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ICE AND PULSED ELECTROMAGNETIC FIELD TO REDUCE PAIN AND SWELLING AFTER DISTAL RADIUS FRACTURES

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Objective: **To examine the relative effectiveness of ice therapy and/or pulsed electromagnetic field in reducing pain and swelling after the immobilization period following a distal radius fracture.**

Methods: **A total of 83 subjects were randomly allocated to receive 30 minutes of either ice plus pulsed electromagnetic field (group A); ice plus sham pulsed electromagnetic field (group B); pulsed electromagnetic field alone (group C), or sham pulsed electromagnetic field treatment for 5 consecutive days (group D). All subjects received a standard home exercise programme. A visual analogue scale was used for recording pain; volumetric displacement for measuring the swelling of the forearm; and a hand-held goniometer for measuring the range of wrist motions before treatment on days 1, 3 and 5.**

Results: **At day 5, a significantly greater cumulative reduction in the visual analogue scores as well as ulnar deviation range of motion was found in group A than the other 3 groups. For volumetric measurement and pronation, participants in group A performed better than subjects in group D but not those in group B.**

Conclusion: **The addition of pulsed electromagnetic field to ice therapy produces better overall treatment outcomes than ice alone, or pulsed electromagnetic field alone in pain reduction and range of joint motion in ulnar deviation and flexion for a distal radius fracture after an immobilization period of 6 weeks.**

Key words: ice, pulsed electromagnetic field, pain, swelling, fracture.

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INTRODUCTION

Fracture of the distal radius is a typical result after a fall on an outstretched hand. Interventions following distal radius fractures are directed at restoring the anatomic alignment of the fractured bones, promoting the repair of injured structures and fostering the normal function of these structures during the healing process (1, 2). The treatment plan for each patient is determined by various factors including the pattern of bone fracture, bone quality, degree of soft tissue damage, medical condition and compliance with treatment (3). Controlling pain and swelling in the early stage can restore maximal function with minimal complications in later stages of rehabilitation.

After the immobilization period, patients usually experience pain and swelling because of inherent biochemical, histological and mechanical changes during the immobilization (1). Ice, compression and elevation are the standard physiotherapy treatments for controlling acute swelling. Ice therapy helps to reduce pain and swelling via a counter-irritation effect (4) and the gate control theory of pain. The activation of the A delta fibres (large diameter fibres) can block the pain-gate by presynaptic inhibition (5), which stops the transmission of pain signals (4, 6). Besides pain reduction, Lewis (7) proposed a "hunting response" during ice therapy, i.e. an initial vasoconstriction followed by a period of vasodilatation, which can reduce pain and subsequent capillary damage in the acute or subacute stages. The compression force during ice therapy improves contact between the ice and skin surface. This further increases the conductivity of the transmission of cold and maintains the cooling effect (8).

Pulsed electromagnetic field (PEMF) treatment has been used for therapeutic purposes for more than 40 years (9). The application of external electrical and/or mechanical energy to the area of injury induces changes to the cell environment and restores the integrity and function of tissues within the organisms (10–12). This form of therapy was approved for the treatment of delayed and non-union fractures in humans by the United States Food and Drug Administration in 1979 (13). Besides, PEMF was also found to be effective in reducing pain and oedema after soft tissue injury, osteoarthritis changes, in repairing ligaments and tendons, healing wounds and for promoting the regeneration of nerves (14–19). According to the user's manual of the Pulsed Magnetic Field Therapy System (20), this unit can be applied as an adjunct treatment with ice therapy or ultrasound treatment to enhance the effects of controlling swelling or haematoma. However, research evidence to support such an adjunct treatment is lacking.

Therefore, the objective of the present study was to examine the relative effectiveness of 5 daily applications of ice, PEMF and a combination of ice and PEMF together with exercise in reducing forearm pain and swelling and improving the range of wrist motions after the period of immobilization following distal radius fracture.

