BIOMECHANICAL STRATEGIES ADOPTED BY PATIENTS WITH POSTERIOR CRUCIATE LIGAMENT DEFICIENCY WHEN CROSSING OBSTACLES OF DIFFERENT HEIGHTS WITH THE LEADING LIMB

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SUMMARY
The current study aimed to identify the biomechanical deficits and/or strategies in patients with posterior cruciate ligament deficiency (PCLD) when crossing obstacles of different height. Eighteen patients with unilateral PCLD and 18 healthy controls were recruited in the current study and were asked to perform obstacle-crossing, with each of the affected and unaffected limb as the leading limb, while their kinematic and kinetic data were measured. Patients with PCLD were found to cross obstacles with significantly higher toe-clearance, greater trailing toe-obstacle distance and less crossing speed when compared to controls. Smaller ankle plantarflexor and greater knee extensor crossing moments in the PCLD group were found when the leading toe was above the obstacle. Patients with PCLD reduced the ankle plantarflexor moments that were produced mainly by the gastrocnemius muscle. This may help reduce the posterior instability of affected knee as a result of the loss of the PCL during obstacle-crossing. These altered patterns in the joint kinetics and end-point control during obstacle-crossing as a result of PCLD were not only seen on the affected side but also on the unaffected side, suggesting that rehabilitative intervention on both affected and unaffected sides are necessary in patients with PCLD.

INTRODUCTION
Deficiency of posterior cruciate ligament (PCLD) leads to structure and neural problems of the knee [1]. Establishing an effective evaluation tool will contribute to the clinical management of the patients. Since highly challenging functional tasks, such as obstacle-crossing, is common in daily living, it would be helpful to identify the biomechanical deficits and/or strategies in patients with PCLD in these activities. A safe and successful obstacle-crossing requires stability of the body and sufficient foot clearance of the swing limb. Patients with PCLD may face demands different from normal when negotiating obstacles of different heights. The objective of this study was to investigate the biomechanical deviations/strategies of the lower limbs in the subjects with PCLD during obstacle-crossing using motion analysis techniques.

METHODS
Eighteen patients with unilateral PCLD and 18 healthy controls were recruited and asked to cross obstacles of heights of 10%, 20% and 30% of their leg lengths at self-selected speeds. The PCLD patients were asked to perform obstacle-crossing with each of the affected and unaffected limb as the leading limb while their kinematic and kinetic data were measured with a 7-camera motion analysis system (Vicon, Oxford Metrics, U.K.) and two force plates (AMTI, U.S.A.). Thirty-six infrared retro-reflected markers were placed on specific landmarks of the lower limbs to track the motion of the segments. Crossing speed was calculated as the ratio of the distance traveled by mid-ASISs in the walking direction and the time spent during the crossing cycle. The leading toe clearance was calculated as the vertical distances between the toe markers and the obstacle when the leading toe was directly above the obstacle. The trailing toe-obstacle distance was defined as the horizontal distance between the trailing toe marker and the obstacle when the leading toe was directly above the obstacle. The trailing toe-obstacle distance was defined as the horizontal distance between the obstacle and heel marker of the trailing stance limb. The angles of the stance and swing limbs (crossing angles) and the moments of the stance limbs (crossing moments) for each joint in the sagittal plane when the leading limb was above the obstacle were calculated for statistical analysis. Peak extensor moments of the trailing stance limb were also obtained. A 2 by 3, 2-way mixed-model analysis of variance with one between-subject factor (group) and one within-subject factor (obstacle height) was performed (α =0.05). SPSS version 15.0(SPSS Inc., Chicago, IL) was used for all statistical analysis.

RESULTS AND DISCUSSION
Patients with PCLD were found to cross obstacles with significantly higher toe-clearance, greater trailing toe-obstacle distance and reduced crossing speed compared to controls. When the leading toe was above the obstacle, the PCLD group showed greater hip flexion in the swing limb whether the affected or unaffected limb leading whereas greater knee flexion was found in the unaffected swing limb. At the same time, there were significantly smaller ankle plantarflexor and greater knee extensor crossing moments in the PCLD group than in the control group (Figure 1). The PCLD group also showed significantly reduced peak hip extensor moments, peak knee extensor moments, and ankle peak plantarflexor moments in both affected and unaffected stance limb (Figure 1).

When crossing the obstacle, patients with PCLD in the current study might have lowered the crossing speed and placed the trailing limb further from the obstacle to reduce ankle plantarflexor moments that were mainly produced by the gastrocnemius. This may help reduce the posterior instability of the affected knee. Greater knee extensor crossing moments may also help reduce the posterior instability of the standing
knee when the leading toe was above the obstacle. At the same time, greater hip flexion and knee flexion angle of the swing limb would increase the toe-clearance and prevent tripping the obstacle. Deficiency of the PCL may affect the joint proprioception, which contributes to the altered kinematics of the lower limbs observed during obstacle-crossing. The altered gait patterns as a result of PCLD in terms of the joint kinetics and end-point control during obstacle-crossing were not only seen on the affected side but also on the unaffected side. This symmetrical pattern may be necessary in performing functional activities that may require either the affected side or the unaffected side.

CONCLUSIONS
Patients with PCLD were found to reduce the ankle plantarflexor moments produced mainly by the gastrocnemius muscles during obstacle-crossing, which may help reduce the posterior instability of affected knee as a result of the loss of the PCL. Symmetrical alterations in the gait patterns found in these subjects during obstacle-crossing may be necessary in performing functional activities that may require either the affected side or the unaffected side as the leading limb. These results suggest that rehabilitative intervention, including muscular strengthening, on both affected and unaffected sides are necessary in patients with unilateral PCLD.

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REFERENCES

Figure 1: Moment curves in the sagittal plane of the hip, knee, and ankle joints of the trailing stance limb when crossing obstacles of 30% of leg length for the PCLD group affected leading (dotted lines), PCLD group unaffected leading (dashed lines) and control (solid lines) groups during stance phase. The stars indicate significant differences between the two groups (*p<0.05)