A classic approach to assessing sagittal plane intrinsic knee joint kinematics has been through application of the concept of the path of instant centers of rotation (PICR).\(^1,2,3\) Joint surface rolling/gliding kinematics have been inferred qualitatively from such studies. When the PICR is located in close approximation to the point of contact between joint surfaces, greater rolling is believed to occur. Conversely, when the PICR is located distant from the point of contact, a lesser amount of rolling relative to gliding is believed to occur. Several studies have used this concept to infer intrinsic joint kinematics in unimpaired knees\(^4,5\) and impaired knees with ligament deficiency.\(^6,7\) Studies of anterior cruciate ligament (ACL) deficient human knees have reported that PICR patterns differ from unimpaired knees.\(^8,9\) Notably, none of these studies applied dynamic analysis techniques, examined knee function under weight bearing (WB) movement conditions, quantified joint surface gliding, EMG data, or examined associated electromyographic (EMG) activity. Nevertheless, it is reasonable to hypothesize from these studies that changes in intrinsic joint surface gliding are associated with ACL-deficiency.

The purposes of this study were to compare, within and between unimpaired and ACL-deficient knees, joint surface rolling/gliding kinematics and EMG activity of selected lower extremity muscles during knee extension during non-weight bearing (NWB) and WB movement conditions. 

METHODS

15 adult ACL-deficient subjects and 15 age- and gender-matched unimpaired subjects participated in this study. PICR was measured during NWB (active knee extension) and WB (sit-to-stand) movement conditions using videographic motion analysis according to the method first described by Winter.\(^4\) An analytic knee model was developed to quantify rolling/gliding knee kinematics from sagittal plane PICR data obtained experimentally. This model has been described elsewhere.\(^9\) Rolling kinematics were calculated based on the relationship between PICR location in the femoral condyle relative to selected contact points, from 90° to 10° knee flexion, at the joint surface. EMG was sampled from the vastus lateralis, medial hamstring, medial gastrocnemius, gluteus maximus and anterior tibialis muscles and normalized to maximal voluntary isometric contractions.

To test for differences in % rolling, a 4-way ANOVA (α ≤ 0.05) was conducted that included 1 between-subjects factor (Group: Unimpaired and ACL-deficient) and 2 within-subjects factors (Movement Condition: WB and NWB; Knee Angle: 90°, 80°, …, 10°). We tested the main effects of Group (G), Movement Condition (M), and Knee Angle (K), as well as the following interaction effects: GM, GK, MK, and GMK. Bonferroni-corrected t-tests were conducted post-hoc to determine at which Knee Angle(s) % rolling differed between Movement Conditions or between Groups. To test for differences in normalized EMG activity between the 2 groups, we conducted a 4-way ANOVA (α ≤ 0.05) including the 3 factors previously tested and an additional within-subjects factor (Muscle: N=5).

RESULTS

Rolling values are presented in Figure 1. The main effect of Movement Condition was significant (p = 0.004), and the GM, GK, MK, and GMK interaction effects were also significant (p = 0.004, p = 0.013, p < 0.001, and p = 0.003, respectively). In unimpaired subjects, post-hoc tests revealed that less rolling (greater gliding) occurred at the 10° knee flexion angle in the NWB movement condition compared to the WB condition (p = 0.002). In ACL-deficient subjects, post-hoc tests also revealed that less joint surface rolling (greater gliding) occurred at the 10° knee flexion angle in the NWB condition (p = 0.006). Between unimpaired and ACL-deficient subjects, post-hoc tests revealed that significantly less joint surface rolling (greater gliding) occurred in ACL-deficient knees compared to unimpaired knees in the NWB condition, again at 10° knee flexion (p = 0.004). In the WB movement condition, more joint surface gliding occurred in ACL-deficient knees than in unimpaired knees throughout the range of motion.

EMG analysis revealed a significant main effect of Movement Condition, Knee Angle, and Muscle (p < 0.001 in each case). There was no significant difference in EMG activity between Groups.

DISCUSSION

In the NWB movement condition, there was significantly greater joint surface gliding (less rolling) in ACL-deficient knees compared to unimpaired knees at 10° knee flexion. The fact that % rolling was less than 50% in the NWB condition at 10° knee flexion in ACL-deficient knees (Figure 1) indicates that relatively more joint surface gliding than rolling occurs as the knee approaches terminal extension. In the WB movement condition, there was also significantly less joint surface rolling (greater gliding) in ACL-deficient knees compared to unimpaired knees, and this difference occurred throughout the range of motion.

Measurement of joint surface gliding is an indirect measure of segmental translation. Results of this study suggest not only that anterior tibial translation increases in ACL-deficient knees relative to unimpaired knees during NWB knee extension, particularly as the knee approaches terminal extension, but increases relative to unimpaired knees during WB knee extension as well. Our results assert the validity of using PICR to quantify intrinsic joint motion and concur with abundant evidence that less anterior tibial translation occurs during WB knee extension. While WB exercise has become the standard of care in ACL-deficient rehabilitation, however, our results suggest that anterior translation may not be completely reduced solely as a function of the WB movement condition. At minimum, further biomechanical investigation is warranted concerning the efficacy of WB exercise and potential effects of WB movement conditions on the ACL-deficient knee.

REFERENCES


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