INTRODUCTION:

"Closed kinetic chain" (CKC) exercise has become popular in the last 20 years for use after anterior cruciate ligament (ACL) reconstructive surgery because many clinicians believe that CKC exercises are safer and more functional[1]. It was suggested that CKC assessment more validly assesses lower extremity strength changes following CKC strength training[2]. However, there are few machines for CKC testing available for ACL patients. We developed the isokinetic CKC training and testing system for ACL patients[3]. It is difficult to measure the strain behavior of the ACL during isokinetic CKC exercise. The objective of this study was to assess isokinetic CKC exercise of the knee and to develop an optimal post-operative rehabilitation program for the ACL deficient knee.

MATERIALS AND METHODS:

A new isokinetic CKC training machine was developed using the cycloid curve principle (Fig. 1). With this machine, subjects can move their legs in gradual arc of motions. A custom made foot plate and load cell were attached to the tip of the dynamometer arm. Stabilization straps were fastened across the anterior ankle and forehead. A CYBEX isokinetic dynamometer was used for open kinetic chain (OKC) exercises. Eight patients (2 males, 6 females) with unilateral ACL deficient knees, average age of 22.1 ± 11.6 years (range, 14 – 44), were included in this study. Before the study, all participants provided written informed consent in accordance with guidelines issued by the University's IRB. Each subjects was instructed to exert maximal voluntary effort in leg press. The CKC three isokinetic measures of interest in this investigation were each joint torque, pressing force angle to tibia and knee joint angle at which peak pressing force is reached. We also evaluated 10 healthy women, average age of 21.2 ± 0.7 years (range, 20 – 23), with same methods as the control.

Prediction of tibiofemoral joint reaction forces: After informed consent was received, the patient who had had reconstruction of the ACL with use of an autologous patellar-ligament graft was instructed to exert maximal voluntary effort in knee extension during all the isokinetic CKC exercise period. The subject was 18-year-old male (Ht175cm, BW73kg), and the experiment was performed four months after reconstruction of the ACL of the right knee. The pressing forces were measured by the load cell. A standard digital video camera and biomechanical software (ToMoCo-LC; Tousou-system Inc., Japan) were used to analyze kinematic data. The EMG activity from eight muscles was monitored simultaneously for each exercise using surface electromyography. The lower extremity was divided into three segments; thigh, shank and foot. Each segment’s mass and moment of inertia were calculated by the landmarks of the body. The orientation of the segments was calculated using the scaling method described by Brand et al[4]. The inter-segmental force and moment were calculated using the inverse dynamic method, and muscle forces and joint resultant forces were calculated using the optimization method. The results were validated by the EMGs.

RESULTS:

There was statistically correlation between knee extension and flexion in OKC and total lower extremity joint torque in CKC. The peak torque of knee extension and flexion in the injured side were smaller than that in uninjured side during OKC exercises, but there was no significance in quadriceps/hamstrings ratio. The knee extension torque and pressing force angle of injured side were smaller than that of uninjured side during isokinetic CKC exercises.

As a result of simulation, co-activation of quadriceps and hamstrings were observed during all the isokinetic CKC exercise period (Fig. 2). Joint compressive and anterior-posterior(AP) shear forces during the isokinetic CKC exercises were calculated. AP shear forces are related to the tibial anterior and posterior translation. This translation is assumed to be constrained by ACL and PCL ligaments. The ACL resists anterior tibial shear forces. The simulation results showed that anterior shear forces were almost negative with both knees during all the isokinetic CKC exercise period. Furthermore, anterior shear forces were always smaller in right injured knee (Fig. 3).

DISCUSSION:

In ACL deficient knees, torque of knee flexion and extension was significantly reduced with OKC method. In ACL deficient knees with CKC method, knee torque was reduced because hip and ankle joint torque was increase for this compensation and the direction angle of force at foot was reduced to the axis of lower leg. It was mean that hip extensor and hamstring muscle was dominantly activated and thus to prevent the anterior movement of the tibia. This study showed that isokinetic CKC exercise was quite safe for the ACL deficient and reconstructed knees. The patients with ACL deficient knees recruit with the hip extensors and the hamstrings to assist knee extension during isokinetic CKC exercises.

From a biomechanical perspective, isokinetic CKC exercises are safer because they produce stresses and forces that are potentially less of a threat to healing structures. Also, increased compressive loads across the knee joint tend to reduce anterior tibial translation which in turn should reduce ACL strain. These exercises are also more functional than isokinetic OKC exercises since they involve all of the lower extremity muscles. Isokinetic CKC exercise should be the first option after ACL reconstruction.