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MATERIAL AND METHODS

Subjects

Eighty-three subjects, 55 women and 28 men, (mean age 63.1 years; range 17–80) were recruited from a local out-patient clinic. No subjects dropped out of the study. The criteria for inclusion were subjects diagnosed with stable distal radius fractures who had been treated by closed reduction with 6 weeks of immobilization in plaster of Paris and who were able to communicate with the physiotherapist independently. The exclusion criteria were those suffering from reflex sympathetic dystrophy, inflammatory arthritis, peripheral vascular diseases, previous fractures or neurovascular injuries in the affected hand. Also excluded were people with heart disease; those wearing heart pacemakers or other auxiliary organs; those suffering from tuberculosis, viral infections, juvenile diabetes, mycosis and internal haemorrhages; those who were pregnant, people who had recently received deep X-ray therapy or pulsed electromagnetic treatment during the immobilization period.

Treatment procedures

A single-blinded, randomized controlled study was used. After informed consent had been obtained, demographic data including gender, age and measurement of pain and forearm swelling were recorded. The subjects were randomly allocated to receive either ice plus PEMF (group A); ice plus sham PEMF (group B); PEMF alone (group C), or sham PEMF (group D, controls). Participants were blinded as to whether they received PEMF or sham PEMF. The Pulsed Magnetic Field Therapy System, Magnetopulse International, model XKC-660W (Griffin, Australia) was used to deliver the PEMF. A U-shaped applicator, with an internal diameter of 12 cm and length of 30 cm, was used to deliver the PEMF to the wrist and hand region. The PEMF was delivered at a frequency of 50 Hz, with a field intensity of 99 gauss for 30 minutes. The parameters were determined by the guidelines in the user's manual (20).

The starting position of the subjects was a sitting positing, with the upper arm resting on the treatment table. Each participant was examined at a similar time of the day to minimize diurnal variations. Subjects in groups A and B received an ice pack made of flaked ice, which weighed about 1 kg and folded into a damp terry towel of around 30 cm long, 20 cm wide and 3 cm thick. The ice pack was placed over the dorsal aspect of the forearm for 30 minutes, covering the mid-forearm to proximal phalanx of the fingers. Those subjects receiving real or sham PEMF were told to rest their hands inside the applicator for 30 minutes. All of subjects could see the timer and the control panel working during the sham PEMF treatment. However, no PEMF output was delivered in the sham PEMF group because the circuit was disconnected at the back of the machine.

The outcomes were assessed before the intervention on days 1, 3 and 5. A home program of active wrist and finger mobilization exercises was taught to all of the subjects after the treatment. They were advised to do the exercise program twice a day, with each session lasting for 20 minutes. Written guidelines for this exercise programme were provided to the subjects and exercise compliance was checked by the therapist in each treatment session.

Outcome measures

A visual analogue scale (VAS), consists of a 10 cm horizontal line with "no pain" anchored to the left and "pain as bad as it could be" to the right, was used to record the subjective intensity of wrist pain during active movements of the wrist (21). This scale has been demonstrated to be reliable (22), generalizable (23) and valid (24). The swelling of the injured forearm was assessed by volumetric measurements (25, 26). This was performed using a commercially available hand volumeter set, which included a volumeter tank, a collection beaker and a graduated cylinder. Three trials of measurements were taken and the average reading was recorded in millilitres. A standard plastic hand-held goniometer was used to measure the wrist range of motion (ROM) in extension, flexion, supination, pronation, radial deviation and ulnar deviation. The goniometer is considered a reliable means of measuring linear joint movements if re-test reference points are marked (27). The testing position of the forearm and the alignment of the goniometer axis were standardized according to the recommendations from the clinical assessment (28).

