The Effect of Therapeutic Whirlpool and Hot Packs on Hand Volume During Rehabilitation After Distal Radius Fracture: A Blinded Randomized Controlled Trial

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Abstract

Background: Edema is a possibility with all heating modalities due to the increase in local blood flow caused by vasodilation. Despite the frequent application of superficial heat modalities, their relative effect on hand volume has not been determined for the upper extremity. The objective of this study was to compare the immediate effects of hot packs and whirlpool on hand volume for patients with distal radius fracture (DRF) and to determine whether any changes in volume between these modalities were still present 30 minutes after heat application. Finally, to determine whether there were any differences in volume change between groups after 3 repeated therapy visits. **Methods:** Sixty patients with clinically healed DRFs were divided into 2 groups. Half received therapeutic whirlpool at each therapy visit, and the other half received a moist hot pack treatment for 3 consecutive visits. Hand volume was measured before heat, after heat, and at the end of each 30-minute therapy session. **Results:** There was a significant difference between groups immediately after heat application, as patients in the whirlpool group experienced an initial volume increase greater than those who received a hot pack. When remeasured after a hand therapy session approximately 30 minutes later, this group difference in volume change was no longer significant. The overall change in volume from enrollment in the study to completion of the study 3 weeks later was not statistically different between groups. **Conclusion:** Whirlpool is a potential consideration when selecting a heat modality for patients with DRF.

Keywords: wrist fracture, modality, superficial heat, edema, volumetric assessment

Introduction

Distal radius fracture (DRF) is the most common fracture in the upper extremity,² with reported incidence being as high as 4 in 1000.⁶ The efficacy of therapy management following DRF is a subject of ongoing debate in the literature. Several authors have found that formal hand therapy programs are unnecessary for simple, uncomplicated DRF.^{5,14} In a systematic review, Valdes et al¹⁷ concluded that there was no significant difference between a supervised hand therapy program and a home exercise program for simple fractures but recommended further study for populations commonly sent to hand therapy, including those with complicated fractures and significant comorbidity. One of the potential reasons for the challenges toward the efficacy of therapy interventions could be a wide variety of practice patterns used by therapists during rehabilitation.

In a survey of more than 240 therapists, Michlovitz et al⁸ found a high variability in therapy practice patterns with DRF rehabilitation. One common theme of this survey was that nearly all therapists (>90%) use some form of heat/cold modality during the postimmobilization phase of therapy. Therapists may choose to employ superficial heat for several reasons, including improving range of motion, improving blood flow/nutrition to a localized area, and decreasing pain. However, edema is a possibility with all heating

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modalities due to the increase in local blood flow caused by vasodilation. There are several possible methods for delivering superficial heat to target tissues in the upper extremity, including moist hot packs, whirlpool baths, paraffin wax baths, and Fluidotherapy. Despite the frequent application of these modalities, the relative effectiveness of these diverse methods for heat application has not been determined for the upper extremity.

One of the most common methods of superficial heat application is the use of a moist hot pack. Several studies have looked at the benefits of hot packs, but not for the upper extremity. In the lower extremity, hot packs have been studied with mixed results. Petrofsky et al¹¹ found that the use of hot packs for 20 minutes decreased the amount of force required to move the knee by 25% when compared with cold application. Looking at hamstring flexibility, Sawyer et al¹² did not find any changes in flexibility after hot pack application, whereas Funk et al³ found that hot pack application was superior to static stretching for increasing flexibility. Although the benefits of various heat applications are important, the drawbacks/risks of these modalities also need to be considered. One effect of hot pack application that has not been previously measured is change in hand edema using this modality.

Therapeutic whirlpool baths have historically not been recommended for upper extremity heating because of the potential for increased hand volume that can occur when placing the hand in a dependent position in the whirlpool during this treatment. In a landmark study looking at volumetric changes with whirlpool use, Magness et al⁷ used a linear regression analysis to determine that volume increased by 5 mL for every degree past 94°F, but they did not comment on the overall fit of the regression line in their study. Volumetric measures in this study were taken from the midhumerus level, with total arm volumes of approximately 3000 mL. A 50-mL change in volume (an average change with immersion at 104°F) represents only a 1% percent increase in upper extremity volume based on their measurement technique. Furthermore, this study did not look at whether these changes in volume were lasting effects. This is critical because a prolonged increase in hand edema is a far more concerning outcome than a transient one. Many therapists use this study as their rationale for avoiding whirlpool as a heating modality for clinical use.

