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Optimizing the Composition and Delivery of Assessment and Treatment Following Distal Radius Fracture

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A thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in Physical Therapy

Abstract & Keywords

Distal radius fracture (DRF) is the most common fracture.[1] The most recent Cochrane review indicated "The available evidence from randomized controlled trials is insufficient to establish the relative effectiveness of the various interventions used in the rehabilitation of adults with fractures of the distal radius".[2]

Since the relative effectiveness of the various interventions used for rehabilitation after DRF is unknown, the main goal of this thesis is to focus on one aspect of both assessment and treatment to add to the current literature base. The first paper (Chapter 2) describes a new method using a modified finger goniometer (MFG) for measuring forearm rotation, and suggests some potential benefits for using this technique over the currently accepted method. The second paper (Chapter 3) investigates the inter-rater reliability of the MFG method. The MFG method demonstrated excellent inter-rater reliability and compared favorably to the currently accepted method for measuring the forearm.

In addition to investigating a new method to optimize assessment following DRF, this thesis also studies common modalities used for treatment. The third paper (Chapter 4) investigates the volumetric changes that occur in the hand with the use of hot packs and whirlpool, which are often used for preconditioning the wrist prior to treatment. The effect of these modalities for improving range of motion (ROM) of the wrist and forearm are reviewed in Chapter 5. Overall, whirlpool was shown to temporarily increase swelling in the hand more than hot pack, but this difference was not evident at the end of each therapy visit. Whirlpool was shown to be more effective for improving ROM of the wrist than hot pack during therapy.

In summary, this thesis provides a valuable contribution to the current literature base for rehabilitation after DRF by proposing a new method for measuring forearm rotation, investigating this method's reliability, and comparing the volumetric and ROM effects of two heat modalities commonly used for treatment. This information can be used as a building block for future research to determine best practice for the treatment of patients with DRF.

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KEYWORDS: distal radius fracture, goniometry, superficial heat modalities, edema, range of motion

Co-Authorship Statement

This thesis contains three published manuscripts and one manuscript awaiting submission. The conceptual ideas for the research, study design, data collection, statistical analysis, and writing were all performed by me, with valuable assistance and direction from my supervisor, Dr. Joy C. Macdermid, and my thesis advisory committee members, Dr. Trevor Birmingham, and Dr. Ruby Grewal. The unique contribution and co-authors of each chapter are as follows:

CHAPTER 1: INTRODUCTION

Mike Szekeres – sole author

CHAPTER 2: A NEW METHOD FOR MEASURING FOREARM ROTATION USING A MODIFIED FINGER GONIOMETER.

Mike Szekeres – primary author, conceptual idea, development of the assessment tool

Joy C. Macdermid – reviewed manuscript

Joanne Rooney – helped with development of the assessment tool, reviewed manuscript

CHAPTER 3: THE INTER-RATER RELIABILITY OF THE MODIFIED FINGER GONIOMETER FOR MEASURING FOREARM ROTATION.

Mike Szekeres- study design, data collection, primary author, data analysis

Joy C. Macdermid – assisted with study design, reviewed manuscript,

Trevor Birmingham – reviewed manuscript

Ruby Grewal – reviewed manuscript

CHAPTER 4: THE EFFECT OF THERAPEUTIC WHIRLPOOL AND HOT PACKS ON HAND VOLUME DURING REHABILITATION AFTER DISTAL RADIUS FRACTURE: A BLINDED RANDOMIZED CONTROLLED TRIAL.

Mike Szekeres – study design, data collection, data analysis, primary author

Joy C. Macdermid – study design, reviewed manuscript

Ruby Grewal – reviewed manuscript, helped with fracture classification

Trevor Birmingham – reviewed manuscript

Emily Lalone – reviewed manuscript, helped with fracture classification

CHAPTER 5: THE SHORT-TERM EFFECTS OF HOT PACKS VERSUS THERAPEUTIC WHIRLPOOL ON WRIST RANGE OF MOTION FOR PATIENTS WITH DISTAL RADIUS FRACTURE: A RANDOMIZED CONTROLLED TRIAL.

