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EFFECT OF PARTIAL MEDIAL MENISCECTOMY ON THE INTERACTION BETWEEN PRIMARY AND SECONDARY KNEE MOTION DURING GAIT

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INTRODUCTION

Meniscal injury is a well-known risk factor for osteoarthritis (OA); the leading treatment (meniscectomy) increases the risk for osteoarthritis four times over sixteen years [1]. Reports that meniscectomy patients display altered gait kinetics and kinematics post-operation [2,3] suggest altered gait mechanics as a potential link between meniscal resection and increased risk for OA. Specifically it has been suggested that altered gait is a pathway to OA by causing a shift in tibiofemoral cartilage contact location to unprepared regions, which leads to cartilage breakdown [4]. The altered gait mechanics of particular interest are secondary motions of the knee, including internal-external (IE) rotation and adduction angle. While previous research has shown there to be a decrease in early stance (ES) and mid-stance (MS) range of motion (ROM) in knee flexion angle along with decreased peak extension of the affected versus contralateral limb, there is a lack of data relating the interaction between primary (flexion) and secondary (IE rotation and adduction angle) motions of the knee in the meniscectomy population [2,3]. Yet this information is important for understanding the ambulatory conditions associated with knee OA following meniscectomy.

Therefore, the purpose of this study was to examine the interactions between primary and second movements of the knee following meniscectomy by testing the following hypotheses: 1) There is a decrease in flexion ROM over the stance intervals from heel strike to maximum flexion (ES) and from maximum flexion to maximum extension (MS) in the affected limb versus the contralateral limb. 2) There is a significant difference in the adduction angle and IE rotation over the same intervals as in Hypothesis 1 between the affected limb and contralateral limb.

METHODS

Eighteen subjects with partial medial meniscectomies were enrolled in this study (age: 39.6±2.7 years (mean±SE), height: 176.3±3.9 cm, weight: 75.5±3.0 kg, 9.6±3.2 months post-operation, 4 female). These subjects had no other knee ligament or articular cartilage injury, reported no OA symptoms, and could walk without pain. Subjects provided signed Institutional Review Board-approved consent forms. Each participant walked at a self-selected normal walking speed in a laboratory equipped with an eight-camera opto-electronic 3-D motion capture system (Qualisys Medical AB) and a multi-component force plate (Bertec Corporation). A previously described point cluster technique was used to quantify the kinematics of each limb segment from the 3-D data [5]. Only the stance phase of walking, heel strike (HS) to toe off (TO), was analyzed and reported here. Maximum knee flexion is the maximum flexion angle after the initial loading at HS whereas maximum extension is the minimum flexion angle after loading response. ES ROM for a particular measure was calculated by subtracting the desired variable value at HS from that at the maximum flexion angle. Similarly, MS ROM was calculated by subtracting the variable value at maximum knee extension from that at maximum knee flexion. Mean values were compared with Student's t-tests with $\alpha = 0.05$.

RESULTS

Supporting the initial hypothesis, the affected and contralateral knee flexion angle ES ROM (15.6°±1.2° vs 19.9°±1.1°, $p<0.001$) and MS ROM (13.4°±1.4° vs 18.1°±1.6°, $p<0.001$) were significantly different (Figure 1). However, there was not a significant difference in the average knee flexion angle throughout stance between the affected and contralateral limbs. In contrast, the tibia was more externally rotated by 2.56°±1.13° ($p<0.05$) and more adducted by 1.0 °±0.45° ($p<0.05$)

on the affected versus the contralateral limb when averaged throughout stance. As such, the IE rotation at both peak knee flexion and extension was significantly more externally rotated in the affected versus contralateral limbs (p<0.05), and the affected limb was more adducted at peak knee extension (Figure 2, p<0.01). However when the ES ROM and MS ROM intervals were considered, there were no significant differences (affected versus contralateral limb) in IE rotation or adduction angle ROM (Figure 3), suggesting that the secondary motions in these intervals were not coupled to the change in flexion.

