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Paper #93

Mechanics of the Knee and Hip Joints During the Pivot Shift Test

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Summary:
We present a novel cadaver model, which included physiological hip and knee articular and soft tissue constraints, to characterize the loads applied to the knee during the PS exam, as well as the knee and hip kinematics.

Abstract:

Introduction

The pivot shift (PS) is the gold standard clinical exam for diagnosing anterior cruciate ligament (ACL) rupture. Despite its importance, it is based on the subjective feel of the examiner, and thus has low interobserver reliability. Very little has been done to quantify the forces required to elicit a PS event. Moreover, many prior models are trans-femoral and fail to include the hip joint and the iliotibial band, which are thought to be critical contributors to the PS event. Thus, we sought to quantify simultaneously the loads applied by different examiners to the knee during the PS exam and the resulting knee and hip kinematics utilizing a novel cadaver model.

Methods

Two specimens (37, Female), which included the hemi-pelvis proximally and foot distally was utilized. The pelvis was attached to a universal force-moment sensor (UFS) via external fixation to measure the loads at the knee. Reflective markers were rigidly fixed to the pelvis, femur, and tibia and tracked via motion capture. With the ACL sectioned, the knee was independently tested by three board certified senior sports medicine surgeons. Each examiner performed five PS exams, and the average of the final four trials was reported. Loads applied to the tibia before, during and after the PS event, as well at knee and hip kinematics were reported.

Results

Each surgeon applied multidirectional loads to the knee directly preceding the reduction event indicative of the pivot shift phenomenon, which included compression (64 to 94 N), and medial forces (5 to 35 N), as well as valgus (10 to 18 Nm) and external rotation torques (3.4 to 3.7 Nm). During the PS event, a mean lateral knee compartment AP translation of 33mm, 23mm and 27mm was observed respectively for the 3 surgeons, all of which resulted in a clinical grade of 2 (clunk) as defined by all surgeon. Mean hip rotation during the PS event was 20° of external rotation, 31° of internal rotation and 2° of external rotation for each surgeon, respectively. The PS event occurred at knee flexion angles of: 28°, 16° and 32°; hip flexion angles of: 52°, 50° and 50° and hip abduction angles of: 15°, 23° and 2°, respectively.

Paper #93

Discussion

We present a novel cadaver model, which included physiological hip and knee articular and soft tissue constraints, to characterize the loads applied to the knee during the PS exam, as well as the knee and hip kinematics. Each surgeon applied knee compression to elicit the PS event in addition to the commonly understood valgus torque, while externally rotating the tibia relative to the femur. Surprisingly, each surgeon elicited different hip kinematics while producing the PS event; thus, variations in the applied loads at the knee could produce differing hip kinematics from surgeon to surgeon. Despite the variations in applied load and resultant hip kinematics, the clinical grade was consistent across surgeons suggesting that no singular combination of loads and kinematics evokes the PS phenomenon. In addition, these findings suggest the potential for further refining the pivot classification system to better identify specific pathologies (e.g., complete vs. partial ACL tear or concomitant meniscal damage) based on the hip kinematics and the specific combination of applied load. These data promote a better understanding of the PS event and stimulate further research taking into account the hip kinematics; they also provide important guidelines for future in vitro and in silico studies to simulate the PS exam and with greater clinical fidelity, thereby advancing optimal assessment of the ACL injured and reconstructed knee.