Data analysis

Data analysis was performed using the Statistical Package for the Social Sciences Program (0PSS/PC V12.0). As significant between-group differences (tested using one-way analysis of variance) were detected in some outcome measures (see Results below) on day 1, we calculated the changes from day 1 to day 3 (by computing the differences between the 2 days) as well as the changes from day 1 to day 5. Analysis of variance followed by Duncan's *post hoc* multiple comparisons were then used to test whether the changes were significantly different between the 4 treatment groups. While the overall level of significance was set to 0.05, the Sharpened Bonferroni method was used to adjust for individual alpha level for the multiple comparisons.

RESULTS

The demographic and clinical profiles of the subjects are shown in Table I. They attended the initial evaluation at an average of 3.6 days (range 1–5 days) after the 6-week period of immobilization in plaster of Paris. The volumetric measurement ranged from 325 ml to 655 ml (mean (SD) 455 ± 68). The median baseline VAS scores during active wrist movements was 4.0 and ranged from 2 to 8.

Cumulative effects on the VAS scores

Table II shows the mean pre-intervention VAS scores at the beginning of the study, which were only low to medium ranging from 3.4 to 4.4. No significant differences in the drop (from baseline) of VAS scores on day 3 were observed between the

Table I. *Demographic and clinical characteristics of the subjects*

	Group A	Group B	Group C	Group D	
	With ice		Without ice		
Variables	True PEMF ($n = 23$)	Sham PEMF ($n = 22$)	True PEMF ($n = 22$)	Sham PEMF ($n = 16$)	p-value
Age (years) Mean (SD)	65.5 (8.1)	62.0 (10.7)	63.8 (12.6)	60.3 (20.2)	0.616
Females (%)	56.5	86.4	63.6	56.3	0.130
Days after the removal of plaster of Paris Mean (SD)	3.8 (1.2)	3.1 (1.3)	3.6 (1.2)	3.8 (1.7)	0.183
Percentage of limbs that were on the dominant side (%)	39.1	63.6	68.2	50.0	0.206

PEMF = pulsed electromagnetic field.

Table II. *Comparison of mean (SD) pre-intervention visual analogue scale pain scores between the 4 intervention groups*

Visual analogue scale	Group A With ice True PEMF ($n=23$)	Group B With ice Sham PEMF ($n=22$)	Group C Without ice True PEMF ($n=22$)	Group D Without ice Sham PEMF ($n=16$)	p-value	*Post hoc* comparison
Day 1	4.4 (1.3)	3.4 (0.80)	4.3 (1.2)	3.8 (0.77)	0.008	
Day 3	3.8 (1.3)	3.0 (0.87)	3.8 (1.1)	3.7 (1.2)	0.071	
(reduction from day 1)	0.61 (0.66)	0.41 (0.50)	0.45 (0.67)	0.06 (0.68)		
Day 5	2.6 (1.5)	2.2 (0.87)	3.3 (1.2)	3.1 (1.1)		
(reduction from day 1)	1.8 (0.8)	1.2 (0.8)	1.0 (0.8)	0.7 (0.6)	0.001	Group (A ≠ [B = C = D])

4 groups, although there was a trend that the group receiving sham PEMF without ice (i.e. group D: the control group) had the least amount of reduction. However, the mean reduction in VAS score by day 5 was significantly higher among subjects receiving PEMF and ice treatments (group A) together than that among subjects in the other 3 groups.

Cumulative effects on the volumetric measurement

Table III compares the volumetric measurements between the 4 intervention groups. The baseline measurements were comparable between the groups. By day 3, the measurements in the control group decreased less than those in the other 3 groups ($p = 0.005$). On day 5, the mean reduction between the 4 groups was significantly different again. *Post hoc* multiple (comparisons revealed that: group A (ice plus PEMF) was substantially better than groups C (PEMF alone) and D (the control); group B (ice plus sham PEMF) was substantially better than group D. No significant difference between the groups receiving one form of treatment i.e. groups B and C) was detected for the sample size used.

Cumulative effects on the range of wrist motions

From the sample size used, no significant differences were detected between the 4 groups in extension, supination and radial deviation. Therefore the results for flexion, pronation and ulnar deviation, are given in Table IV.

