ERIK: a controllable exercise equipment for the lower limb

Ken'ichi Koyanagi\textsuperscript{a}, Yoshinori Kimura\textsuperscript{b}, Maki Koyanagi\textsuperscript{c}, Akio Inoue\textsuperscript{d}, Tatsuo Motoyoshi\textsuperscript{a}, Hiroyuki Masuta\textsuperscript{a} and Toru Oshima\textsuperscript{a}

\textsuperscript{a}Faculty of Engineering, Toyama Prefectural University, Imizu, Toyama, JAPAN; \textsuperscript{b}Department of Rehabilitation, Osaka University Hospital, Suita, Osaka, JAPAN; \textsuperscript{c}Faculty of Biomedical Engineering, Osaka Electro-Communication University, Shijonawate, Osaka, JAPAN; \textsuperscript{d}ER-tec Co., Minoh, Osaka, JAPAN

1. Introduction

We report an isokinetic exercise equipment prototype, named the ERIK, for the lower limb. The ERIK allows a type of single-limb squat exercise providing a translational load to the swing leg while loading on the stance leg in the standing position. This training produces loads to the gluteal muscles that are effective for the prevention of the knee valgus moment, a major factor in anterior cruciate ligament injuries. To enhance the quality of the load, an electro-rheological (ER) fluid brake system is implemented. The ER brake can reversibly control its resistive torque with a rapid response. Nevertheless, the high resistance created within the trainee's wide motion area to provide some training manner by controlling the brake torque, the ERIK has the advantage of safety since it has only a passive element for the load. The control methods for the training and certification of their performance through basic experiments are addressed in the paper.

2. Method

2.1 ERIK

We propose the ERIK for a type of single-limb squat exercise in the standing position with the translational load on the swing leg in the closed kinetic chain (CKC) style. We term this training style as a resistive leg reach exercise (Kimura et al., 2010). This training loads on the gluteal muscles of the stance leg and is effective in the prevention of the knee valgus moment, which is a major factor in anterior cruciate ligament (ACL) injuries. The primary goal of this style of training is to rehabilitate and/or preserve the ACL, or to provide a method for an athlete's strength training and its evaluation. CKC training makes a closed-loop linkage with both legs and the floor, such as with squats, so that the quadriceps femoris and the hamstrings and/or the gastrocnemius contract cooperatively. The authors analyzed the resistive leg reach exercise using a device with a sliding table and a rubber band. They reported that this training could be applied safely and effectively as a rehabilitation after reconstruction of the ACL, because the increase of the loads on the target muscles was measured without anterior shear nor knee valgus forces (Kimura et al., 2010). To enable some patterns of exercise, allow easy and arbitrary setting of the resistant force, and provide acceptable levels of safety and effectiveness, we developed an Electro-Rheological Iso-Kinetic exercise equipment prototype, the “ERIK” (Fig. 1; Kimura et al., 2014; Koyanagi et. al., 2014). The ERIK has an electro-rheological (ER) fluid brake system, which contains the ER fluid, a functional fluid, to reversibly control its resistive torque with a rapid response, for simple, effective and safe training system. The ERIK realizes a resistive lateral/backward leg reach exercise in the CKC style loading on muscles in the standing position providing some strength training styles.

2.2 Training styles using ERIK

To enhance the quality of the load during motion, we tried to mount the isokinetic exercise, which has particular advantages: (1) adequate resistance can be loaded for the whole range of motion; (2) the load can be easily tuned in coordination with the reference velocity; (3) few incidental muscle injuries occur; and (4) quantitative evaluations of the training effects, since the exercise requires to be controlled with the computer like as the ERIK. Including the isokinetic exercise performed at a constant velocity, an isotonic exercise performed with a constant load and other forms of loads such as an initial load mode and a final load mode which the ERIK provides resistant forces gradually decreased or increased can be provided.
3. Result and Discussion

Basic experimental results of 2 strokes in the isokinetic mode by the ERIK were achieved as shown in Fig. 2. The EMGs of vastus medialis (VM), gluteus maximus (GMa) and gluteus medius (GMe) were measured because their strengthening is effective to prevent an external knee valgus moment. Data was normalized by divided the maximum value of each data when the ERIK generated no additional load, respectively. VM generated larger force in wider motion range in the isokinetic mode while GMa and GMe had no significant differences. This is just an example of training, however, the target value and the posture during training should be adjusted individually.

![Figure 2: Normalized EMG of VM, GMa, and GMe without additional load by the ERIK (left) and with resistant forces of 0.40 m/s isokinetic mode (right)](image)

References