Understanding the volumetric effects of various superficial heat modalities is important as it allows clinicians to make informed decisions to achieve the desired effects for their patients. The purpose of this study was to compare the immediate effects of hot pack application and therapeutic whirlpool on hand volume for patients with DRF during the postimmobilization stage of therapy. Our hypothesis was that whirlpool would increase hand volume greater than hot pack application due to the dependent position of the hand during heating. A secondary purpose of this study was to determine whether any changes in volume between these

modalities were still present 30 minutes after heat application, and whether there were any differences in volume change between groups after 3 repeated therapy visits.

Methods

Participants

Ethics approval for study commencement was obtained from the Western University Research Ethics Board. Informed consent for study participation was obtained from all participants, and rights were protected throughout participation. Patients were included in the study if they were older than 18 years, lived in a geographic region close enough to the Health Center that allowed for 3 therapy follow-up visits, and did not have any conditions or symptoms that precluded the use of superficial heat during hand therapy treatments (complex regional pain syndrome, open wound, excessive edema, etc.).

All enrolled patients had sustained a recent DRF, received initial medical management by a fellowship-trained hand surgeon at a tertiary care center, and were referred for hand therapy treatment. Relevant demographics, including AO fracture classification type, surgical intervention, and length of immobilization prior to study enrollment, are given in Table 1. All patients who had surgical intervention had a volar locking plate for fixation. At the time of enrollment, all patients had been cleared to begin motion by their hand surgeon. Timing of therapy varied depending on whether patients were treated with cast immobilization or had surgical fixation but was not initiated until range of motion could be performed. Patients were enrolled in the study and were seen in hand therapy the same day the decision was made to discontinue immobilization.

Interventions

A flow diagram of the interventions and measurements is in Figure 1. Patients were randomized into 2 groups using a random number sequence (each group receiving a different form of superficial heat application) and were seen for 3 consecutive, weekly therapy visits. After 3 visits, patients were discharged from the study. During each of the 3 visits, measurements of hand volume were recorded at the beginning of the visit, immediately after heat application, and at the end of a 30-minute hand therapy treatment session. This effectively created a total of 9 measurements of hand volume for each patient during their enrollment in the study. The therapist measuring volume and treating the patients was blinded to group allocation.

For each of the 3 therapy visits, heat application was performed in a separate room to conceal group allocation. Patients were led to this room and provided with instruction by a therapist who was not involved in any patient measurement or treatment. During heat application, patients in

Table 1. Patient Demographics.

	Hot pack group (SD)	Whirlpool group (SD)
Days between fracture and study enrollment	39.3 (13.2)	40.0 (11.8)
Age, y	54.4 (11.3)	52.7 (16.1)
Gender, n		
Male	7	4
Female	23	26
Surgery (ORIF with volar plate), n		
Yes	7	5
No	23	25
AO classification type, n		
A	18	18
B	5	3
C	7	9
Mean volume (mL) before heat on first visit	481.7 (90.5)	449.7 (68.5)
Initial visit		
Pain visual analog scale	2.3 (1.8)	2.5 (2.1)
DASH score	40.0 (17.8)	43.3 (20.6)
PRWE	48.0 (22.4)	52.2 (21.2)
Final visit		
Pain visual analog scale	1.12 (1.16)	1.32 (1.59)
DASH score	21.1 (13.6)	24.0 (18.7)
PRWE	26.0 (19.3)	30.5 (21.3)

Note. Mean values are shown with standard deviations; ORIF = open reduction and internal fixation; DASH = Disabilities of the Arm, Shoulder, and Hand Questionnaire; PRWE = Patient Rated Wrist Evaluation.

group 1 had their forearm, wrist, and hand wrapped in a hot pack that was taken directly from a hydrocollator set to a temperature of 73°C. A standard hot pack cover and 2 layers of towel were used to prevent overheating (Figure 2). Patients in group 2 immersed the upper extremity in a whirlpool bath in a semidependent position, with the hand as close to the surface of the water as possible and the elbow flexed (Figure 3). The temperature of the whirlpool was 40°C. Patients were instructed to perform active wrist flexion, extension, radial and ulnar deviation, pronation and supination, and composite finger flexion/extension while in the whirlpool. Each exercise was to be repeated 10 times, holding each stretch for 10 seconds. The total heating time for both groups was 15 minutes, recorded by a minute timer with an alarm to alert the patient when heating time had elapsed. Once heat application was complete, patients quickly washed their hands and proceeded back to the therapy area in an adjacent room for postheat volumetric measurements. This was then followed by a 30-minute hand therapy session and a final volumetric measurement prior to departure.

