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Effects of neuromuscular electrical stimulation on the range of motion recovery in hand proximal interphalangeal sprain

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Aim – To compare the effects of Active Range Of Motion *versus* NeuroMuscular Electrical Stimulation superimposed to Active Range Of Motion on the range of motion recovery at the proximal interphalangeal joint following sprain.
Patients and Methods – Twenty patients in need of physical therapy to recover proximal interphalangeal range of motion participated voluntarily. Ranges of motion at the proximal interphalangeal joint were measured before and after each treatment with a finger goniometer.
Results – Both treatments allow getting back the range of motion on the proximal interphalangeal joint. Moreover, the effectiveness of the Superimposed Technique in improving the range of motion is significantly better than that observed after Active Range Of Motion on its own.
Conclusion – These findings highlighted the Superimposed Technique as an effective method, which could be integrated in rehabilitation protocols for recovering the proximal interphalangeal joint range of motion following sprain.
Keywords – Neuromuscular electrical stimulation / Sprain / Hand / Proximal interphalangeal joint.

Introduction

Numerous proximal interphalangeal joint (PIP) injuries which appear to be innocuous represent actually very severe injuries to this small hinged joint and carry a high percentage of disability for the hand as well as the individual digit. Indeed, a flexion contracture of the PIP joint of one digit may significantly reduce the functional capacity of the entire hand. To prevent such physical impairment, the range of motion (ROM) must be recovered as soon as possible.

At this point, although previous studies have investigated the short-term (motor unit recruitment [6], blood flow variations [19]) and long-term (cortical excitability [8], motor recovery after stroke [15]) effects of the neuromuscular electrical stimulation (NMES), none has yet assessed, to our knowledge, the possible effects of this method on recovering joints ROM [12, 11].

The joint mobilization is used to limit adherences, evacuate edema, stop the pain circle and point the healing [14, 5, 3]. This mobilization can either be passive, active or electrically induced. In the hand rehabilitation, the techniques of active range of motion (AROM) and of NMES are superimposed (superimposed technique ST: application of electrical stimulus during a voluntary muscle action) [13] in order to activate more motor units than AROM or NMES performed alone. The present study was designed to compare the efficiency of the ST to the AROM technique in improving ROM getting back. This comparison may allow us to better adapt the patient's treatment by optimizing the PIP ROM recovery after sprain.

Considering the clinical observations previously done in our rehabilitation center [17], it was hypothesized that both treatments would enhance the PIP ROM after sprain and that the ST would allow a superior ROM getting back than the treatment applying AROM on its own.

Population, materials and methods

Twenty subjects (mean age: 36 ± 12 years) who were undergoing treatment within our rehabilitation center participated voluntarily in this study. They gave their informed consent to the experimental procedure as required by the Helsinki declaration (1964) and the local Ethics Committee. All subjects were cared for following a trauma with a lesion on the PIP ligaments inducing a ROM loss. The etiology of the PIP joint limitations is thus a joint contracture with passive and active ROM equal prior to treatment.

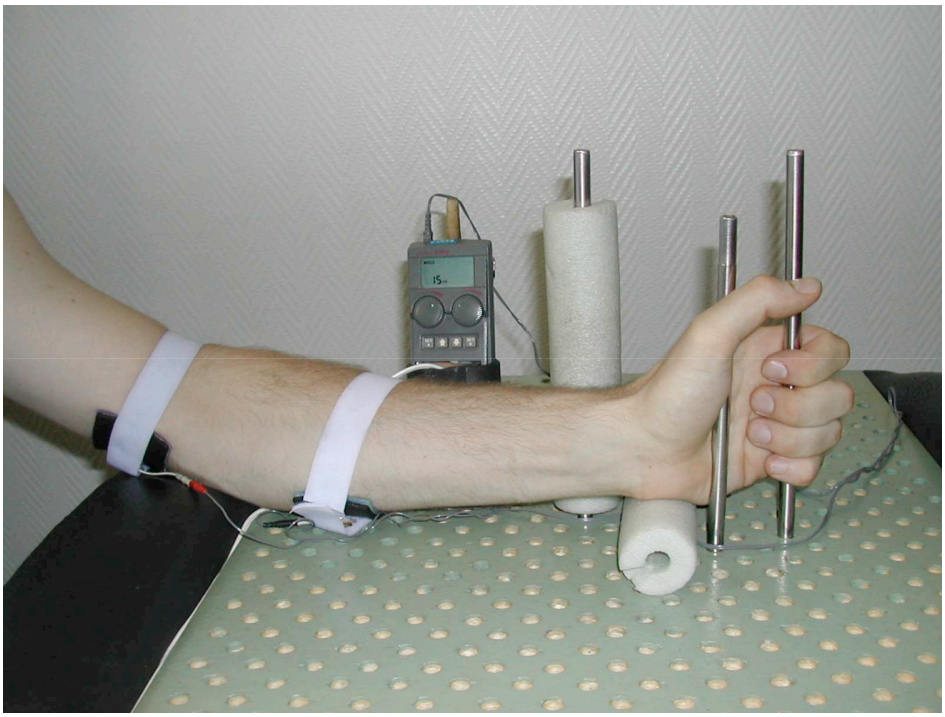

Figure 1. ST sessions: patient's hand was installed on a hand rehabilitation Canadian board with electrodes onto the median nerve and the SFF muscle belly

