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ORIGINAL REPORT

EFFECTS OF DEEP AND SUPERFICIAL HEATING IN THE MANAGEMENT OF FROZEN SHOULDER

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Objectives: **To determine whether the addition of deep or superficial heating to stretching produces better clinical outcomes than stretching alone in the management of frozen shoulder.**
Design: **A single-blinded, randomized controlled study.**
Subjects: **Thirty subjects suffering from the stiffness phase of frozen shoulder.**
Methods: **Subjects were randomly allocated to receive: (*i*) deep heating plus stretching; (*ii*) superficial heating plus stretching; or (*iii*) stretching alone. Both heating groups received the respective treatments 3 times per week for 4 weeks. All groups received a standard set of shoulder stretching exercises. The American Shoulder and Elbow Surgeons assessment form was recorded at the baseline, sessions 6 and 12, and at the 4-week follow-up session.**
Results: **A significant improvement was seen in all groups in all outcome measures except for that of shoulder flexion range. The improvement in the shoulder score index and in the range of motion was significantly better in the deep heating group than in the superficial heating group.**
Conclusion: **The addition of deep heating to stretching exercises produced a greater improvement in pain relief, and resulted in better performance in the activities of daily living and in range of motion than did superficial heating.**

Key words: shortwave, hot pack, stretching, frozen shoulder, range of motion.

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INTRODUCTION

Frozen shoulder or adhesive capsulitis is a common insidious condition that is associated with pain and with a restricted range of motion (ROM) around the shoulder joint. Its prevalence in the general population has been estimated at between 3% and 5%. It can arise from idiopathic or post-traumatic causes. Frozen shoulder usually involves 3 phases: (*i*) the painful phase, which usually lasts for 2–9 months and leads to progressive stiffness; (*ii*) the stiffness phase, which usually lasts for 3–9 months, during which the pain gradually subsides but marked stiffness develops in all planes of the shoulder joint; (*iii*) the thawing phase, which usually persists for 12–42 months, during which there is a slow gain in motion and comfort (1, 2). Stretching exercises are a key component of exercise therapy for musculoskeletal disorders. In addition, heat modalities are frequently used as an adjuvant treatment to exercise therapy in order to help the patient regain ROM and restore function to the affected shoulder.

The rationale for achieving therapeutic goals through heating is to alter the viscoelastic properties of connective tissues (3–5). Studies have shown that a significant drop in tensile stress occurs with a rise in the temperature of soft tissues to between 40°C and 45°C, compared with that recorded at room temperature (25°C) (6–8). Heat modalities are commonly classified as superficial or deep heating agents. Examples of deep heating agents are ultrasound (9) or shortwave diathermy (SWD) (10). SWD can heat up a larger treatment area and volume of tissue than is possible with ultrasound, while ultrasound can produce some mechanical effects in addition to the heating effect. Hot pack (HP) is the most traditional method of providing superficial heating. It has been suggested that a deep heating agent could produce a greater increase in tissue extensibility than superficial heating (9, 10). Robertson et al. (10) found that, in normal healthy subjects, SWD produced a significantly greater gain in tissue extensibility than did HP. Peres et al. (11) showed that the combination of pulsed SWD and stretching exercises could significantly increase the ROM of an ankle compared with what could be achieved by stretching alone.

However, negative findings have also been reported. A previous study found that deep heat applied before stretching was no better than stretching alone in increasing the flexibility of hamstring muscles (12). However, the study involved only a 5-day treatment period, which may have been too short to produce any significant improvement in the range of the joint. Gursel et al. (13) found that true ultrasound brought no further benefits than sham ultrasound when applied in addition to other physical therapy interventions in the management of soft tissue disorders of the shoulder. However, they did not control the other physical therapy interventions that were delivered to their patients.

A study examining the effects of superficial thermal agents and shoulder stretching exercises in normal subjects concluded that the use of superficial heat in conjunction with low-load prolonged stretching produced more long-lasting changes in

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the extensibility of soft tissue than did stretching alone (14). The authors postulated that a superficial thermal agent can lead to muscle relaxation, thus reducing the resistance to stretches within and around the muscle, and consequently increasing the ROM of the shoulder (14). However, some studies found that stretching exercises alone could increase the extensibility of rats' tails (15) and the ROM of human shoulders (1, 16).

