ELECTRICAL STIMULATION-ASSISTED ERGOMETER LEG CYCLE MOTION

Takeshi Saitoh[1], Yoshihiko Tagawa[1], Kensuke Usui[1], Toshiya Usumoto[1], Takeshi Sugiyama[1], Naoto Shiba[2], Yuichi Umezu[2], Toshiyasu Yamamoto[3], and Jeffrey R. Basford[4]
[1]Department of Mechanical and Control Engineering, Kyushu Institute of Technology, Kitakyushu 804-8550, Japan
[2]School of Medicine, Kurume University, Kurume 830-0011, Japan
[3]Toyama Prefectural Koshi Rehabilitation Hospital, Shimoiino, Toyama 931-7517, Japan
[4]Department of Physical Medicine and Rehabilitation, Mayo Clinic, Rochester, MN 55905, USA

INTRODUCTION

We recently developed a hybrid exercise system in which electrically-stimulated antagonist muscles are used to resist volitional contractions of the opposing agonists. (Figure 1) This system has already been used successfully to strengthen the lower extremities of healthy men. (Yanagi et al, 2002) This pilot study explores the feasibility of extending this concept to the training of motor function.

Reciprocal limb movements are central to walking and many activities of daily living. Despite their importance, training is usually relatively primitive and typically involves multiple repetitions of the desired activity. This approach permits training of the desired pattern of movements but does not lend itself to increasing the subject's strength much above that needed for the task. Our goal was to combine hybrid exercise and ergometer training and study its potential in strengthening muscle in a functional reciprocal pattern that matches that of daily life.

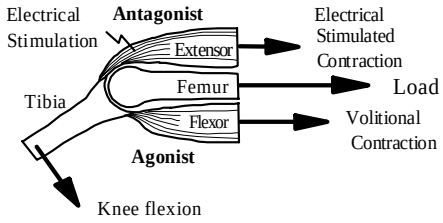

Figure 1 Hybrid exercise of the knee flexors.

METHODS

This study was approved by our Ethics Committee. The subject was an able-bodied 22-y/o man. The study consisted of two parts. First, stimulation intensities and patterns were established on the basis of the electromyographic (EMG) activity observed in the subject's rectus femoris and hamstring as he sat in the ergometer and his knees went through a flexion-extension cycle. The patterns were approximated as trapezoidal waves: tolerable-maximum and threshold voltages were chosen as upper and lower bases. Second, vastus lateralis EMG activity was examined to study the effects of stimulation on EMG recording. EMG activity was sampled at 5 KHz and passed through a 5-1,000 Hz band-pass filter. The electrical stimulation device has been described in Yanagi et al (2003) and has a bipolar waveform with pulse widths of 2.4 msec at 50 msec intervals.

RESULTS AND DISCUSSION

Figure 2 shows the limb motion and the reaction forces that occur during a simulation-induced leg cycle. It should be noted that while knee motion was produced as desired, stimulation overflow effects also induced ankle movements.

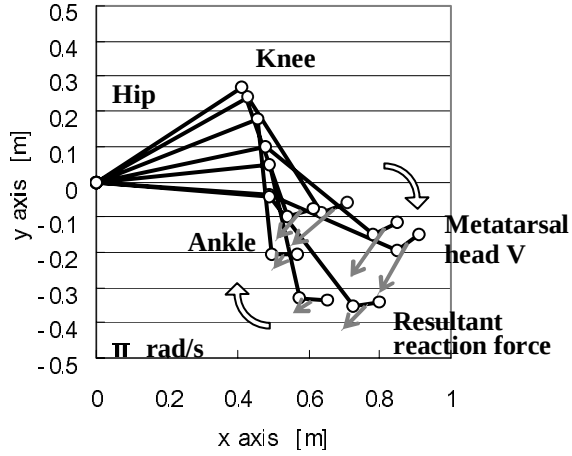

Figure 2 Electrical stimulation-induced leg cycle.

Figure 3 shows the EMG recording of the subject's vastus lateralis as he underwent a flexion-extension cycle of stimulation to his vastus lateralis and rectus femoris at an intensity of 20 V. The intervals (a) and (b) reveal transient responses to stimulation of < 30 msec that include M and H waves. The EMG activity of vastus lateralis volitional muscle contraction is obvious once the transients have passed.

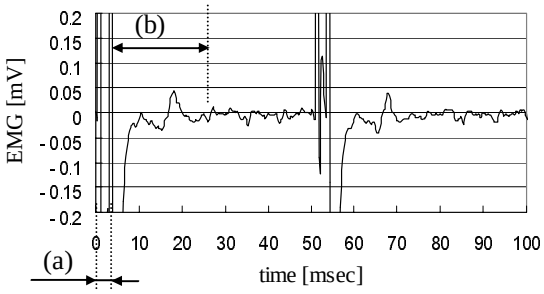

Figure 3 EMG with electrical stimulation.

SUMMARY

Motor function training with a combination of hybrid exercise and an ergometer appears feasible. However, more research on refining stimulation patterns and techniques is necessary before its clinical potential role can be established.

REFERENCES

Yanagi, T. et al (2003). *Arch Phys Med Rehabil* (In press)