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THE INFLUENCE OF NON-PARETIC LEG MOVEMENT ON MUSCLE ACTION IN THE PARETIC LEG OF HEMIPLEGIC PATIENTS

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ABSTRACT. The aim of this investigation was to study the effect of non-involved-side exercise on the involved (paretic) leg-muscle of patients with stroke. Each of the ten adults studied attempted to perform, while seated, a predetermined sequence of the following actions : (1) a voluntary knee extension on the involved side; (2) a maximal, isometric knee-flexion on the non-involved side; (3) a maximal, isometric knee-flexion on the non-involved side with counter-resistance (in front of the ankle joint) on the involved side. The root-mean-square voltage was measured across the rectus femoris, the medial hamstring, the tibialis anterior, and the medial gastrocnemius muscles (on the involved side) with surface electrodes. The root-mean-square voltages of the involved-side rectus femoris and the tibialis anterior muscles were found to increase substantially during non-involved-side knee flexion relative to that detected for voluntary knee extension on the involved side. The voltage of the rectus femoris muscle increased substantially also when counter-resistance was present. There was no similar substantial increase of muscular activity, in the medial hamstring and medial gastrocnemius, induced by contralateral isometric knee-flexion. This study suggests that, among patients with severe hemiplegia, isometric knee flexion in the non-involved side may be useful for facilitating the paretic rectus femoris and tibialis anterior muscular activities.

Key words: hemiplegia; facilitation; exercise; RMS (root-mean-square) voltage.

INTRODUCTION

It is often found that agonist recruitment decreases and antagonist recruitment increases, abnormally, in muscles of hemiplegic limbs. Hemiplegic persons cannot perform selective muscular contraction, and the synergy pattern seems to be a stereotyped muscular contraction. In rehabilitation programs for stroke patients, a number of muscle re-education programs (based on neuromuscular facilitation) have been developed and are widely used (2, 3). The general purpose of these programs is to acquire selective muscle coordination as Kottke et al. (7–9) have described and termed “neuromuscular coordination”. Studies among healthy subjects have shown that the movement in one leg can increase the vigor of contralateral antagonist activities in the other, the so-called “cross-educational effect” (5, 6). In locomotion, when one knee is flexed, the contralateral knee extends. Knee extension on one side reduces contralateral knee extensor activities and increases the flexor activities. In this manner, leg movement on one side may affect that on the other. This contralateral effect may be useful for facilitating muscular contraction in persons with hemiplegia who cannot otherwise selectively contract muscles. The aim of this study was to analyse the effect of the non-involved side by applying isometric knee flexion on the involved side in severe hemiplegic patients.

METHODS

Ten patients (5 men and 5 women), exhibiting symptoms of hemiplegia caused by cerebrovascular disease within 6 months of onset, participated in this study, 5 with left and 5 with right hemiplegia. Their mean age was 61.5 years, ranging between 53 and 75. Their lower extremity function was assessed using the hip flexion, knee extension, and foot patting tests of the Stroke Impairment Assessment Set (SIAS) (4). None of these patients could voluntarily perform hip flexion, knee extension, or ankle dorsiflexion against gravity on their paretic side.

Seated subjects were asked to do one of three different actions: (1) Voluntary knee extension of the involved (paretic) side; (2) maximal isometric knee flexion of the non-involved side; and (3) maximal isometric knee flexion of the non-involved side, with counter-resistance added in front of the ankle joint on the paretic side. These three trials were performed in a random predetermined order three times. A precise interval of two minutes was maintained between each trial.

Root-mean-square (RMS) voltages (1) were measured from the rectus femoris, medial hamstring, tibialis anterior and medial gastrocnemius muscles of the paretic side. A Dantec counterpoint TM electromyography machine was used to record

