TEM: THERAPEUTIC EXERCISE MACHINE FOR HIP AND KNEE JOINTS OF SPASTIC PATIENTS

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Abstract: The Therapeutic Exercise Machine (TEM) is a newly developed exercise machine for the hip and knee joints of spastic patients. This study aims at evaluating the short-term effects of Continuous Passive Range of Motion Exercise (CPROM-E) on passive resistive torque of the hip and knee in spastic patients and in normal subjects. During the CPROM-E in 40 individual sessions, TEM carried out CPROM-E of the lower extremity copying the therapists' initial motion, and recorded the load torque of each subject's hip joint and the integrated EMG (I-EMG) of the subject's quadriceps femoris and hamstrings. In the normal subjects, the peak torque of the hip significantly decreased by 5 percent, and the peak amplitude of I-EMG was not always reduced. In the spastic patients, the peak torque significantly decreased by 35 percent, and the peak amplitude of I-EMG significantly decreased after exercise on TEM. These results suggest that CPROM-E with TEM may have beneficial effects in the management of spasticity.

BACKGROUNDS

Range of motion exercise (ROM-E) is a therapeutic exercise to improve ROM and prevent contracture of the joint. Many therapists have noticed a decrease of spasticity by repetitive ROM-E. The exercise itself includes simple flexion/extension motion using the uniarticular muscle and straight-leg-raising (SLR) motion using the biarticular muscles to stretch the quadriceps femoris, hamstrings, gastrocnemius, and so on.

Two kinds of machines are employed for this therapeutic exercise. One is an exercise machine often used for sports rehabilitation. The other is a continuous passive motion (CPM) device, which is usually used after surgical treatment on the knee or hip. The limitations of these machines lie in their motion pattern and motion dynamics. Since these devices execute only one degree of freedom motion in rotation or in linear direction, they cannot extend the biarticular muscles. Further, these machines cannot modify the motion against the patient's load smoothly, thus their use may include pain.

NEW REHAB-MACHINE: TEM

The Therapeutic Exercise Machine

(TEM) is a novel exerciser for the hip and knee joints of spastic patients [1-5]. Two mechanical arms of TEM move the targeted lower extremity. The arms are driven by electric motors, controlled by a computer using load sensor information (Fig.1).

The machine has the following features.

1) Wide range of motion

The arm mechanism can follow the three-degrees-of-freedom motion of the lower extremity in the sagittal plane. Thus, a highly flexible and wide range of motion, including flexion/extension mode, SLR, etc., is realized. Stretching motion is accessible not only to the uniarticular muscles but also to the biarticular muscles around the hip and knee.

Knee	0 – 110 [deg.]	
Hip	15 – 90 [deg.]	In SLR with knee extended.
Hip	15 – 100 [deg.]	With knee flexed.

Available ROM in Exercise with TEM

2) Soft-motion

If the patient exerts external force to TEM, the mechanical arms move compliantly against the force. Based on the model of virtual compliance, the actual load to the patient's leg is continuously and appropriately modulated. TEM can accomplish a smooth and elastic movement similar to that achieved by human therapists (Fig.2).

3) Direct-teaching

Therapists can teach TEM the appropriate types of motion by articulating them while the patient is on the machine. TEM follows and memorizes the therapist's motions, and then the device replays the pattern of exercise precisely. Implementation is very easy for therapists (Fig.3).

4) Measurement functions

TEM measures the angle and the torque of hip and knee, and records the three channels of surface integrated-electromyogram (I-EMG).

Fig.1 TEM Apparatus

Fig.2 Concept of Soft-motion Function.

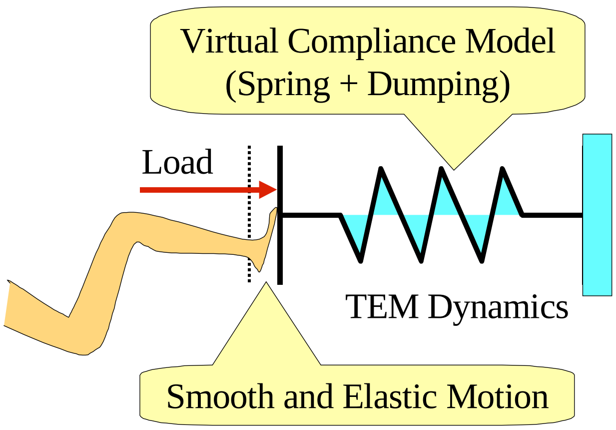

Fig.3 Direct-teaching to TEM by Physical Therapist.

