SECONDARY KINEMATIC PATTERNS OF OSTEOARTHRITIC KNEES DURING ACTIVE EXTENSION AND FLEXION

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INTRODUCTION

Motion of the healthy knee has been described by a coupled path of ab/adduction, int/external rotation and ant/posterior translation with flexion [1]. Kinematic patterns have been shown to differ between osteoarthritic and healthy knees [2], and it has been hypothesized that this may initiate or increase the rate of cartilage degeneration [3]. These kinematic differences have not been compared between unweighted open-chain knee extension and flexion, and it is unknown to what extent muscles activation influences the secondary knee kinematics. This study investigates seated knee extension and standing knee flexion in subjects with osteoarthritis and varus deformity. We hypothesize there will be differences in secondary knee kinematic patterns and lower extremity muscle activations between these two movements.

METHODS

Twelve subjects (4 males age=60.5±8.0 y, ht=1.77±0.03 m, wt=95.6±14.0 kg, standing varus alignment= 8.7±3.1°; 8 females age=60.5±4.7 y, ht=1.61±0.06 m, wt=87.1±9.1 kg, standing varus alignment=6.2±2.7°) awaiting unilateral total knee arthroplasty provided IRB approved informed consent to participate in this study. Each subject completed four repetitions of unilateral seated knee extension and unilateral standing knee flexion with their involved limb. A modified Point Cluster Technique [4] was used with ten motion capture cameras (MX-F40; Vicon), capturing at a frame rate of 150 Hz, to calculate the three degree of freedom angular motions and anterior-posterior (AP) translation between the tibia and femur. Surface electromyography was recorded at 1500Hz for the vastus medialis, vastus lateralis, rectus femoris, biceps femoris (long head), semitendinosus, medial gastrocnemius and lateral gastrocnemius using a wireless system (Telemyo DTS; Noraxon). Activation of each muscle was high-pass filtered, full wave rectified, smoothed and normalized to the maximum value recorded during standing bilateral calf raise, seated unilateral knee extension, and standing unilateral knee flexion. Normalized data were grouped to calculate overall average activations for the quadriceps (QUAD), hamstrings (HAM), gastrocnemii (GASTR).

The varus/valgus angle (VV), internal/external rotation (IER), AP translation, average muscle activation for the QUAD, HAM, and GASTR were discretized at 5 degree intervals of knee flexion during the concentric portion of the active extension and active flexion movements. These data were fit with a fourth order polynomial and the above variables of interest were evaluated at five knee flexion angles (15, 30, 45, 60, 75 degrees) for the extension and flexion curves.

A mixed model with two within-subjects factors (motion and flexion angle) and random subject effect was used for VV, IER, AP, QUAD, HAM, and GASTR. All two way interactions for fixed effects were included in the model. Holm’s multi-comparison procedure was used to account for the tests of the difference between extension and flexion in the six variables of interest.

RESULTS AND DISCUSSION

For IER and AP translation, there was a significant difference between the single leg seated knee extension and standing knee flexion motions (Fig. 2, P<0.001). During seated knee extension, there was less internal rotation (mean difference ± SD: 4.2±3.2°) and less anterior translation of the femur (mean difference ± SD: 12.0±8.3 mm) compared to
standing knee flexion. There was no significant difference in VV angle between the two activities (P=0.263). All variables were significantly different by flexion angle (P<0.001).

Gravity acts on the tibia differently in these two movements, which most likely causes the observed muscle activation changes. The larger QUAD and smaller HAM activation during seated extension, compared to standing flexion (Fig. 1), may account for the differences in AP translation of the femur.

In extension the QUAD are pulling forward on the tibia and in flexion the HAM are pulling posteriorly on the tibia. The change in direction of muscle pull may account for the offset in AP curves seen with flexion (Fig. 2).

Figure 1: QUAD and HAM activation during extension and flexion.

QUAD, HAM and GASTR activity were also significantly different (Fig. 1, P<0.001) between motions. QUAD was more active in extension (mean difference ± SD: 48.1±15.4%), while HAM and GASTR were more active in flexion (mean difference ± SD: 49.2±9.1%, 13.3±7.6% respectively).

CONCLUSIONS

The secondary knee kinematic patterns showed significant differences even when comparing two unweighted, open-chain, single joint motions. These data show the interplay of changing muscle activations and secondary kinematics of the osteoarthritic knee. Future studies should consider the role of muscle activation in cartilage loading for patients with severe osteoarthritis.

REFERENCES


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