Previous studies have produced conflicting findings about the effects of heat treatment in increasing the extensibility of soft tissues. There is a lack of evidence to support the use of SWD or HP in combination with stretching in managing patients with frozen shoulder. Therefore, the aim of this study was to determine whether the addition of deep heating (using SWD) or superficial heating (using HP) to stretching exercises would produce better clinical outcomes than stretching alone in the management of frozen shoulder.

MATERIAL AND METHODS

Subjects

Thirty subjects (9 men and 21 women, age range 37–79 years, mean 59.87, standard deviation (SD) 12.45) with idiopathic frozen shoulder in the stiffness phase participated in this study. The diagnosis of frozen shoulder was made by an orthopaedic surgeon. Subjects were included if they had experienced shoulder pain and limited shoulder movement for at least 8 weeks. Subjects were excluded if they had a history of trauma to the shoulder, acute signs of inflammation over the shoulder, intrinsic shoulder pathology, were taking analgesic or anti-inflammatory drugs, had metal implants, impaired sensation of hot and cold, were pregnant, or had a cardiac pacemaker. Demographic data for the subjects are shown in Table I.

Treatment procedures

A single-blinded, randomized controlled study was conducted. The rater was blinded to the group allocation. The study was approved by a local ethics committee. After informed consent had been obtained, the subjects were randomly allocated into one of the following 3 groups: (*i*) SWD plus stretching ($n=10$); (*ii*) HP plus stretching ($n=10$); or (*iii*) stretching exercises alone ($n=10$). Randomization was performed using an on-line randomization plane (http://www.randomization.com). The subjects in the SWD and HP groups received the respective treatments 3 times per week for 4 weeks. Each treatment session lasted for 20 min. All treatment groups received a standard set of shoulder stretching exercises.

A shortwave diathermy machine (Curapuls 419, Enraf Nonius, The Netherlands) with an operating frequency of 27.12 MHz was used to deliver the deep heating treatment. The subjects were positioned comfortably sitting on a wooden chair with their back and affected arm supported. A pair of disc electrodes was placed on the anterior-posterior aspects of the affected glenohumeral joint, separated by a hand's-breadth from the surface of the body. The intensity of the current was adjusted according to the subject's subjective feeling of comfortable warmth. If the level of perceived heating changed during the application, the machine's output was adjusted to maintain the sensation of comfortable warmth throughout the treatment. For the HP group, an electrical hot pack sized 35.5 × 68.5 cm was used to deliver superficial heating. The temperature was set at 63°C. The subjects were informed that the only purpose of the heating was to produce a feeling of comfortable warmth. If they felt that the heat was excessive, the temperature of the electrical HP was adjusted immediately to ensure that the heat remained at a comfortably warm level only throughout the treatment.

Immediately after the heat treatment, subjects were asked to perform 4 stretching exercises in the following fixed sequence: stretching in external rotation, in flexion, followed by stretching in hand-behind-the-back and cross-body adduction. They were asked to repeat the stretches 4 times. Each stretch was sustained for 30 sec, with 10 sec rest between each stretch. The subjects were asked to perform the stretching exercises at home every day. Assessments were made prior to treatment at the baseline, at sessions 6 and 12, and at the 4-week follow-up session (Fig. 1). A therapist checked for compliance with the exercise regime.

Table I. *Demographic data for the subjects in the 3 groups*

	SWD + stretching ($n = 10$)	HP + stretching ($n = 10$)	Stretching alone ($n = 10$)
Age (years); mean (SD)	59.80 (12.87)	62.50 (12.13)	57.30 (13.10)
Sex F/M	5/5	8/2	8/2

There were no significant differences among the 3 groups (all $p<0.05$)
SD: standard deviation; F: female; M: male; SWD: shortwave diathermy; HP: hot pack.

