Current Neurobiology 2012; 3 (2): 98-102 ISSN 0975-9042

A comparative study of the neurophysiologicalremote effects of different resistive staticfacilitation techniques on the flexor carpi radialis H-reflex.

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Abstract

Resistive static contraction facilitation technique applied by manual resistance using a proprioceptive neuromuscular facilitation patternin the mid-range pelvic posterior depression technique(RSCPDT) or anterior elevation technique (RSCAET) with the subject on the affected side produces greater increase in range of motion of remote parts.However, few studies have providedevidences for neurophysiological remote effectsof resistive static exercise that consider the direction of resistance force. The purpose of this study was to clarify therebound effects of RSCPDT on the time-course of excitability of the flexor carpi radialis (FCR) H-reflex in comparison withRSCAET as an opposite direction of resistance force. Six healthy subjects were randomly assigned two groups: the RSCPDT (n = 3)andRSCAET group (n = 3) groups. Repeated FCR H-reflexes with small M-waves (1 Hz) were sequentially elicited in a row without interval for a period of 220 s. The repeated ANOVA revealed thatneurophysiologicalrebound effects induced by RSCPDT on the FCR H-reflex causea significant initial inhibition phase during RSCPDT and a significant subsequent facilitatory phase after RSCPDTwhen compared toRSCAET. We named those phenomena as remote rebound effects (RRE).These results suggest that the neurophysiological RREof resistive static contractionof pelvic muscles on the FCR H-reflex may depend on the direction of resistance.The RSCPDTis a specific resistive exercise to induce RRE.

Keywords: FCR H-reflex, rebound remote effect, resistive static contraction,resistic static facilitation, PNF

Accepted August 17 2012

Introduction

Resistive static contraction facilitation technique applied by manual resistance using a proprioceptive neuromuscular facilitation pattern[1]in the mid-range pelvic posterior depression technique (RSCPDT) or anterior elevation technique (RSCAET) with the subject on the affected side produces greater increase in active range of motion (AROM) and passive range of motion of remote parts such as upper shoulder and elbow joint than passive or static stretching methods in the patients with orthopedic impairments [2, 3] and in the patients with stroke patients [4]. Ourprevious study also showed that the remoteeffectsof a static contraction by strong pinch force combined with the diagonal position of the shoulder jointon the improvement of the wrist joint AROMwas significantly larger compared with therebound effects of neutral position combined with a weak pinchin normal subjects [5].The after effectsof resistive exercise on the remote parts may dependent not only on degree of strength but also on the position during static exercise. Previous studies have suggested that the neurophysiological effectsof exercise on remote parts depend on the direction of movement[6,7].The neurophysiologicalrebound effects such as increased and decreased the flexor carpi radialis (FCR)H-reflexes with plantar flexion and dorsiflexion, respectively, are observed during voluntary foot oscillations [6], whereas the opposite effects are observed when the forearm is held in supination [7]. Specific exercises may facilitate the linkages between the arm and foot. However, there are few studies to determine the linkages between the arm and trunk. In addition,few studies have providedevidencesfor neurophysiological rebound effectsof resistive static contractionthat consider thedirection of resistance force.The purpose of this study was to clarify the neurophysiologicalrebound effectsofRSCPDT on the time-course of excitability of the remoteFCR H-reflex in comparison with a resistive static contraction of the pelvic elevators technique (RSCAET) as an opposite direction of resistance force.

Since H-reflex is difficult to measure in the wrist extensors or extensor digitorum, we selected the highly reliableFCRH-reflex[8] as an indicator of neurophysiological rebound effects.We performed each resistive static contraction facilitation technique to detect the influence of the relaxed FCR H-reflex, which provides a gross measure of motoneuron pool excitability [9]. If the amplitude of the H-reflex is high, it is assumed that there is an increase level of excitation of the motoneuronal pool and vice versa.

Subjects and Methods

Six subjects, aged 21–31 y (mean, 26.3 y; standard deviation (SD), 3.9 y) and with no history of neurological illness, volunteered for this study. Exclusion criteria also included any injury to the extremities or back within the last year that required medical attention. All participants gave their written informed consent. This study was performed in compliance with the revised declaration of Helsinki.

