Effect of Unstable Meniscal Injury on Three-dimensional Knee Kinematics in ACL-deficient Patients During Gait

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Introduction: Although many researches have performed gait analysis for patients with anterior cruciate ligament (ACL)-deficient knee, there is a lack of evaluating differences of dynamic knee function between those patients with and without unstable meniscal injury. Therefore, to know the in vivo knee kinematics during gait in ACL-deficient patients with meniscal injury is important. The purpose of the current study was to investigate and to clarify the differences of three-dimensional knee kinematics between ACL-deficient patients with and without meniscal injury using gait analysis.

Methods: A total of 32 knees in 16 young athletes (11 females and 5 males) with primary unilateral ACL injury, with a mean age of 21.2±7.1 years, participated. All patients were scheduled for arthroscopic surgery. They had no history of other serious lower limb injuries. All the subjects provided informed consent and the present study was approved by the ethics committee of our institution.

Gait analysis was done at our gait laboratory before arthroscopic surgery. Mean time after injury was 3.3±2.7 months. The measurements were performed using a Ten-camera system (120Hz, Vicon MX, Oxford Metrics, UK). The three-dimensional gait analysis was carried out by the Point Cluster Technique [1]. Retroreflective markers were placed on standardized landmarks. The subjects were asked to walk on a level floor (10m walk way) with their own preferred speed after the markers were attached. The walking trials included warm ups, and best trial was selected. The measurements for each leg were done independently as follows; first, walking trials were carried out in the injured limb. Second, the measurements of the uninjured limb were done after the markers were detached from the injured limb and attached in the uninjured limb.

Knee flexion angle, tibial rotation with respect to the femur, and tibial adduction with respect to the femur were calculated. First, knee excursion during the whole gait cycle was evaluated in each plane. Second, in the sagittal plane, knee excursion was evaluated during weight acceptance phase (Fig.1, Angle a) and mid-stance phase (Fig.1, Angle b) separately. Finally, in the axial and frontal plane, knee excursion during stance phase was assessed (Fig.1, Angle c and d).

After gait analysis, ACL reconstruction was done for each patient several days later. In the operating room, meniscal condition was evaluated in each patient using standard knee arthroscopic technique. Tear type of meniscus was investigated using probe. Unstable meniscal tear was determined if large
mobility was observed using probe such as longitudinal tear from posterior horn to middle aspect or flap tear greater than 50% of meniscal width. Patients were divided into 2 groups. Patients with unstable meniscal tear were allocated to meniscal injury group (ACL+M group), and patients without meniscal tear were allocated to no meniscal injury group (ACL group).

As a statistical analysis, we performed Mann-Whitney U-test to compare the differences in affected knees between groups. In addition, paired t-test was done to compare the differences between affected and unaffected knee in each group. Categorical variables were analyzed using Fisher exact test. P-values of < 0.05 were considered as significant.

**Results:** Patients’ demographics in each group were seen in Table 1. Seven patients had severe meniscal injuries. Basically, patients in both groups exhibited lower sagittal plane knee excursions on the affected limb compared to the unaffected limb during mid-stance (stiffening strategy). In frontal and sagittal plane excursions, no significant differences were detected during whole gait cycle. Concerning the tibial rotation, axial knee excursions in ACL+M group were notably larger in the affected limb than in the unaffected limb during stance phase and whole gait cycle despite the fact that an opposite phenomenon was observed in ACL group (p<0.05). Besides, significantly differences were detected between groups in the affected limb. The tendency of external rotation offset in ACL group was maintained in affected knees compared to contralateral knees (Fig.2, pivot-shift avoidance). However, the tendency of external rotation offset in the affected limb disappeared from mid-stance phase in ACL+M group (Fig.3).

**Discussion:** Stiffening strategy or pivot-shift avoidance gait is well known using gait analysis in ACL-deficient knee [2,3]. Although these gait mechanics was observed in isolated ACL-deficient patients without meniscal injury, ACL-deficient patients with severe meniscal injury could not control tibial rotation during gait. Meniscal condition may be a key factor for compensatory gait mechanics to prevent anterolateral rotatory instability in ACL-deficient patients.

**Significance:** Stiffening strategy or pivot-shift avoidance gait is well known using gait analysis in ACL-deficient knee. Although these gait mechanics was observed in isolated ACL-deficient patients without meniscal injury, ACL-deficient patients with severe meniscal injury could not control tibial rotation (pivot-shift avoidance) during gait.
Fig. 1  Knee excursion was evaluated during gait

Fig. 2  Representative sagittal and axial knee motion in ACL group.

Fig. 3  Representative sagittal and axial knee motion in ACL+M group.
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<th></th>
<th>ACL</th>
<th>ACL+M</th>
<th>P Value</th>
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<tbody>
<tr>
<td>Age (yrs)</td>
<td>19.8 ± 4.3</td>
<td>24.1 ± 9.4</td>
<td>0.37</td>
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<tr>
<td>BMI(kg/m2)</td>
<td>21.9 ± 1.3</td>
<td>22.3 ± 2.9</td>
<td>0.71</td>
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<tr>
<td>Sex</td>
<td>7 / 2</td>
<td>4 / 3</td>
<td>0.60</td>
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<td>Tegnar activity score</td>
<td>6.8 ± 1.2</td>
<td>7.0 ± 1.2</td>
<td>0.70</td>
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<td>Time after injury (month)</td>
<td>2.3 ± 1.0</td>
<td>4.4 ± 3.5</td>
<td>0.12</td>
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