Outcome measures

The American Shoulder and Elbow Surgeons (ASES) assessment form was used to measure the treatment outcomes in the present study. The ASES assessment form has been shown to be valid, reliable, and responsive to shoulder disorders (1, 17). The ASES assessment form consists of 2 parts: a patient self-evaluation section and a physician assessment section.

The patient self-evaluation section is designed to measure pain and functional limitation of the shoulder. The pain score is calculated from the patient's response to a single question about pain, using a 10-cm horizontal visual analogue scale (VAS) line. The function score is calculated from the sum of the 10 questions addressing the activities of daily living (ADL) function. The responses to the questions are scored on a 4-point ordinal scale of level of difficulty (0: unable

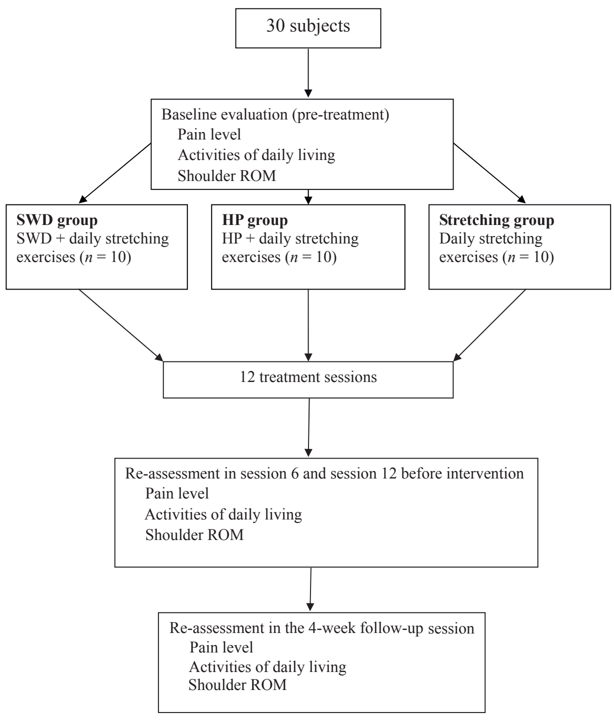

Fig. 1. Study design. ROM: range of motion; SWD: shortwave diathermy; HP: hot pack.

to do; 1: very difficult to do; 2: somewhat difficult; 3: not difficult). Both the pain score and function score are weighted equally (50 points each) and combined for a total score of 100 points, with a higher score indicating a better function. This final shoulder score was generated using the following formula (18):

(10 – VAS pain score) × 5 + (5/3 × cumulative ADL score).

The physician assessment part involved measuring the joint's ROM. The shoulder forward elevation, external rotation with the arm by the side, external rotation with the arm in 90° abduction was measured using a standard goniometer. The hand-behind-back position, the distance between 2 thumb tips (with both shoulders performing the hand-behind-the-back), was measured by using a tape measure. Cross-body adduction was measured as the distance between the antecubital fossa and the opposite shoulder (2). The subjects were positioned standing for all of the ROM tests. All of the assessments were performed by the same physiotherapist, who was blinded to each subject and intervention order throughout.

Data analysis

Statistical analyses were performed using the software package SPSS for Windows, version 10. A repeated measures analysis of variance was performed to examine the change in each outcome measure among the treatment groups and across treatment sessions. The analysis of variance was followed by Tukey's *post hoc* multiple comparisons. If the interaction effect was significant, subsequent analyses were conducted separately for the "groups" and the "sessions". The level of significance (alpha) was set at 0.05 and the Bonferroni Correction was used to adjust the inflation of alpha due to multiple comparisons.

RESULTS

None of the participants in any of the treatment groups dropped out throughout the study period. The exercise compliance of the 3 treatment groups was satisfactory. No significant difference ($p > 0.05$) was found among all of the outcome measures at the baseline. The changes in the shoulder score index and shoulder ROM in different directions over time are presented in Tables II, III and IV.

