Introduction: Closed kinetic chain (CKC) exercise has become popular for use after anterior cruciate ligament (ACL) reconstructive surgery because many clinicians believe that CKC exercises are safer and more functional than open kinetic chain (OKC) exercises. Although isokinetic testing is widely used and has been studied extensively as a clinical and experimental outcome measure, recent evidence demonstrated that isokinetic dynamometry was not able to detect increases in lower extremity performance after four weeks of CKC strength training [1]. It was suggested that CKC assessment more validly assesses lower extremity strength changes following CKC strength training [1]. However, there are few machines for CKC testings available for ACL patients. We developed the isokinetic CKC training and testing system for ACL patients. The objective of this study was to assess isokinetic open versus closed kinetic chain testing of the knee and to develop an optimal testing method and post-operative rehabilitation program for the knee joint that can accomplish specific functional requirements effectively without inducing harmful side effects.

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 (Fig. 2). 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 forefoot. A CYBEX 6000 isokinetic dynamometer was used for OKC exercises. Twenty healthy young male subjects with ages between 20 to 23 years (21.2 ± 0.8) performed both isokinetic CKC and isokinetic OKC exercises. An angular velocity of 60 deg/s was used. Tests were made on the right lower extremity. After informed consent was received, each subject was instructed to exert maximal voluntary effort in knee extension during all the exercise period. The CKC two isokinetic measures of interest in this investigation were each joint torque and knee joint angle at which peak torque is reached. The EMG activity from eight muscles was monitored simultaneously for each exercise using surface electromyography. The muscles selected were the gluteus maximus, rectus femoris, vastus medialis, vastus lateralis, medial hamstring, lateral hamstring, medial gastrocnemius, and the lateral gastrocnemius.

Results: There was statistically correlation between knee extension in OKC and total lower extremity joint torque in CKC. There was no significant difference between peak torque of the concentric isokinetic closed kinetic chain testing and that of the eccentric isokinetic closed kinetic chain testing (Fig. 3). In isokinetic CKC conditions, the foot draws gradual arc and the output was directed from the point between the hip joint and the knee joint to the foot. EMG showed that only quadriceps groups were active during open kinetic chain exercises while all the muscles of the lower extremity were active during closed kinetic chain exercises. Co-activation of quadriceps and hamstrings were observed during all the isokinetic CKC exercise period.

Discussion: According to our previous results, when the maximal pressing force exists in the range between the hip to the foot direction and the knee to the foot direction, co-activation of quadriceps and hamstrings occurred and the total force was the greatest [2]. By controlling the direction of motion, it was possible to control the muscle activation patterns. These results can assist with the selection of appropriate exercises for knee rehabilitation and training. In ideal CKC training system for ACL patients, foot plates should be designed to move in an arc of motion rather than in a straight line [3]. The ideal motion is the cycloid curve motion. The movement of the leg showed what is called a cycloid curve where the leg moves in gradual arc. This movement would facilitate hamstring recruitment by increasing the hip flexion moment and decreasing the knee moment.


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