The improvement in flexion by day 3 was significantly higher in the 2 PEMF groups (with or without ice) than the 2 sham groups (6.3 (5.7) and 7.1 (6.1) vs 3.4 (4.5) and 3.1 (3.6), $p = 0.034$). Although a similar pattern was observed on day 5, the differences were marginally non-significant ($p = 0.084$).

In contrast, the amount of change in pronation between the 4 groups from day 1 to day 3 was not large enough to be statistically significant. The cumulative effects were more evident by day 5 ($p = 0.021$); *post hoc* analysis revealed that the significance was mainly attributable to the difference between groups A and D as well as that between B and D. The difference between group B (ice but sham PEMF) and group C (PEMF without ice) was minimal (15.9 (9.3) vs 13.4 (7.0)).

The effect of different treatments on ulnar deviation was the largest, as significant differences were observed on both day 3 and day 5. The change in ulnar deviation from day 1 to day 3 was significantly higher for group A than groups C and D. By day 5, the improvement for group A was significantly higher than the other 3 groups.

DISCUSSION

People with distal radius fractures are usually referred for physiotherapy rehabilitation after a period of immobilization. Swelling control and early mobilization is important at this stage. By day 5, our findings demonstrated that group B was significantly more effective than group D in reducing volumetric measurement. Also, group B produced significantly greater improvement in pronation ROM than the control group. The effects of ice demonstrated in the present study were consistent with those of previous studies. Using a Cryo/Cuff device, Scheffler et al. (30) examined the effects of ice treatment on

Table III. *Comparison of mean (SD) pre-intervention volumetric measurement between the 4 intervention groups*

	Group A With ice True PEMF ($n=23$)	Group B With ice Sham PEMF ($n=22$)	Group C Without ice True PEMF ($n=22$)	Group D Without ice Sham PEMF ($n=16$)	p-value	*Post hoc* comparison
Volumetric measurement (ml)						
Day 1	462 (73)	430 (45)	442 (83)	445 (68)	0.479	
Day 3	452 (72)	425 (44)	436 (81)	446 (72)		
(reduction from day 1)	10.4 (10.3)	5.2 (8.1)	6.6 (7.0)	−0.94 (12.5)	0.005	Group ([A = B = C] ≠ D)
Day 5	437 (67)	410 (47)	428 (82)	438 (73)		
(reduction from day 1)	25.0 (16.2)	20.2 (11.5)	13.9 (7.4)	6.9 (18.4)	0.001	A ≠ C; A ≠ D; B ≠ D

Table IV. *Comparing the mean (SD) cumulative effects on the range of wrist motions between the 4 treatment groups*