Shoulder score index

By session 12, the shoulder score index in the SWD group had increased by 63.4%, compared with 45.2% in the HP group and 38.4% in the stretching alone group (Table II). The improvement was well maintained or a further improvement was noted at the 4-week follow-up session. The overall within-group difference across the study period was significant in the 3 groups ($p < 0.001$). A *post hoc* test showed that the differences came from the comparisons between the data obtained in session 6 or session 12 to the baseline. The between-group difference was significant ($p = 0.046$). The *post hoc* test showed that the SWD group improved more than the stretching alone group did ($p = 0.036$). There was no significant difference between the HP group and stretching alone group ($p > 0.05$).

Table II. *Average group mean (SD) of the shoulder score index*

	SWD + stretching (n=10)	HP + stretching (n=10)	Stretching alone (n=10)	p-value (between-group)
Shoulder Score Index				
Baseline	41.5 (12.1)	38.9 (11.8)	33.3 (12.51)	
Session 6	56.3 (15.0)	54.2 (15.4)	45.3 (11.2)	0.046
Session 12	67.8 (15.1)	56.5 (14.1)	46.1 (12.7)	
4-week follow-up	71.3 (19.3)	57.8 (16.3)	53.8 (16.5)	
p-value (within-group)		<0.001		

There is no significant interaction between "session" and "group". Repeated measures ANOVA showed an overall between-group difference as 0.046, and within-group difference as <0.001.
SWD: shortwave diathermy; HP: hot pack; SD: standard deviation.

Flexion range

Since the interaction effect for this outcome was significant, analyses were conducted separately for the "groups" and the "sessions" for this outcome. By session 12, the shoulder flexion range had increased by 13.9% in the SWD group and 3.5% in the HP group (Table III). By contrast, the range in the stretching alone group decreased by 4.2%. By the 4-week follow-up session, the effect was maintained or a slight improvement was seen in the SWD and HP groups. The within-group difference across the study period was significant only in the SWD group

Table III. *Average group mean (SD) of the shoulder flexion range of motion (ROM) and shoulder cross-body adduction across the study period*

	SWD + stretching (n=10)	HP + stretching (n=10)	Stretching alone (n=10)	p-value (between-group)
Shoulder flexion range (degree)				
Baseline	129.0 (18.4)	117.9 (20.3)	137.9 (16.1)	0.068
Session 6	146.9 (13.5)	120.2 (21.0)	134.7 (16.6)	0.007
Session 12	146.9 (14.2)	122.0 (20.9)	132.1 (25.7)	0.049
4-week follow-up	148.2 (14.4)	124.7 (20.3)	137.6 (20.8)	0.031
p-value (within-group)	0.002	0.538	0.247	
Shoulder cross-body adduction (cm)				
Baseline	29.8 (3.4)	30.3 (3.9)	29.3 (3.7)	0.830
Session 6	25.9 (2.9)	29.0 (3.7)	29.4 (3.7)	0.079
Session 12	25.0 (2.2)	29.0 (3.3)	29.1 (4.4)	0.079
4-week follow-up	24.2 (2.0)	29.1 (3.5)	27.8 (5.1)	0.079
p-value (within-group)	0.000	0.000	0.000	

As there were significant interaction between "session" and "group"; a subsequent analysis of the sessions was performed separately for the 3 groups. Type I errors are corrected by the Bonferroni method.
SWD: shortwave diathermy; HP: hot pack; SD: standard deviation.

Table IV. *Average group mean (SD) of the shoulder external rotation (arm by the side and arm in 90° abduction) and hand-behind-back range of motion (ROM) across the study period*

	SWD + stretching (n=10)	HP + stretching (n=10)	Stretching alone (n=10)	p-value (between-group)
Shoulder external rotation range (arm by side) (degree)				
Baseline	50.4 (14.1)	28.2 (23.4)	39.5 (21.7)	
Session 6	59.3 (19.8)	27.6 (18.7)	39.5 (20.6)	0.009
Session 12	60.9 (14.5)	32.6 (21.1)	43.3 (22.6)	
4-week follow-up	62.1 (11.5)	32.6 (21.7)	41.1 (23.2)	
p-value (within-group)		0.008		
Shoulder external rotation range (arm in 90° abduction) (degree)				
Baseline	51.6 (18.2)	26.7 (26.0)	42.5 (18.7)	
Session 6	57.8 (22.7)	27.0 (26.5)	43.4 (20.8)	0.021
Session 12	59.6 (19.3)	30.1 (26.8)	45.7 (23.3)	
4-week follow-up	60.6 (11.0)	30.5 (24.4)	49.0 (27.2)	
p-value (within-group)		0.011		
Hand-behind-back (cm)				
Baseline	12.3 (4.8)	24.9 (11.5)	16.0 (9.6)	
Session 6	7.2 (6.1)	22.2 (11.5)	14.7 (8.1)	0.004
Session 12	7.6 (5.7)	18.5 (8.9)	14.7 (8.0)	
4-week follow-up	6.0 (7.3)	18.3 (7.5)	13.0 (6.7)	
p-value (within-group)		<0.001		