METHODS

The purpose of this study is to evaluate the short-term effects of CPROM-E on passive resistive torque of the hip and knee in spastic and normal subjects. The subjects were 4 healthy adults and 6 spastic adult patients. By using the direct-teaching function, the therapist taught one session of the flexion/extension motion to TEM (Fig.3). During 40 serial sessions of the CPROM-E, TEM carried out these exercises on the lower extremity of study participants, repeating the initial motion guided by the therapist (Fig.1). One session took 15 seconds. TEM measured the angles and load torque of knee and hip, and recorded the I-EMG of medial hamstrings and quadriceps femoris (vastus medialis). The data were analyzed with the t test.

RESULTS

Figure 4 shows the time history of the changes of the hip torque and I-EMG during the first to last session after 40 individual repetitions of exercise in the series of normal subjects (NL). The hip torque, which is shown as the average of the changing ratio of its peak, decreased steadily and significantly ($p<0.0001$) by about 5 percent. And the average of peak amplitudes of I-EMG of hamstrings and quadriceps remained low. Figure 5 shows the counter-illustration of Fig.4 in the spastic patients (CVA). The peak torque of the hip decreased significantly ($p=0.01$) by 35 percent and the peak amplitudes of I-EMG also decreased significantly ($p=0.003$ and $p=0.01$, respectively).

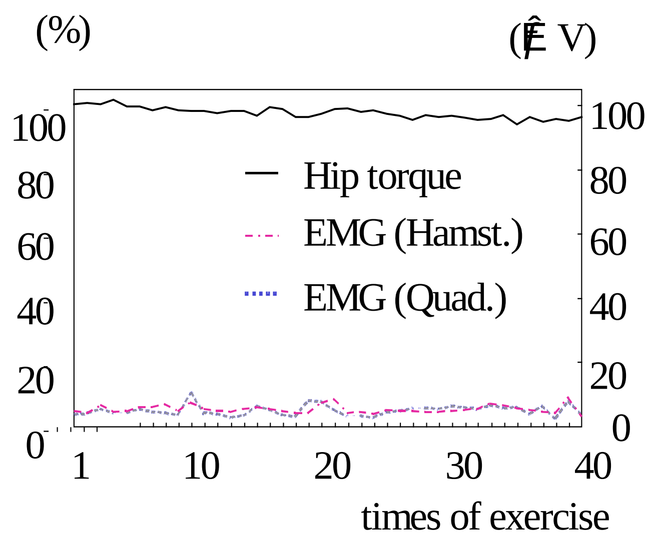

Fig.4 Hip Torque and I-EMG in NL.

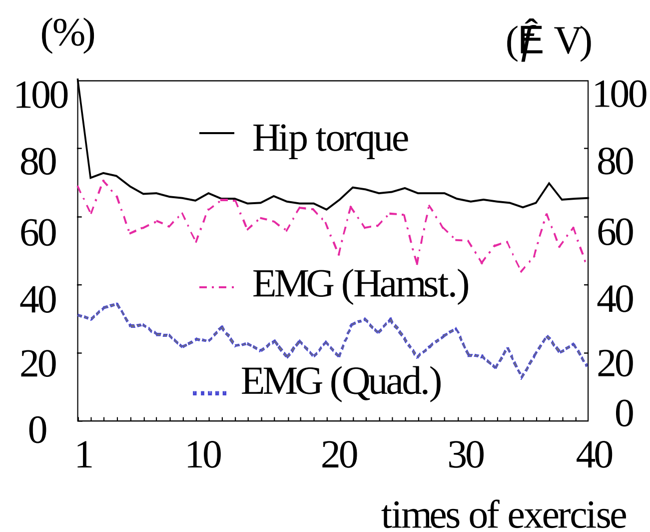

Fig.5 Hip Torque and I-EMG in CVA.

DISCUSSIION

Joint stiffness involves of the reflex and/or non-reflex components [6-9]. The non-reflex components may be related to changes of collagen in connective tissue and the proportion of binding cross-bridges in muscle. Reduction of joint torque without decrease of muscle activity is caused by the non-reflex components, while the reduction of joint torque with decrease of muscle activity is caused by the reflex components. The reduction of joint torque was shown in healthy adults and in spastic patients. However, in healthy adults, the torque was reduced without decrease of muscle activity, while in spastic patients the torque was reduced with such a decrease. Therefore, the non-reflex components may contribute to the decrease of torque in normal cases, and a combination of reflex and non-reflex components may cause the decrease of torque in spastic patients. We are elucidating these mechanisms by experiments with the H reflex.

CONCLUSIONS

The new rehabilitation TEM for the therapeutic exercise of the lower extremity was presented. We examined the short-term effects of Continuous Passive Range of Motion Exercise with TEM on muscle tone in 4 healthy adults and 6 spastic patients. The results suggest that CPROM-E with TEM may have beneficial effects on spasticity.

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