Mike Szekeres – study design, data collection, data analysis, primary author

Joy C. Macdermid – study design, reviewed manuscript

Ruby Grewal, reviewed manuscript

Trevor Birmingham – reviewed manuscript

CHAPTER 6: DISCUSSION

Mike Szekeres – sole author

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I would like to acknowledge the contributions of my thesis advisory committee, Dr. Ruby Grewal and Dr. Trevor Birmingham. They have provided guidance and assisted with editing of manuscripts published within this thesis. They were both excellent committee members, with honest, timely feedback when editing and revision of papers was needed.

Sincere thanks to Joanne Rooney, PT, who helped immensely with data collection, and also assisted with editing of Chapter 2. She was willing to be interrupted countless times in the middle of treating other patients to come and perform measurements of subjects and helped with group allocation to ensure blinding.

I would like to thank my lab mates at the Hand & Upper Limb Centre for their feedback on all of the papers found within. Special thanks goes to Emily Lalone, PhD, who assisted with classification of distal radius fracture types and contributed to editing of Chapter 3.

Last, but not least, I would like to thank my family. To my wife, Tamara, who is the love of my life. She has supported me in my personal life and in my professional career since high school. She is my best friend and the person to whom I tell everything. To my parents, who raised me to believe in hard work, respect for others, and supported me in all of my activities. My four daughters, Hannah, Morgan, Alea, and Taylor, who brighten my life every day and bring me joy and laughter every minute.

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Chapter 1

Introduction

1.1 Rehabilitation after Distal Radius Fracture

Distal radius fracture (DRF) is very common[1], and can lead to limitations in range of motion (ROM), increased swelling, pain, and ultimately reduced function. Due to the high incidence of these fractures, patients are often seen by Hand Therapists for rehabilitation. In fact, DRF is the most common diagnosis seen in hand therapy at the Roth-Macfarlane Hand & Upper Limb Centre, the location of the data collection for this thesis.

The primary goal of therapy following DRF is to restore functional use of the hand and wrist. Patient reported outcome measures such as the Patient Rated Wrist Evaluation (PRWE) and Disabilities of the Arm Shoulder and Hand Questionnaire (DASH) are often used to measure disability for patients with wrist pathology and DRF and are essential for measuring functional performance. Therapists also often focus on improving measures of impairment (ROM, grip strength, pinch strength) and use these as surrogate measures for functional performance. Previous work has shown that functional ROM of the wrist is 40 degrees of flexion, 40 degrees of extension, and 40 degrees of combined radial and ulnar deviation.[2] For the forearm, functional ROM has been shown to be 40 degrees of pronation and 60 degrees of supination.[3] One of the primary goals of therapy is consistently to improve ROM. This includes ROM for flexion/extension, radial/ulnar deviation, and pronation and supination of the forearm. In order to establish successful achievement of these goals, accurate assessment of ROM is needed, and treatment techniques that maximize ROM must be used.

1.2 Is Therapy Beneficial?

Controversy exists surrounding the efficacy of therapy for treatment of patients with DRF. In 2011, Souer et al. investigated the recovery of 94 patients who had open reduction and internal fixation (ORIF) of unstable DRF.[4] They concluded that patients who were given an independent home exercise program had better ROM, grip strength, and pinch strength than patients who attended a formal occupational therapy program. In 2014, a systematic review concluded that the available evidence was insufficient to support a home program or therapist supervised therapy program for patients with DRF.[5] Valdes et al.[6] also investigated patients with DRF ORIF, and found no significant differences in wrist ROM, grip strength, or scores on the patient rated wrist-hand evaluation

(PRWHE) for patients that received a home program versus those that had regular therapy visits with a Hand Therapist. They went on to conclude that simple cases of DRF may not need therapy, but more complex cases where a large number of comorbidities or complications exist may benefit from formal therapy programs.

Standardizing hands-on techniques is very difficult. For example, when performing passive stretching or mobilization techniques, the pressure applied by the therapist would be nearly impossible to standardize. Patient related factors, such as fracture stability or pain tolerance would also be difficult to control. Therapy programs for rehabilitation of DRF have been shown to have significant variability.[7] The choices that therapists make for specific interventions could have a profound impact of therapy outcomes. Minimizing the variability by using evidence-based techniques that have been shown to optimize chosen outcomes is essential for validating the efficacy of therapy.

