KINEMATICS AND MYOELECTRIC ANALYSIS OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTED KNEE IN DROP LANDING – A PILOT STUDY

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This study aimed to investigate the lower extremity kinematics and electromyography (EMG) of anterior cruciate ligament (ACL) reconstructed knee during single-leg drop landing. One female elite basketball athlete rehabilitated from ACL reconstruction surgery 33 months prior this study performed five trials of single-leg drop landing from a 300mm-high platform with the arms crossed over the chest. The motion in sagittal plane was videotaped and was analyzed by a motion analysis system. Foot strike was recognized by a force plate. Synchronized EMG signals from four thigh muscles (vastus medialis, vastus lateralis, medial hamstring, and lateral hamstring) of the landing leg were collected and amplified by an EMG system. The EMG data were trimmed, normalized and filtered. Root mean square (RMS) values of the processed signals were compared. Results showed that thigh muscle activities of ACL-reconstructed leg were lower. Hip joint was more extended before foot strike. Prolonged hip and knee flexion occurred after foot strike, which delayed the recovery of anatomical position.

KEY WORDS: ACL reconstruction, electromyography, lower extremity, biomechanics

INTRODUCTION: The anterior cruciate ligament (ACL) functions as primary restraint to anterior tibial translation (ATT). People who participated in sports that required twisting and decelerating were at highest risk for the production of an ACL tear. The majority of the ACL injuries in sports were caused by non-contact injury mechanisms; that was, no direct physical contact between athletes when the injury occurs, such as landing from a jump on one or both legs. Noyes et al (1983) reported that approximately one-third of ACL deficient patients were able to improve knee function following rehabilitation with few subsequent or no symptoms during activities of daily living or recreational activity. One-third of their patients showed no improvement with rehabilitation. The final third, despite attending therapy, had worsening of their symptoms of knee instability. This finding suggested that some patients were able to develop compensatory adaptation to accommodate their lack of intrinsic knee stability while others were not.

Previous studies showed that adaptation in lower extremity kinematics, kinetics and electromyography occur in response to ACL injury. Patients with ACL deficiency or reconstructed ACL were investigated while performing various movements such as running, jumping and walking after different period of rehabilitation. The differences between ACL reconstructed and normal subject were reduced extensor moment and power at the knee and increased extensor at the hip. No or little significant differences were found in lower extremity EMG signals. The period of rehabilitation ranged from 6 months up to 20 months from the time of injury and operative treatment. This pilot study aimed to investigate these biomechanics parameters during drop landing at a time of 33 months after injury.

METHODS: One female elite basketball athlete (age: 22 years, body mass: 55kg, height: 166cm) with her right knee suffered from complete unilateral ACL tear participated in this study. She received operative ACL reconstruction with hamstring graft 33 months prior to this study, and she completed a 6-month rehabilitation program right after the operative treatment, and continued with her regular basketball practice in the local Division I basketball league. Informed consent was obtained prior the study. Five trials of single-leg drop landing on both ACL-reconstructed and the healthy leg were performed. Before each trial, subject stood on a 300mm-high platform with the testing leg, and with her arms crossed over her chest (McNair and Marshall 1994). Upon verbal instruction, subject jumped off the platform in forward direction and landed balanced on a force plate (Kistler 9281CA, Switzerland) without arm movements. The force plate was located 200mm in front of the platform, and was employed to locate the moment of foot strike in each trial.

Figure 1 Standard postures for collecting EMG normalization signals: left – lower leg raise, right – squatting.