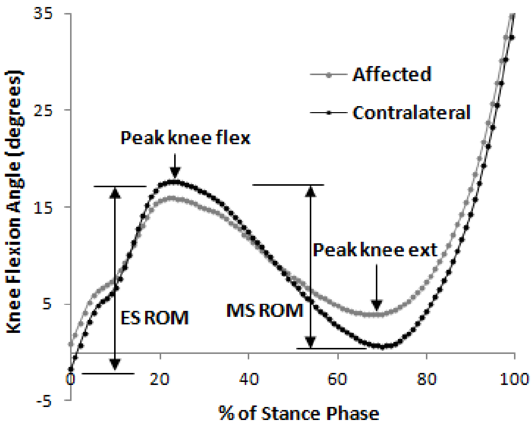

Figure 1: Affected and contralateral knee flexion angle throughout stance phase

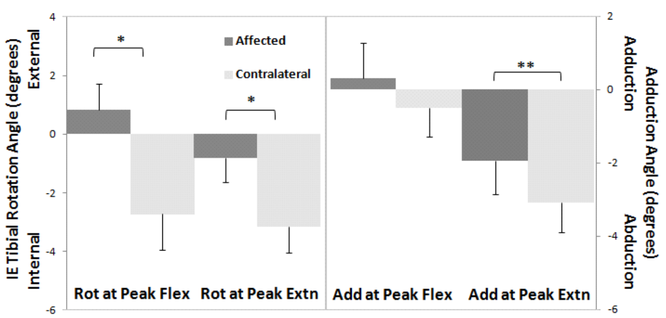

Figure 2: IE rotation of tibia with respect to femur and adduction angle at maximum flexion and extension, * denotes p<0.05 and ** denotes p<0.01

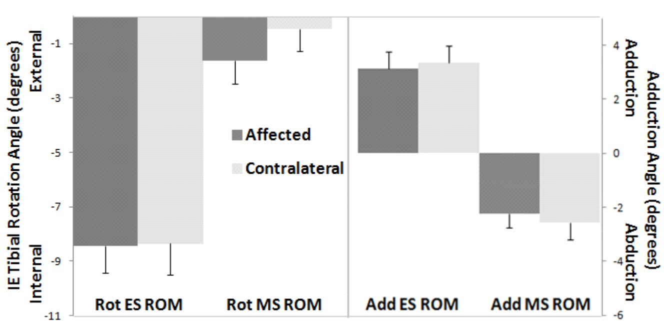

Figure 3: IE rotation and adduction angle early (ES) and mid-stance (MS) ROMs; no significant differences

DISCUSSION

The finding that the difference in the knee flexion angle ROM in early and mid-stance was not seen in the IE rotation or adduction angle ROM over the same time period of stance suggests that the limb differences in IE rotation and adduction angle are offsets, present throughout the stance phase, and not directly coupled to the change in knee flexion motion in early and mid-stance. Therefore, it seems that the flexion differences and the secondary motion differences arise from separate causes.

The IE rotation offset can be attributed to the specific location of resected tissue. According to a 1370 patient survey conducted by Metcalf and Barrett, 98 percent of medial meniscial tears involve the posterior horn [6]. Hence, it is reasonable to assume the subjects of the current study had the medial posterior section of meniscus resected. Therefore, the tibia is free to rotate externally as there is no longer posterior tissue to restrain the tibial plateau with respect to the medial femoral condyle. Additionally, the medial femoral condyle is free to recede into the concave medial portion of the tibial plateau, creating a more adducted alignment of the knee. As previously discussed, this creates a new point of contact between the tibial and femoral cartilage, potentially initiating the onset of OA [4].

Previous literature has reported reduced knee flexion ROM and decreased quadriceps strength in the affected limb post-meniscectomy [3,7]. Therefore, rehabilitation often incorporates quadriceps strengthening, which could decrease the flexion ROM deficit [8]. However, this study shows that secondary motions of the meniscectomized knee are decoupled from the knee flexion, and the fact that these motions are decoupled provides insight into the different causes for these kinematic changes.

Further work is thus necessary to understand the implication of not restoring both primary and secondary motions of the knee post-medial meniscectomy.

REFERENCES

[1] Englund M., Roos E. M., and Lohmander L. S., 2003, Arthritis and rheumatism, **48**(8), pp. 2178-87.

[2] Sturnieks D. L., Besier T. F., Mills P. M., Ackland T. R., Maguire K. F., Stachowiak G. W., Podsiadlo P., and Lloyd D. G., 2008, Journal of orthopaedic research : official publication of the Orthopaedic Research Society, **26**(8), pp. 1075-80.

[3] Netravali N. a, Giori N. J., and Andriacchi T. P., 2010, Journal of biomechanics, 43(15), pp. 2948-53.

[4] Andriacchi T. P., Mündermann A., Smith R. L., Alexander E. J., Dyrby C. O., and Koo S., 2004, Annals of biomedical engineering, **32**(3), pp. 447-57.

[5] Andriacchi T. P., Alexander E. J., Toney M. K., Dyrby C., and Sum J., 1998, Journal of biomechanical engineering, **120**(6), pp. 743-9.

[6] Metcalf M. H. and Barrett G. R., 2004, American Journal of Sports Medicine, **32**(3), pp. 675-680.

[7] Ericsson Y. B., Roos E. M., and Dahlberg L., 2006, Arthritis and rheumatism, **55**(6), pp. 946-52.

[8] Webster B. S., Verma S., Willetts J., Hopcia K., and Wasiak R., 2011, Archives of physical medicine and rehabilitation, **92**(10), pp. 1542-51.

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