1.3 Range of Motion Assessment

One area of therapy that can be standardized is assessment. ROM measurement of the wrist and forearm are important during rehabilitation of DRF to establish a baseline and document improvement over time. ROM measurements of the wrist and forearm have both been shown to have acceptable reliability, but measurement of forearm rotation proposes unique challenges that have made reliability values lower than for flexion/extension and radial/ulnar deviation.[8, 9]

Two distinct methods of forearm measurement have been published in the literature. The first involves measurement of motion at the distal radio-ulnar joint (DRUJ), and is recommended by the American Society of Hand Therapists as the standard of forearm measurement.[10] The second method involves the measurement of the hand's position in space, taking into account the pronation and supination that occurs within the carpus and hand.[11, 12] This second method has been termed "functional" forearm ROM measurement, as position of the hand is more important for function than the actual amount of motion at the DRUJ.

It is likely that both methods of forearm measurement are important. Berger and Dobyns reported that up to 40 degrees of rotation could occur at the radio-carpal and mid-carpal joints.[13] Patients with a "lax" wrist, but stiff DRUJ may still have reasonably good overall rotation. The stiffness within the DRUJ might lead to stress on the carpus during functional activity and cause other long term issues with the triangular fibrocartilage complex or other extrinsic wrist ligaments. Measuring only functional forearm rotation might miss these patients. Conversely, a patient with reasonably good DRUJ ROM and limited motion in the radio-carpal and mid-carpal joints may still have functional limitations for tasks requiring full pronation or supination. An interesting future study would be to develop a clinical ratio for the two measurements related to the contralateral side. This ratio may have prognostic ability to determine the potential for future ulnar sided wrist pain that may occur after wrist injury.

One potential reason that measurements of forearm motion have lower reliability than those measuring other wrist motions is the method of measurement. It requires placing a flat surface of a goniometer on a round surface of the forearm, necessitating visual estimation of goniometer placement. A new technique for solving this problem is the basis for part of this thesis.

1.4 Superficial Heat for Distal Radius Fracture

A second area of therapy that could be standardized across therapy centres is the choice of superficial heat modality used for the purpose of pre-conditioning the wrist during therapy. Several options exist for superficial heating of the upper extremity. These include hot packs, therapeutic whirlpool, paraffin wax baths, and Fluidotherapy™. Heat has been shown to beneficial for temporarily improving motion in the lower limb[14, 15], and is commonly used in therapy practice.[7] Despite common use in therapy, there is minimal evidence to support the use of heat for the upper extremity.

1.5 Mechanism of Heat

In vitro studies looking at the effect of heat on soft tissue have shown that increase in temperature corresponds with an increase in tissue elasticity.[16-18] The original rationale for using superficial heat clinically was to improve ROM through this mechanism. Follow up clinical studies have failed to support this mechanism of action for improving ROM through the use of superficial heat, as the actual rise in tissue temperature is minimal compared to in vitro studies and therefore unlikely to increase elasticity in the target tissue.[19, 20] One theory, arising from a systematic review of the literature on thermal agents' effect on soft tissue, is that temperature change reduces the pain response, thus allowing patients to move through greater ROM without eliciting a protective response and co-contraction.[21] Further supporting this theory, heat plus stretching has been shown to improve ROM more than just heat alone.[14, 15, 22]

As mentioned, whirlpool baths are an option for heating the upper extremity during therapy. Given the theory above, the benefit of performing ROM during the heating process may be important. This modality has not been recommended in the past, primarily because of one study that showed an increase in swelling in the hand.[23] The aforementioned study used a simple linear regression model to predict swelling changes, but did not measure patients after any time delay, and did not investigate the potential benefits of this modality for improving ROM.

1.6 Thesis Purpose

The overarching theme of this thesis is the optimization of the composition and delivery of assessment and treatment following DRF. To that end, this thesis focuses on one aspect of both assessment and treatment to add to the current literature base. Having practiced as a Hand Therapist for several years prior to this work, I have had several clinical questions that have remained unanswered during both the assessment and treatment of patients.