There is no significant interaction between ”session” and ”group”. Repeated measures ANOVA showed an overall between-group and within-group difference for each outcome.
SWD: shortwave diathermy; HP: hot pack; SD: standard deviation.

($p = 0.002$) and a *post hoc* test showed that the range achieved by the SWD group was significantly wider than that achieved by the HP group ($p = 0.025$). A between-group difference was found in session 6 ($p = 0.007$), session 12 ($p = 0.049$), and in the follow-up session ($p = 0.031$). However, after an adjustment was made using the Bonferroni Correction (adjusted p-value $= 0.0125$), a significant group difference was maintained only in session 6.

Shoulder cross-body adduction

By session 12, the cross-body adduction range of the SWD group demonstrated a 16.1% cumulative improvement (Table III). By contrast, the corresponding figure was only 4.3% for the HP group, and 0.7% for the stretching alone group. The treatment effects were more or less maintained in the SWD and HP groups in the 4-week follow-up session. The within-group differences were significant for the 3 groups ($p < 0.001$). A *post hoc* test showed that the difference came from the data obtained in session 6, session 12, and the 4-week follow-up session compared with the baseline. However, no significant between-group difference was found among the 3 treatment groups.

External rotation with arm by side

By session 12, the SWD group demonstrated a 14.5% gain in shoulder external rotation, compared with 21.1% in the HP group and 22.6% in the stretching groups (Table IV). The overall within-group difference across the study period was significant ($p = 0.008$). A *post hoc* test showed that the difference came from the comparison made between the 4-week follow-up and the baseline. There was significant between-group difference in the external rotation range ($p = 0.009$). The *post hoc* test showed that the SWD group achieved a greater external rotation range than did the HP group ($p = 0.007$)

External rotation with arm in 90° abduction

In all 3 treatment groups, the external rotation range of the shoulder tended to increase during the study period (within-group $p = 0.011$) (Table IV). By the 4-week follow-up session, the SWD group demonstrated a 17.4% cumulative increase, compared with 14.2% for the HP group, and 15.3% for the stretching alone group. A *post hoc* test showed that the difference came from comparisons made between session 12 and the baseline, and from the 4-week follow-up session and the baseline. The between-group difference was statistically significant among the 3 treatment groups ($p = 0.021$). The *post hoc* test indicated that the range in the SWD group was significantly greater than in the HP group ($p = 0.016$).

Hand-behind-back

The hand-behind-back distance decreased progressively over time (Table IV). By the 4-week follow-up session, there was a cumulative decrease in the group mean of 51.2% in the SWD group, 26.5% in the HP group, and 18.8% in the stretching group. The within-group difference across the study period was significant ($p < 0.001$). A *post hoc* test showed that the difference came from the comparison made between session 6, session 12 and the 4-week follow-up to that of the baseline. There was significant between-group difference in the hand-behind-back range ($p = 0.004$). The *post hoc* test showed that the gain in the hand-behind-back range achieved by the SWD group was significantly greater than that achieved by the HP group ($p = 0.003$).

DISCUSSION

The popularity of the deep heating agent SWD has declined in recent years. This may be partly due to a shortage of quality controlled studies (19–21), or because the SWD machine may cause radio-interference with other medical devices. The present study was the first to compare the effectiveness of deep heating (SWD) or superficial heating (HP) in combination with stretching in the management of frozen shoulder. Our findings demonstrated that SWD plus stretching produced a significantly greater increase in the shoulder score index than did stretching alone. Also, SWD produced a significantly greater gain in the ROM of most shoulder movements than did HP. Thus, it is important to address the issue of whether superficial heat is just as effective as deep heat therapy in the management of joint disorders such as frozen shoulder.