Dominance was determined by asking the subject which arm they preferred to use when writing a name. All the subjects were right-hand dominant based on this criterion.Subjects were randomly assigned to one of two groups: RSCPDT group (n = 3), which took part in RSCPDT, or RSCAET group (n = 3) which took part in RSCAET.

Resistive exercise protocol

Each resistive exercise was induced by manual resistance applied byanexperimenter, while other movement of the trunk and extremities was prevented. The experimenter stood behind the patient with his elbows locked in extension and placed his hands over the subject's upper ischial tuberosity while in side-lying position in the RSCPDT group.Manual resistance was directed toward the sacroiliac joint (SIJ) over the upper ischial tuberosity in the RSCPDT group. In the RSCAET group, the experimenter stood behind the patient and placed his hands over the anterior superior iliac spine (ASIS) while in side-lying position. Manual resistance was directed toward the SIJ over the ASISin theRSCAET group.The amount of resistance provided by the experimenter was between 2–3 kgin each resistive exercise. The duration of each resistive exercise was 20 s in each resistive exercise.

Verbal exercise cues were limited to the following: (1) for RSCPDT orRSCAET protocol, " keep your pelvic steady during exercise as possible as you can. Do not move your body during exercise and relax after exercise".

H-reflex stimulation

While in the side-lying position, each subject was instructed to keep the arm completely relaxed with his/her right shoulder at an angle of 90 degrees and his/her right forearm immobilized in a cuff in a pronated position with wrist and fingers extended. During and after each resistive exercise, the subject maintained the side-lying position on their side in a dark, quiet room. We measured the FCR H-reflex of the right upper extremity in side-lying position during each resistive exercise and at rest before and after each resistive exercise. The H-reflexes were measured with an evoked potential measuring system (model MEB9100, Nihon Kohden Corp, Tokyo, Japan). We elicited H-reflexes in the FCR muscle using electrical stimulation of the median nerve in the cubital fossa. Electromyograpic (EMG) responses were recorded from right FCR muscles using surface electrodes recording from bipolar surface electrodes over the muscle belly. The skin was cleaned with alcohol, and the area was rubbed gently using skin preparation gel (Skinpure; Nihon Kohden Corp., Tokyo, Japan) for removal of dirt, oil and dead skin to lower the impedance at the recording site was below 0.5 kΩ. Test stimuli were administered using a 1-ms pulse delivered through a pair of surface electrodes placed 1.5 cm apart over the belly of the FCR, with the cathode located proximal to the anode. EMG signals were recorded from the FCR with standard nonpolarizable Ag-AgCl surface disk electrodes (outer diameter 9 mm). An electrical stimulus with a rectangular pulse (1-ms duration) was delivered by a stimulator at a frequency of 1 Hz. A small M-wave size was maintained throughout the experiment to ensure that no displacement of the stimulation electrode occurred and that the effects were not due to changes in a reflex recruitment gain during the stimulus gain.

Experimental design

M-wave and H-reflex were obtained using 20 sweeps (20 repeated reflex responses) every 20 s in all conditions (conditions-C2～-C8) while stimulation current was concurrently measured for all experimental trials as shown in Fig. 1. We determined the steady intensity of stimuli necessary to elicit a large H-reflex with a small M-wave in each subject prior to resistive exercise in conditions-C1. Repeated H-reflexes and M-waves (1 Hz) were sequentially elicited in a row without interval for a period of 220 s. The period of 220 s was divided into 8 conditions (conditions-C1(80 s): conditions-C2～-C8 (20 s each)). Conditions-C1 (four trials; 80 s) represented the phase of rest; conditions-C2 (20s) the phase of each resistive exercise; conditions-C3, -C4, -C5, -C6, -C7, -C8 (20 s each) represented the rest phase after each resistive exercise as shown in Fig. 1. The intensity of median nerve to induce H-reflexes with small M-waves was determined in conditions-C1, and this initial stimulus intensity was held constant for each subject during all of the experimental trials [10].By repeating the experiment at several stimulus intensities and using the M-wave as a measure of the effective stimulus strength, H-reflexes occurring at various phases could be compared at equal stimulus intensities [10].

