INFLUENCE OF VASTI ORIENTATION ON THE PATELLAR LIGAMENT FORCE/ QUADRICEPS FORCE RATIO DURING KNEE EXTENSION

Sam Chen[1], Irving Scher[2], Christopher Powers[1], and Thay Lee[3]

[1] Musculoskeletal Biomechanics Research Laboratory, Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA, USA
[2] Exponent, Failure Analysis Associates, Los Angeles, CA, USA
[3]Orthopedic Biomechanics Laboratory, Long Beach VA Heathcare System, Long Beach, CA, USA
E-mail: powers@usc.edu Web: asb-biomech.org

INTRODUCTION

Early biomechanical descriptions of the patellofemoral joint characterized this articulation as a frictionless pulley system in which the patellar ligament force was equal to the force applied by quadriceps tendon. However, more recent studies have revealed that the patella also acts as a lever; a force differential between the patellar ligament and quadriceps tendon results from a moving contact point of the patella on the femur (Yamaguchi et al.; van Eidjen et al.). Previous cadaveric studies have shown that the ratio of patellar ligament force to quadriceps force can range from 0.64 at 70 degrees to 1.16 at 10 degrees of knee flexion (Buff et al., Huberti et al.).

A limitation of previous cadaveric studies in this area is that the loading of the extensor mechanism was accomplished through the central quadriceps tendon (i.e., anterior and parallel to the femoral axis). Given that the vasti originate from the linea aspera, which runs along the posterior aspect of the femur, it is unlikely that the application of the quadriceps force along the axis of the femur is representative of the actual extensor resultant force.

The purpose of this preliminary study was to compare the effects of an axial loading condition (central quadriceps tendon loading parallel to the femur) and an anatomically based, multi-plane loading condition (individual vasti loaded, taking into consideration physiologic muscle fiber orientation) on the ratio of quadriceps force to patellar ligament force at various knee flexion angles. Such information is important to better characterize the biomechanics of the extensor mechanism for more accurate models of the patellofemoral joint.

METHODS

Two fresh frozen cadaver knees without severe arthrosis were dissected, keeping the retinaculum and quadriceps tendons intact, and placed onto a rigid jig. The jig held the tibia distal to the tibial tuberosity, and the femur at mid-diaphysis. The jig was capable of holding the knee in flexion (up to 90 degrees), and allowed the cut rectus femoris and vasti tendons to be loaded in physiologic directions.

The knees were placed into a neutral position at four varying degrees of flexion. Jig settings were recorded while loads were applied to the rectus femoris and vasti tendons in each position. On one specimen (knee 1 – a patella alta), the tibial plateau was excised, and all ligaments were removed except the patellar ligament. This allowed the tibio-femoral joint reaction force to be eliminated while maintaining patello-femoral kinematics.

A buckle transducer (NK Biotechnical Corp., "S" transducer, 670N range, 1N resolution) was placed on the patellar ligament near the tibial attachment. A six-axis load cell on the jig measured the force and torque applied to the femur by the patella. A complete set of data included the magnitude and direction of each applied force, the 6-axis loading on the femur, and the patellar ligament force.

Measurements were taken while weights were used to pull the proximal end of the cut rectus femoris superiorly with 157N of force. Additional measurements were taken with weights pulling the central, medial vasti, and lateral vasti tendons in physiologic directions; the loads for the three groups were calculated to produce a resultant force of 157N. Vastus intermedius was not distinguished from rectus femoris in this experiment.

RESULTS AND DISCUSSION

The F_{PL}/F_Q ratio was different for loading the rectus femoris with and without the vasti (Table 1). This difference was most pronounced at the extremes of the flexion angles.

Table 1: F_{PL}/F_Q ratio for rectus femoris loading with and without vasti.

	Knee 1		**Knee 2**	
Knee flexion	Central tendon	Cental and vasti tendons	Central tendon	Cental and vasti tendons
0°	1.03	1.69	1.15	1.54
20°	1.07	1.14	1.15	1.02
40°	1.04	1.04	0.96	0.86
60°	0.77	0.54	0.86	0.72

Previous authors have determined the F_{PL}/F_Q ratio while loading only along or slightly posterior to the long axis of the femur. Our ratios for rectus-only loading were similar to those reported by Buff et al. and Huberti, et al. However, when loading in more physiologic directions using the vasti, the F_{PL}/F_Q ratio increased substantially at 0 degrees flexion and decreased substantially at higher degrees of knee flexion.

At low flexion angles, the additional force required by loading the vasti was transmitted to the patellar ligament. Thus the F_{PL}/F_Q ratio at low angles may be under-predicted in the models used previously. At higher flexion angles, this alters the effective moment arm of the quadriceps, resulting in a decrease in the patellar ligament force and an increase in the patella-femoral joint reaction force.

SUMMARY

The vasti affect the F_{PL}/F_Q ratio by changing the direction of the quadriceps' resultant force on the patella. The previously reported range of F_{PL}/F_Q ratios were underestimated for low flexion angles and overestimated for high flexion angles.

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