Outcomes

All patients were measured by a separate certified hand therapist with at least 10 years experience who was blinded to group allocation. This same hand therapist also performed the hand therapy treatment sessions. Patients were instructed

not to reveal the type of heat intervention received to maintain blinding. Volumetric measurements were recorded with a standard volumeter and graduated cylinder (Figure 4). This method of measuring volume has excellent reliability.^{1,13} For each of the 3 visits, volume was recorded prior to heat application, immediately following 15-minute heat application, and at the end of the 30-minute therapy visit.

Statistical Methods

Statistical analysis was performed using the Statistical Package for Social Sciences (Version 20; Chicago, Illinois). With 3 measurements of volume taken for each visit, 2 change scores were calculated. The first change score was the difference in volume immediately after heat compared with the initial, cold measurement. The second change score was the overall volume change during the therapy session (difference between final posttherapy measurement and initial cold measurement).

Two separate one-way analyses of variance (ANOVAs) were used to determine whether volume change was significantly different based on group assignment immediately after heat and then after a 30-minute time lapse. As a secondary analysis, overall changes in volume from enrollment in the study to completion of the study were investigated based on group assignment. The measurement points used for this analysis were the first cold measurement on visit 1 and the cold volumetric measurement on visit 3.

Figure 1. Study design and patient flow.
 Note. CRPS = Complex regional pain syndrome.

Cold measurement time points were chosen to remove any potential short-term effects caused by the heating session during the last visit. Assumptions for these analyses were that this was an independent random sample that was normally distributed with homogeneity of variances between groups. Homogeneity of variance was confirmed using Levene's test.

Results

Sixty-eight consecutive patients were assessed for study eligibility. Sixty-one of those who met the study eligibility criteria were enrolled. A total of 60 patients with DRF completed the study, with 30 patients randomized to each group. One patient was excluded from the analysis. This

Figure 2. Hot pack application.

Figure 3. Whirlpool application.

Note. Arm is immersed with the elbow at 90° flexion with hand along the surface of the water.

patient was enrolled in the study but did not return for any follow-up therapy sessions, and no data were recorded for this patient (Figure 1). There was a significant difference between groups immediately after heat application, $F(1, 59) = 15.89$, $P < .001$, as patients in the whirlpool group experienced an initial volume increase greater than those who received a hot pack. Eta squared for this ANOVA was 0.22, indicating that 22% of the variability in volume change was due to group assignment at this time point.

The mean volumetric changes during heating sessions are shown in Figure 4. The mean group difference for volume change at this time point (with 95% confidence interval) was 4.9 mL (2.5-7.4). The average increase in volume immediately after heating for those in the hot pack group (with 95% confidence interval) was 3.6 mL (2.1-5.0), whereas the average volume increase for those in the whirlpool group was 8.5 mL (6.4-10.6). Based on the initial mean volume of the hand for each group, these increases represent a 0.7% increase in volume for the hot pack group and a 1.9% increase in hand volume for those in the whirlpool group.

When remeasured after a hand therapy session approximately 30 minutes later, this group difference in volume change was no longer significant, $F(1, 58) = 2.72$, $P = .11$. Eta squared at this time point was reduced to 0.04. The

mean group difference for volume changes at the end of the therapy session (with 95% confidence interval) was 2.6 mL (−0.6 to 5.7). Patients in the hot pack group had an overall volume change of 2.8 mL (1.1-4.6), and the whirlpool group had 5.4 mL (2.7-8.1). The overall percent change was 0.6% for the hot pack group and 1.2% for those who were in the whirlpool.

The overall change in volume from enrollment in the study to completion of the study 3 weeks later was not statistically different between groups, $F(1, 59) = 0.27$, $P = .61$. The mean difference for volume change between groups (with 95% confidence interval) was 2.0 mL (−5.6 to 9.8). Eta squared for this analysis was less than 0.01, indicating that less than 1% of the variability in volume change was due to group assignment over the course of the study.

Discussion

The initial volume change after heat was significantly greater with whirlpool than with hot pack. These findings are in line with previous work, where whirlpool has a propensity for increasing volume in the hand.¹⁵ The most important finding of this study is there was no significant difference in hand volume between patients in the whirlpool and hot pack groups at the end of the hand therapy session. Our results suggest that the initial volume increase caused by whirlpool was a transient effect, as there was no difference between groups after a 30-minute delay. This has implications for clinical decision-making as therapists could choose either modality without worry of long-term differences in volume. Even the upper limit of the 95% confidence interval for the difference between groups at this measurement time point was only 6 mL, suggesting that there is likely not a clinically important difference even at the most conservative level. This adds new, relevant information to the current literature as no previous studies investigating volumetric changes with whirlpool treatment have remeasured volume after a time lapse.