Parameter of excitability

For comparison, each H-reflex amplitude during and after each resistive exercise (conditions-C2～-C8) was normalized to the corresponding H-reflex recorded in conditions-C1 to reduce inter-subject variability. ThisH-ratioindicating the relative size of the H-reflex amplitude, was used as a parameter of motoneuron excitability. The peak-to-peak amplitude of each H-reflex in conditions-C1 served to determine the neurophysiological rebound effectsof each resistive exercise.

Data analysis

1. A probability level of $P < 0.05$ was used to determine statistical significance.
2. The reliability of H-reflex was ensured by calculating the reliability of peak-to-peak H-reflex ratios, respectively, from 4 trials measured in conditions-C1(Fig.1: C1-1,C1-2,C1-3 and C1-4) using two-way analysis of variance (ANOVA) to derive ICCs.
3. Two-way repeated ANOVA was used to determine the time-course effects, group effects and interactions between the time-course and group with regard to theH-ratio. We used Bonferroni post-hoc analysis to determine whether statistically significant differences in the H-ratio occurred over time (conditions-C2～-C8).

Results

The ICC(1,4) was 0.97 for the FCR H-reflexes, which indicated a high degree of consistency in conditions-C1.The time-course of the H-ratio is shown in Figure 2. A two-way repeated ANOVA showed that the time-course produced a main effect, but not for the group ($F_{(1,5)}$ =3.75, p=0.11 for the group; $F_{(6,30)}$ = 19.03, p=0.000 for the time-course). The interaction between the group and time-course was also significant for the H-ratio ($F_{(6, 30)}$ =18.51, p =0.000). Both a significant main effect of the time-course and a significant interaction between the group and time-course indicated that theH-ratio changed over the time-course, with the extent of change dependent

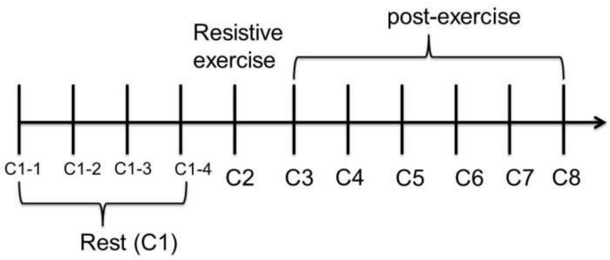

Figure 1. *Experimental design*

Repeated H-reflexes and M-waves (1 Hz) were sequentially elicited in a row without interval for a period of 220 s. The period of 220 s was divided into 8 conditions (conditions-C1～-C8). Conditions-C1 (four trials; 80 s) represented the phase of rest; conditions-C2 the phase of each resistive exercise; conditions-C3,-C4,-C5,-C6,-C7 and -C8 (20 s each) represented the rest phase after each resistive exercise

on the group factor.Post-hoc tests using a Bonferroni analysis revealed that the H-ratioin conditions-C2 during RSCPDT was significantly reduced as compared withthe H-ratio inall conditions during and after RSCAET as shown in Table 1. In contrast, the H-ratioin bothconditions-C7 and -C8 after RSCPDT was significantly enhancedas compared withthat in all conditions during and after RSCAETas shown in Table 1.

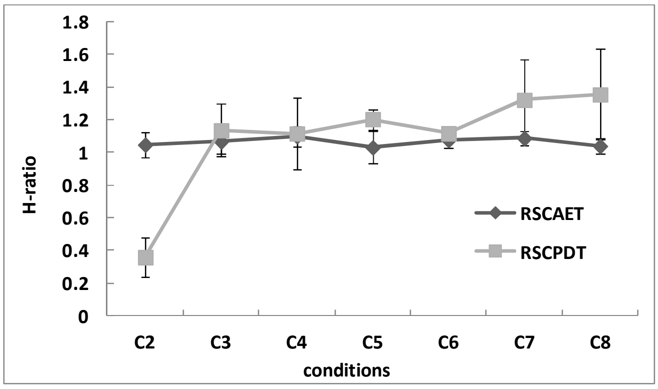

Figure 2. The time-course of the remote rebound effects on the FCR H-ratio.