EMG activity of four thigh muscles: vastus medialis (VM), vastus lateralis (VL), medial hamstring (MH), and lateral hamstring (LH) was recorded by BTS EMG system (Bioengineering Technology & Systems, Italy) with the use of surface electrodes (Medicotest, T-00-S, Denmark). Prior to the test, EMG signals were collecting in two standard postures: 1) lower-leg raise, 2) semi-squatting, for signal normalizing purpose (Figure 1). Twelve reflective skin markers were attached on both sides of the body, including head of the fifth metatarsal and heel, lateral malleolus, lateral femoral condyle, greater trochanter, and shoulder. One CCD digital video camera (JVC 9600, Japan) with 50Hz filming rate was used for videotaping the landing motion. The filmed data were processed by a motion analysis system (Ariel Performance Analysis System, USA) to obtain hip, knee and ankle joint kinematics data, with zero degrees being the anatomical position. Increasing values represented flexion at hip and knee joints and plantarflexion at ankle joint. LabVIEW 4.0 (National Instrument, USA) was employed to collect the force plate and EMG signals simultaneously, with sampling rate set at 1000Hz. The EMG signals were trimmed to three phases: (A) 250ms preceding foot strike, (B) 0-125ms after foot strike, and (C) 125-250ms after foot strike. The trimmed EMG data were rectified and band-pass filtered for 20-300Hz by BioProc software (University of Ottawa, Canada). The signals collected during normalization test were processed similarly for normalization purpose. Root mean square (RMS) values of the processed signals were obtained for comparison.

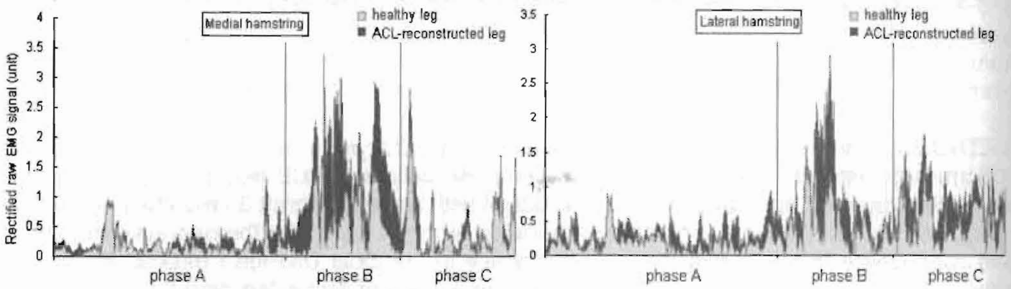

Figure 2 Rectified raw EMG signal of four thigh muscles over the three phases in drop landing.

RESULTS AND DISCUSSION: Both knees showed similar muscle activity patterns (Figure2). In Phase A, the legs were in air and did not bear weight, so the muscle activities were lowest in all muscles. After foot strike, the muscle activities increased sharply as indicated by the RMS values in Table 1. In Phase C, the EMG signal of VL and LH remained comparatively high, and a drop of magnitude was observed in VM and MH. In both Phase B and C, co-activation of the antagonist muscles about the knee was found. It may aid the ligaments in maintaining joint stability, equalizing the articular surface pressure distribution, and controlling tibial translation (Draganich *et. al* 1989).

Table 1 Normalized RMS of the processed EMG signal of all muscles in both legs in three phases.

Phase	Phase A		Phase B		Phase C	
Leg	Healthy	ACL-reconstructed	Healthy	ACL-reconstructed	Healthy	ACL-reconstructed
VM	1.42 (.03)	.65 (.05)	4.07 (.13)	2.93 (.22)	2.70 (.17)	1.81 (.15)
VL	.99 (.20)	.34 (.04)	3.47 (.16)	3.22 (.43)	3.55 (.19)	2.33 (.22)
MH	1.56 (.22)	.33 (.03)	4.03 (.13)	2.39 (.32)	3.18 (.19)	1.11 (.19)
LH	1.89 (.08)	.43 (.07)	3.62 (.15)	1.28 (.22)	4.08 (.11)	1.01 (.12)

VM: vastus medialis, VL: vastus lateralis, MH: medial hamstring, LH: lateral hamstring