	Group A	Group B	Group C	Group D		
	With ice		Without ice			
Wrist motion	True PEMF ($n=23$)	Sham PEMF ($n=22$)	True PEMF ($n=22$)	Sham PEMF($n=16$)	p-value	*Post hoc* comparison
Flexion						
Day 1	33.9 (11.6)	34.3 (12.8)	32.3 (12.2)	35.9 (14.9)	0.852	
Day 3	40.2 (10.4)	37.7 (11.4)	39.3 (12.8)	39.1 (13.6)		
(Change from day 1)	6.3 (5.7)	3.4 (4.5)	7.1 (6.1)	3.1 (3.6)	0.034	Group ([A = C] ≠ ([B = D])
Day 5	46.1 (11.7)	42.5 (11.0)	43.9 (12.9)	44.1 (13.2)	0.084	
(Change from day 1)	12.2 (7.5)	8.2 (5.7)	11.6 (7.0)	8.1 (5.1)		
Pronation						
Day 1	49.4 (21.7)	54.6 (20.1)	58.4 (18.2)	52.2 (23.5)	0.524	
Day 3	55.7 (21.4)	62.1 (19.0)	63.4 (16.2)	56.6 (23.1)		
(Change from day 1)	6.3 (5.9)	7.5 (5.7)	5.0 (4.6)	4.4 (6.0)	0.300	
Day 5	67.4 (20.6)	70.5 (17.2)	71.8 (14.5)	61.3 (21.6)		
(Change from day 1)	18.0 (10.8)	15.9 (9.3)	13.4 (7.0)	9.1 (8.0)	0.021	A ≠ D; B ≠ D
Ulnar deviation						
Day 1	13.3 (4.9)	15.0 (4.6)	16.6 (5.4)	13.4 (6.0)	0.138	
Day 3	16.7 (4.9)	17.1 (4.5)	18.2 (4.8)	14.4 (5.7)		
(Change from day 1)	3.5 (2.8)	2.1 (3.0)	1.6 (2.4)	0.94 (2.0)	0.019	A ≠ C; A ≠ D
Day 5	20.4 (4.7)	19.6 (5.1)	20.5 (4.6)	16.6 (5.1)		
(Change from day 1)	7.2 (2.9)	4.6 (4.3)	3.9 (3.4)	3.1 (2.5)	0.002	A ≠ (B = C = D)
Extension						
Day 1	24.3 (12.2)	28.4 (14.1)	33.9 (9.1)	35.9 (13.3)	0.014	
Day 3	30.4 (12.1)	33.6 (13.1)	41.4 (7.1)	40.9 (12.4)		
(Change from day 1)	6.1 (5.0)	5.2 (5.0)	7.5 (4.6)	5.0 (2.6)	0.284	
Day 5	36.7 (13.3)	38.4 (13.6)	46.8 (5.2)	45.9 (10.8)		
(Change from day 1)	12.4 (7.2)	10.0 (8.0)	13.0 (7.0)	10.0 (5.2)	0.394	
Supination						
Day 1	32.8 (28.2)	43.6 (26.2)	48.4 (27.8)	48.4 (30.5)	0.225	
Day 3	42.8 (26.9)	52.5 (26.5)	56.6 (22.1)	53.1 (27.4)		
(Change from day 1)	10.0 (10.6)	8.9 (7.1)	8.2 (8.8)	4.7 (5.6)	0.272	
Day 5	50.7 (26.3)	60.9 (27.0)	63.6 (20.1)	59.4 (26.4)		
(Change from day 1)	17.8 (13.7)	17.3 (9.8)	15.2 (10.6)	10.9 (8.2)	0.235	
Radial deviation						
Day 1	7.6 (8.4)	5.5 (3.4)	6.8 (4.8)	8.4 (4.7)	0.416	
Day 3	10.0 (12.3)	7.7 (4.3)	8.9 (5.1)	10.3 (6.2)		
(Change from day 1)	2.4 (4.5)	2.3 (2.5)	2.1 (3.0)	1.9 (3.1)	0.965	
Day 5	13.7 (12.8)	10.2 (5.5)	11.4 (4.7)	12.2 (6.3)		
(Change from day 1)	6.1 (5.2)	4.8 (3.9)	4.6 (3.1)	3.8 (4.3)	0.366	

oedema and pain in postoperative ankles. In the first postoperative visit, an overall reduction in pain of 45% was found in 80% of the subjects. Weston et al. (31) studied the effects of ice therapy on subjects suffering from mild to moderate inversion sprains. They found a 50% decrease in local blood volume.

Taber et al. (32) also showed a decrease in local blood volume during the application of a cold pack. They suggested the compression from the weight of cold pack also attributed to the decrease in blood volume. In the present study, the ice pack was also placed on the dorsal aspect of the forearm, continuous pressure helped to decrease swelling. Ice limits the primary oedema resulted by causing vasoconstriction and decreasing cell permeability. As the major portion of the lymphatic and venous return takes place over the dorsal surface (33), the decrease in the oedema of the ice group maybe partly attributed to the combined effect of the ice and the compression from the weight of the ice pack. The application of ice reduced nerve conduction velocity, slowed the stretch reflex and reduced the volume of nocioceptive signals. Hence, it reduced the overall perception of pain. In addition, the release of endorphins and encephalins and the counter-irritant effect of the sensation of cold also reduced pain through the pain gate theory (4–6).

