ACTIVATION PATTERNS OF MONO- AND BI-ARTICULAR MUSCLES IN THE LOWER EXTREMITY AS AN EXPRESSION OF THE REAL NATURE OF CLOSED KINETIC CHAIN EXERCISE OF THE KNEE

INTRODUCTION: "Closed kinetic chain" (CKC) exercise has become popular in the last 10 years for use after anterior cruciate ligament (ACL) reconstructive surgery. Closed kinetic chain exercises appear to have gained popularity over more traditionally used open kinetic chain (OKC) exercises because many clinicians believe that CKC exercises are safer and more functional[1]. Recently various types of CKC exercise method have been developed[2]. But little information is available on the definition of CKC. This study was conducted upon the hypothesis that the co-activation of the quadriceps and the hamstrings during CKC exercise is explained by the coordination of mono- and bi-articular muscles in the lower extremity, with its activation patterns decided by force direction. The objective of this study was to assess coordinating functions among antagonistic pairs of the mono- and bi-articular muscles in the human lower extremity under CKC conditions by electromyographic(EMG) kinesiology.

MATERIALS AND METHODS: Eight healthy young male subjects aged 21 to 22 years (21.0±0.5) were tested. Muscles tested were : gluteus maximus(GM), rectus femoris(RF), rectus femoris short head(BFSH), rectus femoris(RF) and biceps femoris long head(BFLH), vastus medialis(VM), and iliopsoas(IP) (Fig. 1). The CYBEX 6000 isokinetic dynamometer was used. After giving informed consent, subjects were positioned supine on the testing bench with the backrest fixed at 15° from horizontal. 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. The lengths of the lever arm were adjusted to the length of the subject's lower leg. Angle referencing was performed by placing the knee in 60° of flexion with the dynamometer arm 60° from horizontal(Fig. 1). The isometric force at right angles to the axis force generated by the right lower extremity (Fa) was measured by the CYBEX 6000. The axis force(Fb) was measured by the load cell. The actual force(F) was calculated from the two component forces. Forces were normalized to the greatest value for each subject. The EMG activity from six muscles was recorded during isometric leg press and pull movements in all directions (360°) around the center of the foot, with maximal effort in the sagittal plane. EMG data were acquired with surface electrodes on GM, VM, RF and BFLH, and with fine wire electrodes on IP and BFSH. Those were integrated and normalized to the greatest IEMG value for each subject. Each subject was instructed to exert maximal voluntary effort in various directions. All round force directions were divided into six ranges resulting in three opposing ranges. In the other ranges than the opposing pair of ranges where the BFSH, in the ranges between 60° and 90° and between -90° and -120°. Thus, two pairs of the antagonist mono-articular muscles as well as the pair of bi-articular muscles showed criss-cross activity patterns in each pair of the opposing ranges. In the other ranges than the opposing pair of ranges where the criss-cross patterns appeared, one muscle of the antagonistic pair of mono-as well as the bi-articular muscles showed full activity level and the other antagonist of the pair showed almost nothing. The pressing force was largest when the force was directed from hip joint to the center of the foot (30°) (Fig. 3). At this direction only quadriceps(RF and VM) were activated. Co-activation of quadriceps and hamstrings were observed in the range between 30° and 60°.

DISCUSSION: Steindler described that a CKC is one in which the terminal joint meets with some considerable external resistance which prohibits or restricts its free motion[3]. However he did not describe what considerable external resistance is nor the participation of force directions. According to these results, when the maximal pressing force exists in the range between hip to foot direction and knee to foot direction, co-activation of quadriceps and hamstrings occur and the force is greatest. By controlling the force direction, it will be possible to control muscle activation patterns. An understanding of these results can help in selecting appropriate exercises for knee rehabilitation and training.


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