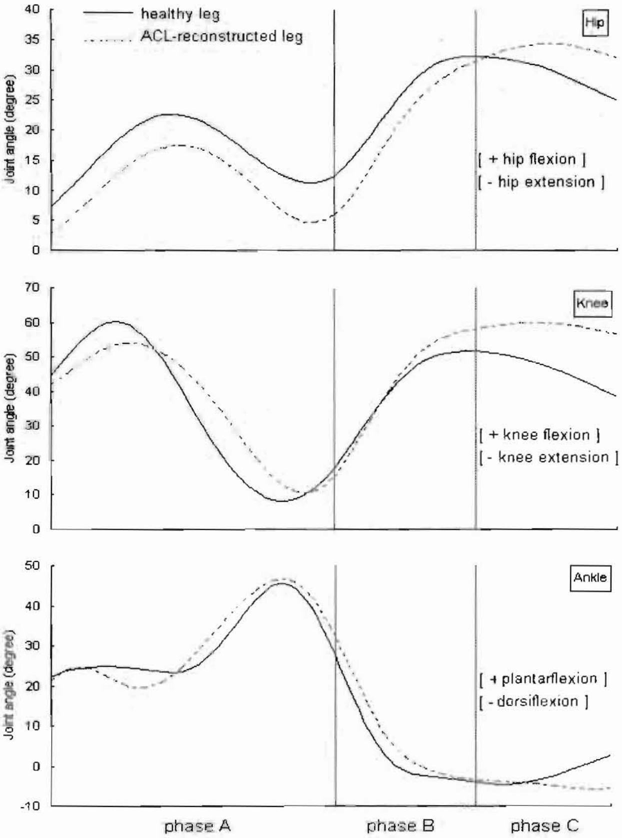

Figure 3 Lower extremity joint angles during the three phases in drop landing.

The muscle activities of thigh muscles of ACL-reconstructed knee were generally lower than that of the normal knee. Previous study (Urbach et al., 2001) also reported that voluntary activation in quadriceps after ACL reconstruction was lower than that of normal leg. The lower hamstring muscles activity might be explained by the fact that hamstring muscles were unable to contract and exert high posterior shear force on the tibia at knee angles near extension (Draganich et al 1989). As the kinematics data indicated the knee flexion angle at foot strike was found to be 15 degrees, which was near to knee extension.

In kinematics, the patterns of both legs were similar (Figure3). At foot strike, the knee and ankle were very similar. The knee was at a flexion of 15 degrees and the ankle was at a plantarflexion of 30 degrees. The hip joint angles show larger difference. From Phase A, the hip joint angle of the ACL-reconstructed leg was observed to be generally more extended for about 5 degrees. At foot strike, it was 12 degrees for healthy leg and 6 degrees for the ACL-reconstructed leg. Knee joint angle showed a sinusoidal pattern with knee flexion followed by knee extension just before foot strike. After foot strike, flexion occurred at both hip and knee joint. Maximum flexions were reached earlier in healthy leg until the end of Phase B, while prolonged flexions occurred in ACL-reconstructed leg until Phase C. The ankle joint returned to its anatomical position in the middle of Phase B. in late Phase C, a slight plantarflexion was shown. It was because of the knee extension, which brought the shank back to a straight position, and thus increased the included angle joint a little. In ACL-reconstructed leg, the prolonged hip and knee flexion pattern revealed that lower extremity extension was delayed, indicating a later anatomical position recovery. This may reflect the inferior ability of lower leg muscle strength due to ACL injury, which was not yet recovered 33 months after treatment.

CONCLUSION: Quadriceps and hamstrings muscle activities of ACL-reconstructed leg were lower than that of healthy leg. Hip joint of ACL-reconstructed leg was generally more extended for 5 degrees before foot strike. At foot strike, ankle and knee joint angles of ACL-reconstructed leg did not differ from that of healthy leg. Prolonged hip and knee flexion occurred immediately after foot strike in ACL-reconstructed leg until late Phase C, which delayed the recovery of anatomical position.

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