When measuring forearm rotation, there was always a sense of inaccuracy of measurement due to a difficulty land marking goniometer placement and the need to place the flat surface of a goniometer on the round surface of the distal forearm. This led to the development of a new technique for measurement. The "assessment" section of thesis contains the description of the new technique and potential advantages for clinical use (Chapter 2), and then follows up this description with a comparison of this new technique with the currently accepted standard of measurement in terms of inter-rater reliability (Chapter

3). Both of these papers have been recently published in the Journal of Hand Therapy. [24, 25]

There is a paucity of evidence in the literature surrounding treatment efficacy for many treatment techniques used by therapists. One of the most common treatments used for treatment of DRF is some form of superficial heat during therapy. While the exact mechanism of how heat improves ROM is unknown, it is often used at the beginning of the therapy visit to precondition the wrist and make it more amenable to stretching. The potential risk of using heat, especially after recent trauma to the wrist, is that vasodilation may lead to increased edema in the hand, leading to secondary stiffness once the immediate effects have worn off. Having used superficial heat in my own practice with seemingly positive effect, I remain surprised that very little empirical data exists for the relative effectiveness of the various methods of heat used for the upper extremity.

In the “treatment” section of this thesis, the volumetric changes that occur in the hand when using hot packs and whirlpool baths during rehabilitation are investigated (Chapter 4).[26] The final study in this thesis investigates the relative short-term effectiveness of each modality for improving ROM of the wrist and forearm during a therapy session (Chapter 5). The findings from this study have clinical implications for therapists, as improving ROM is often a primary goal in rehabilitation of the wrist. Understanding the optimal method for preconditioning the wrist prior to therapy is the first step in achieving this goal.

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Chapter 2

A New Method for Measuring Forearm Rotation using a Modified Finger Goniometer

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2.1 Introduction

Two general types of forearm motion goniometry have been reported using a standard goniometer. The first approach measures a combination of forearm and inter-carpal rotation with a modified handheld goniometer and plumb line, or by measuring a patient while holding a pencil during forearm motion.[1, 2] This approach is sometimes considered functional rotation since it is measuring the hand's position in space. The second type involves measurement of isolated forearm rotation, where measurement occurs directly at the distal radio-ulnar joint and does not include intercarpal and metacarpal motion occurring within the hand. This method of measurement is currently supported by the American Society of Hand Therapists, and several standard range of motion (ROM) textbooks.[3-5] Both approaches have been shown to have acceptable measurement properties.

One conceptual problem with measuring isolated forearm motion is that the current technique involves placing a flat goniometer arm onto the round surface of the distal forearm. (Figure 1) Placement of the goniometer is along the flexion/extension creases of the wrist just distal to the ulnar styloid, and the point of contact along the wrist is "eyeballed" to be the centre of the wrist. The assessor must also visually estimate perpendicular for the stationary arm, or align the stationary arm with the humerus. Inter-rater reliability may be limited as assessors may estimate the placement of the goniometer arms differently depending on their experience, posture, and even their positioning relative to the patient.

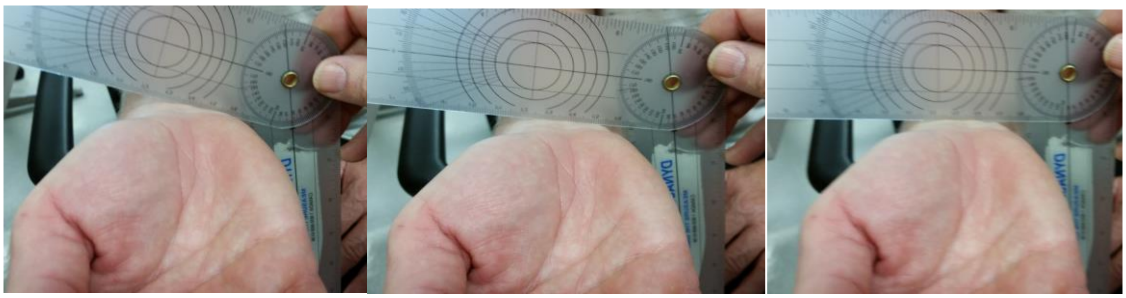

Figure 1. Placing a straight edge on the rounded surface of the distal forearm. The forearm remains in the same position, but a difference of up to 20 degrees is possible depending on angle of placement.