Joint ROM recovering sessions started when pain had gone, patients were cared for 2 times a week for 3 weeks and measurements were taken on each treatment session. Before each session, patients were randomly assigned by draw lots either to a 15 min AROM session, or to a 15 min ST session. Prior to sessions, a five-minute passive mobilization session was performed. After the session of AROM or ST, 5 min tens and 5 min of massage were performed on the PIP and patients were allowed use of their hands in between without pain sensation. During sessions, the frequency of the movements was identical among both conditions and set at six finger flexions of five seconds per minute with five seconds rest period after each muscle contraction. Patients used the Elpha 2000 (Danmeter A/S) stimulator for NMES [17] [Fig. 1]. This device, on a 9 Volts' tension, produced up to 60 mA contingent upon the maximum intensity tolerated by the patient. Current intensity was set prior to each session and always superior to 11 mA that is the mean motor threshold for muscles and the electrodes positioning of our study. The current is biphasic and asymmetric with a mean equal to zero in order to avoid any caustic damage, pulse width of 200 μs and pulse repetition rate of 30 Hz [10, 4] to involve comfortable contraction of muscles. The output was rammed over 1 s at the beginning and end of each contraction for comfort and also to attempt to prevent stretch reflexes in the antagonist muscles in response to sudden movements. This configuration is the clinical protocol applied in our rehabilitation center for many years [17].

The patient's hand was installed on a hand rehabilitation Canadian board to immobilize the metacarpalphalangeal (MCP) and wrist joints in extension [9, 16] [Fig. 1] to

avoid any passive ROM limitation induced by the wrist and finger extensor muscles and to make sure that the wrist and MCP joints are in the same exact position in both conditions (AROM and ST). PIP and DIP joints are free to move in maximal ROM involved by the concentric muscular contraction in AROM or ST condition.

Both sponge electrodes were placed on the skin, in a monopolar way, with an electrode interjecting an electrical stimulation onto the median nerve and the other onto the muscular belly of the superficial flexor of fingers (SFF) [Fig. 1]. Exact positioning choice of the muscular electrode varied from individual to individual being based on which would get the best PIP flexion.

ROM was measured in a passive way by a physical therapist using a GEMMSOR finger goniometer, elbow at 120° flexion, wrist and MCP under extension on the hand rehabilitation Canadian board, distal interphalangeal joint in maximal extension position. The ROM measure was performed just before and just after each session.

Results obtained in these three conditions were averaged for each subject to calculate the mean flexion ROM recovery for each treatment. The statistical test used for the analysis was the non parametrical test of Wilcoxon for paired samples.

Results

Analyses of the ROM measures obtained before and after each treatment showed that all subjects increased their ROM after each treatment ($P<0.001$) [Table I].

Interestingly, ROM recovery was higher following the ST than the AROM treatment ($P<0.001$). It is to be point out that the mean ROM gain for all but one patient (Patient 15) is better with ST than with AROM [Table I].

Patients	Mean ROM gains		NMES Benefit
	AROM	ST	
1	4	12	+8
2	2	20	+18
3	4	6	+2
4	22	25	+3
5	9	12	+3
6	4	8	+4
7	4	8	+4
8	6	9	+3
9	4	6	+2
10	5	8	+3
11	3	5	+2
12	2	4	+2
13	4	6	+2
14	10	19	+9
15	3	3	+0
16	3	9	+6
17	4	10	+6
18	6	12	+6
19	13	24	+11
20	4	6	+2

Table I. Mean values of gains and NMES benefits in degrees

Discussion

The aim of this study was to compare the effects of the AROM and ST treatments on the ROM recovery at the PIP following sprain. To address this objective, twenty patients in need of physical therapy to recover PIP ROM participated voluntarily. ROM at the PIP were measured before and after each session a finger goniometer.

Our results showed that both treatments enhanced ROM recovery at the PIP. What is more the ST treatment has a superior effect than AROM to enhance ROM of the PIP following ligament injury.

One of the most important parameters to take care and to discuss in this study is the NMES. At the first session of ST, although all of subjects were surprised by the new sensation NMES produced, they all tolerated it. None of them dropped out once they felt stimulation. From the second session, all of them were already accustomed. The only difference remaining between the subjects was the intensity level of the stimulation they could handle. We had neither significant problem of pain and edema related by the subjects nor any negative side effects from either treatment.

The mechanism of muscular synergies could partially explain these results. During a voluntary contraction, the agonist muscle produces the movement, while the antagonist one controls and stabilizes joints that need to remain stable [1]. This mechanism works through the myotatic reflex and the central motor patterns [13, 7]. For instance, when the SFF contracts itself to bend the PIP, the intrinsics and the finger extensors contract themselves as well to control the movement and stabilize the wrist and MP joints [20, 2]. In the traumatic context of edema, pain or fibrosis, this synergy enhances central resistances to the movement and limits the development of maximal ROM. The NMES modifies the balance of this synergy, allowing the agonist to contract itself analytically. This analytical contraction allows an enhancement of mobility enable to reach a better ROM, which could have a cyclic effect by draining edema, and therefore accentuating ROM anew.

Thus, in a future study, it would be interesting to measure the effects of the ST treatment on edema, that could be an explanation of the better ROM recovery observed consecutive to this treatment. Studies on animals have shown a direct effect of electro stimulation on the edema formation after distortion [18]. Future research should also investigate the applicability of these findings to other pathologies responsible for hand or other joints ROM restrictions and for how long the ROM gains are maintained.

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