The neurophysiological effects induced byRSCPDT on the FCR H-reflex caused a large degree of reflexive inhibition during RSCPDT followed by a gradual excitation after RSCPD in comparison with RSCAET.

Table 1. *Significant differences between the two groups in the H-ratio*

		RSCPDT		
		Condition-C2	**Condition-C7**	**Condition-C8**
RSCAET	Condition-C2	0.70*	0.442*	0.425*
	Condition-C3	0.69*	0.46*	0.44*
	Condition-C4	0.67*	0.47*	0.46*
	Condition-C5	0.63*	0.51*	0.50*
	Condition-C6	0.67*	0.47*	0.46*
	Condition-C7	0.68*	0.47*	0.45*
	Condition-C8	0.71*	0.43*	0.41*

(; significant difference)*

Discussion

The neurophysiological rebound effects of SCPD on the FCR H-reflex was significantly dependent on the time-course. The results of the repeated ANOVA suggest that neurophysiological rebound effects induced by RSCPD-Ton the FCR H-reflex cause a significant initial inhibition phase duringRSCPDTand a significant subsequentfacilitatory phase afterRSCPDTwhen compared to the RSCAET.We named those phenomena as remote rebound effects (RRE).We found the linkages between the arm and trunk in this study, as well as specific exercise facilitate the linkages between the arm and foot in the previous studies [6,7].Whereas the neurophysiological RRE of RSCPDT on the FCR H-reflex were found in this study,RSCAET did not produce anysignificantchanges.These results suggest that the neurophysiological RREare influenced by thedirection of resistance.RSCPDT are a specific resistive exercise to induceRRE.We propose RRE as a novel explanation for an increase in flexibility observed when different partsare exposed to a specific resistive static contraction. The inhibitory effect on the FCR H-reflex during RSCPDTare interpreted as a "tranquilizing" effect. Decreased motor unit response as expressed by decreased the FCR H-reflex amplitude during RSCPDT may in turn underlie reduced muscle compliance [11] to improve the PROM of upper extremities after RSCPDT.After the inhibitory effect, the facilitatory effect on the FCR H-reflex occurred and lasted over 40 s as shown in Figure 2 and Table 1. The RRE after RSCPDTsuggests an enhancement of motoneuron pool excitability, which may develops on an enhancement of the FCR motor unit discharge synchronization.The increase ofthe FCR H-reflex amplitude after RSCPDT may reflect increased motor unit responseand underlie enhanced muscle contractibility [12] leading to improved AROM of upper extremities. The RRE of the FCR H-reflex by RSCPDT may provide the neurophysiological evidence of the indirect treatment of extremities that cannot be exercised directly in patients with severely restricted joints or painful movements.

Presumable causes of RRE may be coordinated patterns of extremities such as central pattern-generators (CPGs) [14,15]. Triggering of RRE of RSCPDT may be correlated with the activation of load receptors of central pattern-generators (CPGs), which can determine the choice of appropriate coordinated pattern according to the proprioceptive input arising from muscles, skin, joints and tendon [14,15].In our previous study, we found neurophysiological rebound effects induced by RSCAET on reproducible extensor digitorumcommunis long-latency evoked potentials (> 150 ms), which may reflect the excitability of neural circuits in the brainstem when considering the latency period. Thus, the neurophysiological rebound effects of RSCAETmay be correlated withbrainstem activities. Further research is needed to compare the brain activity induced by different resistive static contraction facilitation technique with that induced by other methods such as functional magnetic resonance imaging (fMRI) and motor evoked potential (MEP).

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Abbreviations: RSCPDT = Resistive static contraction of posterior depression technique; RSCAET = Resistive static contraction of anterior elevation technique; FCR =flexor carpi radialis;AROM = active range of motion; RRE = Remote rebound effects

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