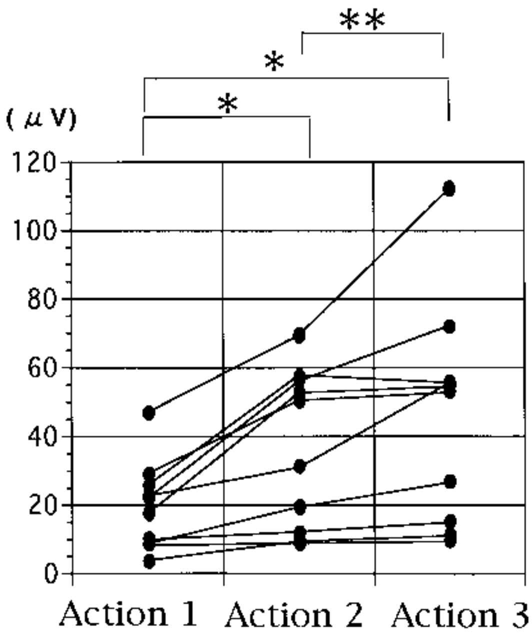

Fig. 1. Voltages measured across the rectus femoris of each subject. The measured root-mean-square voltage across the involved-side rectus femoris for action 2 is substantially larger than that for action 1. The significance of this difference is confirmed statistically via the Wilcoxon signed-ranks test (*$p < 0.01$). The relative voltage for action 3 is also substantially larger than that for actions 1 and 2. The difference satisfies the Wilcoxon signed-ranks test (*$p < 0.01$) in the first case and (**$p < 0.05$) in the second.

these four RMS voltages. Electrical activity in each of the four muscles was detected by means of two silver chloride surface electrodes. Each surface electrode had a diameter of 9 mm and was applied with a center-to-center spacing of 20 mm, placed parallel to the muscle fibers, and distal from the motor point. Before the electrodes were attached, the skin area was rubbed with alcohol. The band pass filter was set at 5–1000 Hz. The sweep speed was set at 200 ms per division to analyse the RMS value over an interval of 4000 ms.

At each trial, the voltage across the rectus femoris, medial hamstring, tibialis anterior and medial gastrocnemius muscles of the paretic side was analysed and recorded automatically. The mean value of the three trials was taken as the RMS value for each muscle.

The RMS voltage produced by each muscle was compared for the three different conditions or actions, as already outlined. The statistical analysis to verify whether meaningful differences had been observed was performed by using the Wilcoxon signed-ranks test.

RESULTS

Fig. 1 shows the mean RMS voltage of each subject, measured across the involved side rectus femoris for actions 1, 2 and 3. The nominal voltage measured across the rectus femoris was significantly greater for action 2 than for action 1 ($p < 0.01$). For action 3, the nominal voltage observed across the rectus femoris was also significantly greater than that for both action 1 ($p < 0.01$) and action 2 ($p < 0.05$) due to the resistance in front of the ankle. There was some visible muscular contraction or knee extension during actions 2 and 3 which was not found during action 1.

Non-involved-side knee flexion also caused the RMS voltage across the involved-side tibialis anterior to increase significantly compared to that for the voluntary knee extension in the involved side (Fig. 2). These contralateral side effects were not found in the medial hamstring or medial gastrocnemius in any of the trials. Induced paretic muscular activity for these two cases remained unchanged or slightly decreased (Figs. 3 and 4).

DISCUSSION

Previous researchers have shown that single-leg exercises can increase the muscular activities of contralateral-side antagonists (5, 6). It had been supposed that this cross-educational effect arose from cross-extension

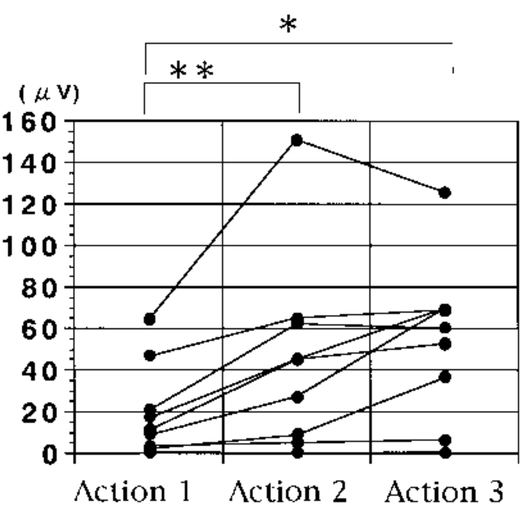

Fig. 2. Voltages measured across the tibialis anterior. The relative root-mean-square voltage across the tibialis anterior for action 2 is substantially larger than that for action 1. The difference satisfies the Wilcoxon signed-ranks test (**$p < 0.05$). The relative voltage for action 3 is also significantly larger than that for action 1. Again the difference satisfies the Wilcoxon signed-ranks test (*$p < 0.01$).

