexion cycle (13 angular increments) for each specimen for each location. A repeated measures analysis of variance was conducted to assess the effect of DVRT (anterior vs. posterior), location (A,B,C), and joint angle on the measured strain parameters. Mean comparisons were performed by the Student-Newman-Keuls Method with a significance level of 0.05.

Results:
In location A (central proximal) the tensile strain increased on the anterior side of the tendon in all (100%) testing situations while moving the knee from extension to flexion. Conversely, the strain decreased on the corresponding posterior side in 63% of the testing sequences. In the other locations the strain behavior was more uniform with increasing strain on both sides of the tendon in 63% of the measurements in location C. The average strain pattern (based on each angular interval) for all specimens is shown for the anterior and posterior sites at each location as a function of joint angle (Figure 1). Strains were found to change significantly (P<0.01) with joint angle for the anterior strain measurements at all locations, but not for the posterior side.

Average strains across the flexion cycle for all specimens are shown (Figure 2). Statistical analysis of these strains revealed significantly higher strains on the anterior side of the tendon as compared to the posterior side in location A (P<0.01). The use of subphysiological loads and the small number of specimens are additional factors that need to be considered in extrapolating these results.

Discussion:
Tensile strain appears to be lower at the posterior side of the patellar tendon, especially at the central-proximal location. MRI studies and reports on surgical treatment have consistently shown that this is the area usually affected by patellar tendinopathy (1). The results of this study challenge the theory that high tensile forces in this area are the cause of patellar tendinitis. These findings suggest that the injury could represent a degenerative lesion due to stress shielding as the knee proceeds into flexion. In addition, the non-uniform strain distribution across the tendon in the central-proximal location may cause internal shear forces that may contribute to the initiation of injury to the tendon. Clinically, these results may suggest alternative rehabilitation techniques for treating such tendon injuries. Limitations of the study include some uncertainty as to the level of loading present in the anterior versus posterior bundle at full extension where the zero strain position was defined. With the addition of 45N of load at extension, the change in strain found on the posterior side was not significantly different than the anterior side; however, it was higher and the power of our statistical test was low. In addition, the use of subphysiological loads and the small number of specimens are additional factors that need to be considered in extrapolating these results.

References:

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