No previous study has documented the effectiveness of using a PEMF to reduce oedema after a simple radius fracture (29). From our findings, the performance in group C (PEMF alone) was not outstanding among the 3 treatment groups. The only significant finding was shown in the flexion ROM, in which group C produced greater flexion ROM than that with groups B or D. The findings of the present study can be compared with those of other related studies conducted on traumatic soft tissue injuries. As shown by Lee et al. (1997), the therapeutic effects produced by PEMF are frequency specific. Pulsed magnetic fields at 17 Hz were able to suppress extravascular oedema at all stages of the process of repairing the Achilles tendon, while pulsed magnetic field at 50 Hz significantly reduced oedema in acute inflammations. More information on the choice of optimal duration of treatment is also needed. However, this has not been reported in the literature.

Different soft tissues may respond differently when exposure to PEMF (16). Electric or magnetic fields may accelerate the healing of wounds only under circumstances in which the healing process is delayed or arrested; i.e. in conditions where the electrical current is deficient or absent (34). The biophysical mechanism of the tissues affects the interaction of PEMF with the biological systems. This leads to the appearance of a "window" effect during PEMF. The "window" represents a combination of the amplitude and frequency of the PEMF within which the optimal response can be achieved (35–37). As no previous study has been conducted on reducing swelling in conditions of simple fracture, the choice of PEMF stimulation parameters in the present study was based on the guidelines provided by the user's manual of the PEMF machine. The correct choice of parameters is supposed to be effective in "increasing circulation," "reducing inflammation" or "speeding up recovery from injuries." The selected parameters in the present study (frequency of 50 Hz, with a field intensity of 99 gauss for 30 minutes) seems to fall within the effective treatment window of PEMF and was found to be beneficial in the management of distal radius fracture. However, further study is required to determine if other parameters would produce better treatment outcomes for simple fractures.

In the present study, the injured tissues may include bones, muscles, tendons, ligaments, capsules, nerves and blood vessels. The biophysical changes caused by a PEMF to these tissues and the underlying mechanisms are unclear. Further study is needed to examine the underlying mechanism of swelling reduction by PEMF, whether or not it is due to the speeding up of bone healing process.

To the best of our knowledge, the present study is the first study to report that the combination of pulsed electromagnetic treatment with ice therapy produces the best overall treatment outcomes than either ice alone or PEMF alone after a distal radius fracture. On day 5, we found that the group receiving ice therapy and PEMF (group A) demonstrated a significantly greater reduction in the VAS scores than the other 3 groups; although we must mention that the initial VAS scores were not high so that there are still not enough evidence to show that the effect of treatment on pain reduction is high. For the volumetric measurement, group A did better than groups C and D. For ROM, group A produced greater increase in flexion and ulnar deviation than most of the other groups on either day 3 or day 5. However, group A did not produce significant improvement in the joint range of wrist extension, supination and radial deviation. This may probably due to the fact that people suffering from distal radius fracture usually have more limited joint range in flexion, pronation and radial deviation. Therefore, greater improvement can be found in these directions of joint movement after receiving treatment. According to MacDermid et al. (29) who conducted a large-scale study on people with distal radius fracture ($n = 275$), they only found a small percentage of improvement in the wrist range of motion at 1 month after the immobilization period. Due to a small effect size, a larger sample size may be required to produce significant improvements in measuring the ROM of these movements. Also, further study can be conducted to investigate whether the treatment effect would vary if ice and PEMF were applied simultaneously, or sequentially (one after the other).

In conclusion, 5 days of ice therapy with exercise is effective in reducing post-immobilization swelling for people suffering from distal radius fracture. However, the addition of PEMF and ice therapy to exercise produces better overall treatments outcomes than receiving either ice plus exercise, or PEMF plus exercise, in terms of pain reduction or range of joint motion in ulnar deviation and flexion.

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