Pain relief

The shoulder score index is composed of a VAS and the ADL. The improvement in the shoulder score index observed in the present study could have resulted from a reduction in pain, causing patients to find it easier to perform the ADL. A study found that heat can provide a significant amount of pain relief to patients with wrist pain stemming from various causes (22). Previous studies have demonstrated that both deep and superficial heating agents can relieve pain (4, 23–26). Our results were consistent with this finding, also showing that SWD and HP produced a significant increase in the shoulder score index within the group across the study period. Interestingly, our findings showed that the SWD group had a greater increase in the shoulder score index than the HP group. The deep heating effect produced by SWD increases the temperature of localized tissue, with the result that vascular dilation is promoted and the pain threshold elevated. Such vascular improvement also accelerates the process of inflammation by increasing nutrition and oxygen supply, and by removing metabolites and waste products. This leads to a decrease in pain and swelling.

Extensibility of soft tissues

When temperature is increased, the stress-relaxation property of collagen fibres increases, which allows for deformation in these fibres when they are being stretched (27). Previous studies have reported that 15 minutes of SWD treatment increased the temperature of soft tissue (3 cm deep) by 4.58 ± 0.87°C (28, 29). By contrast, an HP treatment elevated muscle temperature by only 1°C (30). This implies that SWD could produce deeper penetration than did HP, thus increasing the extensibility of tissue. Studies have found that a deep heating agent (shortwave and ultrasound) in combination with stretching could significantly increase the ankle dorsiflexion range (9, 11). Robertson et al. (10) found that SWD could increase the ankle dorsiflexion range significantly more than HP. Our results also showed that SWD produced a significantly greater gain in shoulder range than did HP.

With regard to the shoulder ROM, no significant difference was found in cross-body adduction among the groups. The postero-inferior part of the shoulder joint is covered by a number of layers of muscle (31). It is difficult for heat to penetrate deep into the tight structures of the muscle, as the layer of muscle is thick. As a result, the rise in temperature may not be enough to produce therapeutic effects. Therefore, in our study the cross-body adduction range did not show significant between-group differences.

According to previous studies, the gain in therapeutic temperature after SWD can be maintained for around 7 min (28, 29). The subjects in our study spent at least 8 min completing the first 3 stretching exercises. When stretching in cross-body adduction was done, it may not have been possible to maintain the temperature of the collagen fibres at the therapeutic temperature level. This could have been another reason why the results of the cross-body adduction range were not significant between the groups.

Previous researchers studied the effect of heat on tissue extensibility with different treatment frequencies. The treatment frequencies that were tried varied from one treatment per day to 2 treatments per week (9–14, 22, 32). Further studies can be conducted to investigate the influence of the treatment frequency of shortwaves on increasing the extensibility of tissue.

In the present study, all subject groups received training of a standard set of shoulder stretching exercise by an experienced physiotherapist in the first treatment session. Then, a therapist checked for compliance with the exercise regime for all subjects. As we aimed to determine whether the application of various heat treatments enhanced the effectiveness of stretching exercise, the group receiving SWD or HP had more contact with the therapist compared with the exercise-alone group, which may affect the treatment outcome. This is a limitation of the study and the interpretation of our findings may need to take this factor into consideration.

In conclusion, our findings suggest that the addition of deep heating (using SWD) to stretching exercises is more effective than superficial heating (using HP) or stretching alone in improving shoulder pain and function. Also, the addition of deep heating to stretching produces a significantly greater gain in shoulder ROM (flexion, external rotation with the arm by one's side, external rotation with the arm in abduction and in the hand-behind-back position) than does the use of a superficial heating plus stretching. However, the addition of superficial heating to stretching will not produce a further enhancement of the shoulder score index or a gain in shoulder ROM for patients with frozen shoulder.

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