The overall change in hand volume in the whirlpool group was only 1.9% when measured immediately after heat. Previous research has suggested that placing the hand in a dependent position during whirlpool contributes to increased edema in the hand. We used a different position in our study (Figure 2), with the elbow flexed and the hand near the surface of the water during heating. In addition to positional change, patients were instructed to perform active range of motion exercises while in the whirlpool. Active motion of the hand, wrist, and forearm may have helped pump fluid away from the hand. These two factors may have contributed to a more modest increase in edema during whirlpool use than shown in previous studies.

A secondary objective within our study was to determine whether there were differences in volume change between those receiving hot pack versus whirlpool over a 3-week time period. There were no statistical

Figure 4. Summary of volumetric changes (mL) with hot pack application and whirlpool.

Note. Time points are at study enrollment prior to any heat application (cold), mean volume change immediately after heat (warm), mean volume change at the end of each therapy session (session), and final cold volumetric measurement at study completion 3 weeks after enrollment (overall). The difference between hot pack and whirlpool is only statistically significant at the warm measurement time.

differences in volumetric changes between our groups from enrollment to the final visit 3 weeks later. This is similar to the work by Toomey et al¹⁵ who were the only previous investigators to study volumetric changes that occur after whirlpool treatment in a longitudinal fashion. Their analysis compared the hand volume of patients before treatment on the first visit with hand volume after treatment up to 12 weeks later. They concluded that, while there was a short-term increase in hand volume with whirlpool, there was no long-term difference in volume that occurred following whirlpool immersion compared with a control group.

Hot pack application offers several advantages. It is an easy modality to use in the clinic, can be replicated by patients at home, and is less costly and requires less maintenance than whirlpool. Although a group difference did not exist after a time lapse in our study, hot pack application did not increase edema to the extent of whirlpool immediately after heat application. A potential disadvantage of hot packs could be uneven heat application to the hand and wrist. Hot packs also cool down during the time period of application. The most obvious disadvantage of hot pack application compared with whirlpool is that patients must remain still during the heating process. If the primary goal of using superficial heat is to increase range of motion, this disadvantage may be a significant one. While the whirlpool has the advantage of allowing motion during heat and remaining at a consistent temperature during heat application, they are

expensive, require ongoing maintenance and cleaning for infection control purposes, and are not easily replicated in the home environment.

The primary risks of using superficial heat include burns and increased edema. Burns are avoidable by ensuring proper technique, sound patient selection (ie, avoiding areas of impaired sensation or vascular compromise), and ongoing communication with the patient during the heating process. Edema is a possibility with all heating modalities due to the increase in local blood flow caused by vasodilation. In our study, this effect was greater with whirlpool than with hot pack, but this was temporary. Blood flow in the skin has been shown to increase with moist heat compared with dry.¹⁰ A temporary increase in blood flow may actually be beneficial for tissue healing, decreasing muscle spasm, reducing muscle soreness, and producing a variety of other therapeutic effects.^{4,9,10,16}

A strength of this study was that it was the first to investigate volumetric change after a 30-minute therapy visit in addition to the changes that occur during the heating process. Other strengths of this study were that randomization was performed by a therapist not involved in measurement, assessors were blinded to group allocation, and there were minimal ineligible patients and participants lost to follow-up. Fortunately, factors that may be prognostic for group differences in edema were equalized quite well through randomization without stratifying for any variables (Table 1).

The main weakness of this study was the lack of protocol standardization during the post heating therapy sessions. In general, therapy visits consisted of passive stretching and active range of motion exercises for the wrist, forearm, and hand. Variations in therapy technique, amount of stretching, and overall time spent during therapy could have affected the volumetric changes found between our postheat measurements and measurements taken at the end of the session. Another related weakness was that therapy sessions were not timed. Therapy sessions were scheduled for 30 minutes and most visits were completed within this time frame, but some visits lasted longer. The maximum length of time for any therapy session was 40 minutes. This difference of a few minutes in length of therapy time between groups may have affected volumetric change.

Superficial heat modalities can be used for several reasons, including decreasing pain and muscle soreness, increasing blood flow to a localized area, and improving range of motion. For patients with DRF, where stiffness is often present due to prolonged immobilization, the latter is most likely the primary reason for their use. In our study, whirlpool increased hand volume when compared with hot pack initially, but there was no difference between groups when measured approximately 30 minutes later. This information suggests that whirlpool could be a potential consideration when selecting a superficial heat modality for patients with DRF. Future study investigating the relative changes in range of motion with the use of these modalities would be beneficial.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

The study received institutional review board approval on August 20, 2010, from the Lawson Health Research Institute, REB #16696E.

Statement of Informed Consent

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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