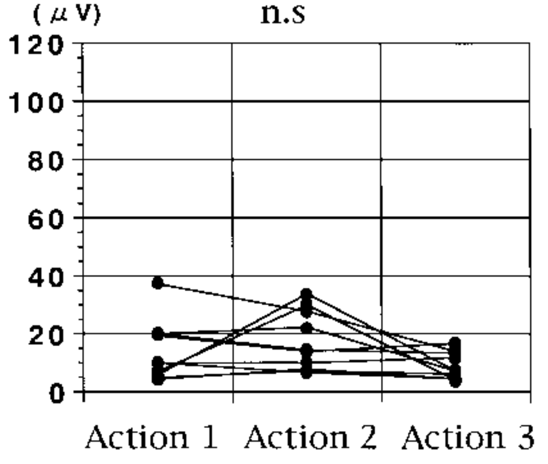

Fig. 3. Voltages measured across the medial hamstring. No significant differences were found between the measured action-induced voltages.

via a flexion or secondary spindle reflex. In hemiplegia, movement of the non-involved limb is often accompanied by excessive unintentional movement of the contralateral limb. This response has been termed "associated movement" and is discussed by Brunnström (3). With regard to the hemiplegic gait pattern, hemiplegia, spasticity and synergic movement prevent ankle dorsiflexion during knee extension at the swing phase on the paretic side.

Our study revealed that non-involved-side knee flexion facilitated the muscular activities of the involved side rectus femoris and tibialis anterior in severe hemiplegic patients who could not voluntarily control these selective muscles. These muscular activities differed from the extensor synergy patterns for knee extension and ankle plantar flexion. There was no increase of muscular activity in the medial hamstring and medial gastrocnemius due to contralateral isometric knee flexion. Ankle dorsiflexion with knee extension could also be facilitated by means of non-involved side knee flexion. This study suggested that isometric knee flexion on the non-involved side might also be useful for facilitating the involved quadriceps femoris and tibialis anterior muscular activities among severe hemiplegics. The resistance on the pretibial part of the contralateral leg during non-involved isometric exercise significantly increased the muscle activity of the rectus femoris and tibialis anterior on the non-involved side. Kang et al. (5) have reported that the contralateral bar, which can load the resistance on the extensors, enhances the contralateral antagonist muscle activities in normal subjects. It had been expected that an extensor load could facilitate the muscular activities of extensor muscles during single-leg exercises. We considered that the resistance bar enhanced the sensory input from skin and muscle spindles. This proprioceptive input might help patients to recognize their paretic leg movement and thereby facilitate muscular activity.

Exercise of the non-involved side can facilitate selective, involved muscular contraction and, in patients with severe hemiplegia, may be a beneficial technique for re-education of selective muscle contractions. We do, however, strongly emphasize that further research is required regarding the long-term efficacy of this cross-educational effect, as is assessment of the outcome of training of this type and preferably a comparison to some training procedure presently in use.

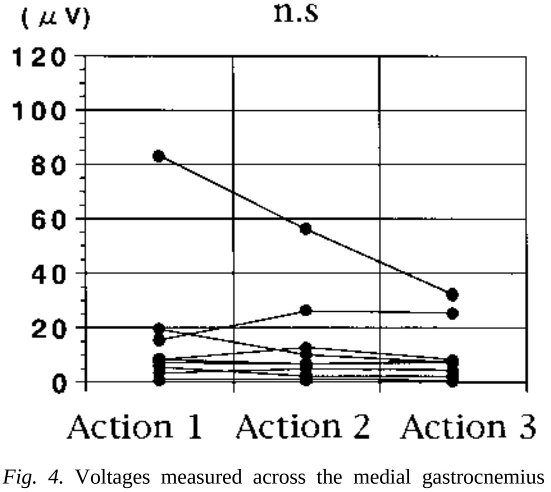

Fig. 4. Voltages measured across the medial gastrocnemius muscle. No significant differences were found between the measured action-induced voltages.

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