MUSCLE CO-CONTRACTION INCREASES THE LOAD ON THE POSTERIOR CRUCIATE LIGAMENT DURING DEEP KNEE FLEXION

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INTRODUCTION

The posterior cruciate ligament (PCL) is the major posterior stabilizer of the knee. Several biomechanical studies [1,2] have shown that the PCL should sustain up to 4 body-weight during the activities that require knee flexion beyond 90 degrees, indicating the dominant role of the PCL in deep flexion compared to the anterior cruciate ligament (ACL). However, the effect of muscle contraction was not thoroughly discussed in these studies. Knee extensors and flexors have a significant effect on the knee joint loading, as well as on the force exerted on the ACL and the PCL. Detailed analysis of the ligament loading during various activities will help clinician to plan the postoperative management of the patients with ligament injury. Furthermore, the evaluation of the force on the ACL during high flexion is another important consideration in the design criteria of total knee arthroplasty (TKA). The greater range of motion possible in current arthroplasty indicates the dominant role of the PCL in deep flexion compared to the anterior cruciate ligament (ACL). However, the effect of muscle contraction was not thoroughly discussed in these studies. Knee extensors and flexors have a significant effect on the knee joint loading, as well as on the force exerted on the ACL and the PCL. Detailed analysis of the ligament loading during various activities will help clinician to plan the postoperative management of the patients with ligament injury. Furthermore, the evaluation of the force on the ACL during high flexion is another important consideration in the design criteria of total knee arthroplasty (TKA). The greater range of motion possible in current TKA may increase the risk of mechanical failure, since a large posterior force is expected in flexion beyond 90 degrees [3]. In this study, the joint forces and ligament forces during deep knee flexion were evaluated, and compared with those during walking and stair-climbing. In particular, the effect of muscle forces on the loading of the cruciate ligaments is examined.

METHODS

Sixteen healthy subjects (age: 32 ± 4 years, 1.7 ± 0.1 m, 597 ± 120 N) performed level walking, stair-climbing, rising from kneeling and rising from deep kneeling, in a protocol previously reported [3]. Only the left leg was tested to limit the test burden on the subjects. Knee kinematics was collected using an optoelectronic system and ground reaction forces were measured using a force plate. Inter-segmental moment about the knee was calculated using methods previously described [4]. A four channel surface EMG was used for collecting the muscle activities from vastus medialis, rectus femoris, hamstrings and medial head of gastrocnemius. A knee model [5] was modified to calculate joint forces and forces on the ACL and the PCL during the activities. In the calculation of joint mechanics, two different approaches were used for every subject to identify the effect of muscle co-contractions: 1) the muscle force was determined as to resist the inter-segmental knee moment only, muscle co-contraction was not considered, 2) the muscle force was determined as to resist the knee moment plus force of the antagonists, considering co-contraction. In the second approach, antagonist activity was determined from EMG signals normalized by the signals during the maximum voluntary contraction. As a statistical test, an analysis of variance (ANOVA) with a single factor for two groups was used.

RESULTS

The co-contraction of the antagonists had significant effects on the joint forces and the ligament forces. Antagonists (hamstrings and gastrocnemius) activities were between 10 to 50% of the maximum contraction during all the activities, while the compressive force on the knee was increased in 20 to 50% during each activity (Figure 1). The force on the ACL during walking was increased with the co-contractions, however those during other activities were not changed (Figure 2A). The forces on the PCL during rising from kneeling and rising from deep kneeling were increased in 40 to 50% with the effect of muscle co-contractions (Figure 2B).

DISCUSSION

The results indicate that the co-contractions of hamstrings and gastrocnemius will strain the PCL during deep knee flexion, but will not significantly strain the ligament during walking and stair-climbing. These facts can be explained by the differences in the muscle lines of action during stance phase of the activities. During walking and stair-climbing, the co-contractions were usually seen in late stance phase, when the knee was flexed between 10 and 50 degrees, and the knee flexors have vertical lines of action against the knee at these angles. On the other hand, the co-contractions during rising from kneeling and deep kneeling were seen during most of stance phase, and the knee was flexed between 60 and 135 degrees during the time. At these angles of flexion, the knee flexors have more posterior lines of action and will add a posteriorly directed force to the knee. The large force on the PCL is an important consideration in the management of knee patients. With the co-contraction of flexors, the PCL may sustain up to 3000N (5 body-weight) during high flexion beyond 130 degrees. Special consideration is required for the patients with the PCL injury or a lack of posterior stability performing rehabilitation exercises such as squatting. The patients who achieved high flexion following TKA should also concern the large posterior force during deep flexion.

REFERENCES


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