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ORIGINAL RESEARCH

Comparison of the effects of remote after-effects of static contractions for different upper-extremity positions and pinch-force strengths in patients with restricted wrist flexion range of motion

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Facilitation

Summary The objective of the study was to examine the after-effects of static contractions of upper extremity muscles in different shoulder joint positions and at different pinch-force strengths on the maximal active range of motion (MAROM) and wrist agonist/antagonist IEMG activities for patients with restricted wrist flexion range of motion (ROM) due to upper limb pain and dysfunction. The subjects were 10 outpatients (3 males, 7 females) with restricted wrist joints. These subjects performed four static contractions of upper extremity muscles in neutral and diagonal shoulder joint positions and with weak and strong pinch-force strengths in random order. Two-way repeated measures analysis of variance showed that the change in MAROM was significantly larger ($P < 0.05$) after diagonal-strong static contractions than after neutral-weak static contractions. There were no significant correlations between changes in MAROM and IEMG activities. These results indicate that shoulder joint position and pinch-force strength should be considered for effective induction of remote after-effects of static contractions for increasing MAROM for restricted wrist flexion ROM.

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Introduction

After-effects are observed in proximal muscles not involved in previous voluntary activity following a 30—60 s static contraction (SC) of distal muscles (Gurfinkel et al., 1989). Muscle contractions are not restricted to the target muscle and activities occur in both ipsilateral and contralateral (non-target) muscles during strong unilateral contractions (Post et al., 2008). In the cat, monosynaptic excitation by muscle spindle Ia afferents from a given muscle is not distributed exclusively to the α-motoneurons of this muscle (homonymous projections), but also reaches the pools of motoneurons of other muscles (heteronymous projections) acting synergistically at the same joint or at different joints (Marchand-Pauvert et al., 2000). To date, the heteronymous connections described in the human upper limb are from wrist to elbow muscles (Cavallari and Katz, 1989; Mazevet and Pierrot-Deseilligny, 1994) and might provide proximal support for distal movements. Intrinsic stiffness or slackness of the intrafusal muscle fibers at any given time is highly dependent on the immediate history of movements and contractions (Hagbarth and Nordin, 1995). The mechanical contributions of various sources of stiffness vary under different functional conditions, such as joint position and voluntary contraction level (Mirbagheri et al., 2001).

The improvement of maximal active range of motion (MAROM) was significantly larger after a static contraction combined with a diagonal shoulder joint position and a strong finger pinch (diagonal-strong SC) than that after a static contraction combined with a non-diagonal position and weak finger pinch (neutral-weak SC) in normal subjects (Arai et al., 2012). The surface integrated electromyography (IEMG) activity of the flexor carpi radialis (FCR) was also greater after a diagonal-strong SC than after a neutral-weak SC, which may be explained by the observation that facilitation of FCR under strong pinch force is an aftereffect in normal subjects (Arai et al., 2012). The increased flexibility mainly results from reduced passive stiffness of the muscle-tendon unit (Guissard and Duchateau, 2004), an increasing muscular recruitment pattern, and the role of the central nervous system (Hashemirad et al., 2009). This physiological phenomenon is explained by significant heteronymous monosynaptic Ia excitation from intrinsic hand muscles supplied by median and ulnar nerves, as found in human forearm motoneurons belonging to forearm motor nuclei of the FCR, flexor carpi ulnaris, flexor digitorum, superficialis, extensor carpi radialis (ECR), and extensor digitorum communis (Marchand-Pauvert et al., 2000). Heteronymous connections from intrinsic hand to wrist muscles may facilitate remote after-effects of a specific SC (Arai et al., 2012).

Direct approaches to improve MAROM and strengthen the agonist muscles of restricted joints are difficult because of pain or weakness of the agonist muscles and/or antagonist muscles. In this context, therapy using after-effects may be useful to improve the restricted joint in an indirect neurorehabilitation procedure. However, effective methods that show a good correlation of static shoulder positions and SC strength on MAROM of wrist flexion with wrist agonist/antagonist IEMG activities for patients with restricted wrist flexion ROM due to upper limb pain and dysfunction have not been reported. Previous research has not focused on the effectiveness of the indirect effects of SC for intrinsic muscles in wrist MAROM. SCs with different shoulder positions and degrees of fingertip strength may show differences in the improvement of MAROM and these differences may be related to facilitation of the agonist (FCR) inhibition of the antagonist (ECR) as a remote after-effect of SC. Therefore, the objective of this study was to compare the effects of after-effects of SC of upper extremity muscles in different shoulder joint positions and at different pinch-force strengths on the change in MAROM and wrist agonist/antagonist IEMG activities for restricted wrist flexion ROM.

Methods

Participants

The participants were 10 outpatients (3 males, 7 females) with restricted wrist joints and no history of upper motor neuron diseases who were referred by an orthopedist for improvement of ROM of the upper extremity, including the wrist joints. The patients were randomly selected from 25 outpatients. The mean age (standard deviation) was 60.8 (5.6) years (range, 34—81 years). Exclusion criteria included any other orthopedic disorders and any neurological disorder within the last year that required medical attention. All patients had pain during movement and restricted wrist motion relative to that of the unaffected side. MAROM may be restricted by upper limb pain and dysfunction. The time since onset of impairment varied from 9 weeks to 10 years. The patients had primary diagnoses of fracture of the radius and ulna, fracture of the radius, surgical neck fracture of the humerus, rheumatoid arthritis, carpal tunnel syndrome, and tenosynovitis of the flexor-tendon sheath of the index finger. MAROM of wrist flexion was measured on the more affected side (left, 9; right, 1). At the start of the study, all patients presented with stiff and mildly swollen wrists. No subject had knowledge of which exercise pattern might be more effective for improving MAROM of the wrist. The protocol was approved by the Hiroshima University Doctoral Degrees Committee. All patients gave written informed consent.

Experimental design

Each subject learned each SC method sufficiently well before the start of the study to allow performance of the activity alone. Because experienced therapists may have a bias toward certain therapeutic methods that may influence the outcome, the experiments were performed by two well-trained physical therapy students. The two students who performed the assessment had been in the program for 4 weeks and received training in the specific experiments for 2 weeks.

In preparation for data collection, the participants sat for 5 min to relax. After resting, the subjects performed each exercise for 2 s. The shoulder joint positions were the diagonal position [shoulder flexion (135°) and adduction (45°)] and the neutral position [shoulder flexion (90°) and adduction (0°)] (Fig. 1). The target strength of the pinch