2.2 The Modified Finger Goniometer

The purpose of this article is to introduce another potential measuring technique for isolated forearm rotation. The tool used for measurement, a modified finger goniometer (MFG), is easily created in the clinic using a finger goniometer, fishing line, and a small weight (Figure 2). The fishing line is simply taped to the small arm of the goniometer. The tape does not affect the goniometer reading as this arm does not touch the patient and is only used for determining vertical position. The amount of weight attached to the fishing line should be sufficient to allow free motion of the small arm of the goniometer when rotated. This design offers several potential advantages to the standard goniometer currently used to measure isolated forearm rotation. The plumb line eliminates the need to estimate vertical position of one of the goniometer arms. The flat surface of the finger goniometer allows the assessor to hold the measurement tool in place over bony landmarks while measuring forearm rotation to avoid estimating a contact point with the wrist.

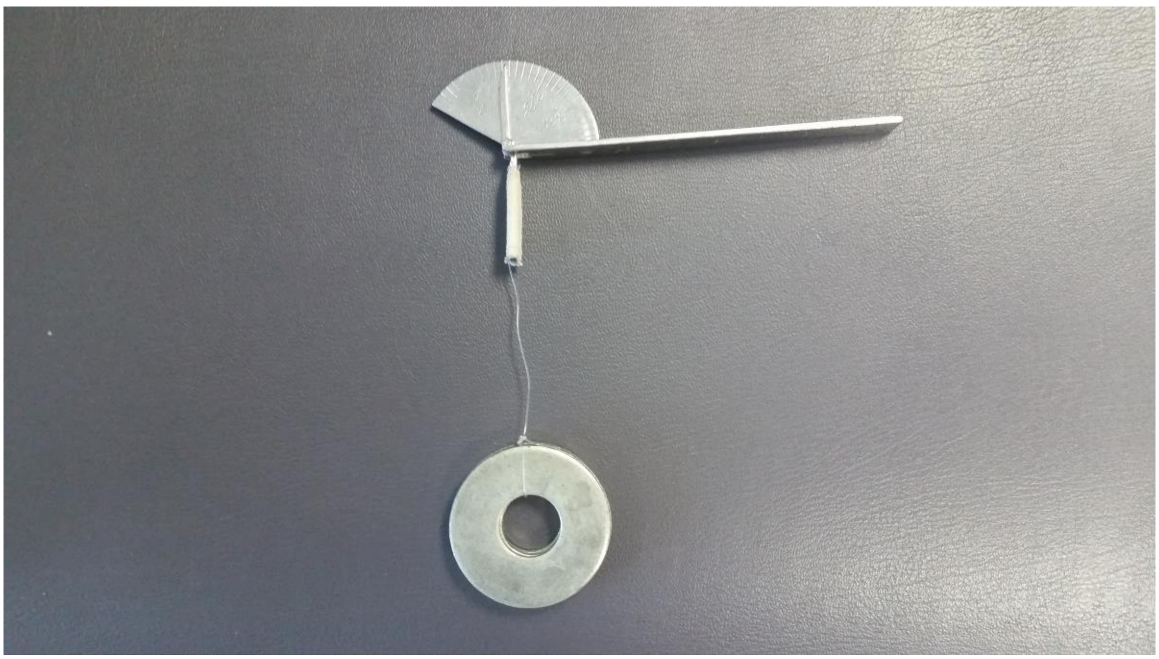

Figure 2. A modified finger goniometer (MFG), with a weight attached to the moveable arm

2.3 Measurement Technique

The patient is in a seated position with the elbow on their hip to maintain the upper arm in a vertical position, and any upper body motion is discouraged. The flat portion of the finger goniometer is placed across the dorsal bony landmarks of the wrist (Lister's tubercle of the radius and the ulnar head). The protractor portion of the goniometer is placed toward the ulnar side of the wrist. Slight pressure is placed on the goniometer between the two bony landmarks by the assessor to hold the goniometer in a fixed position. The goniometer is flipped over to allow the plumb line to measure perpendicular depending on whether pronation or supination is being measured (Figure 3).

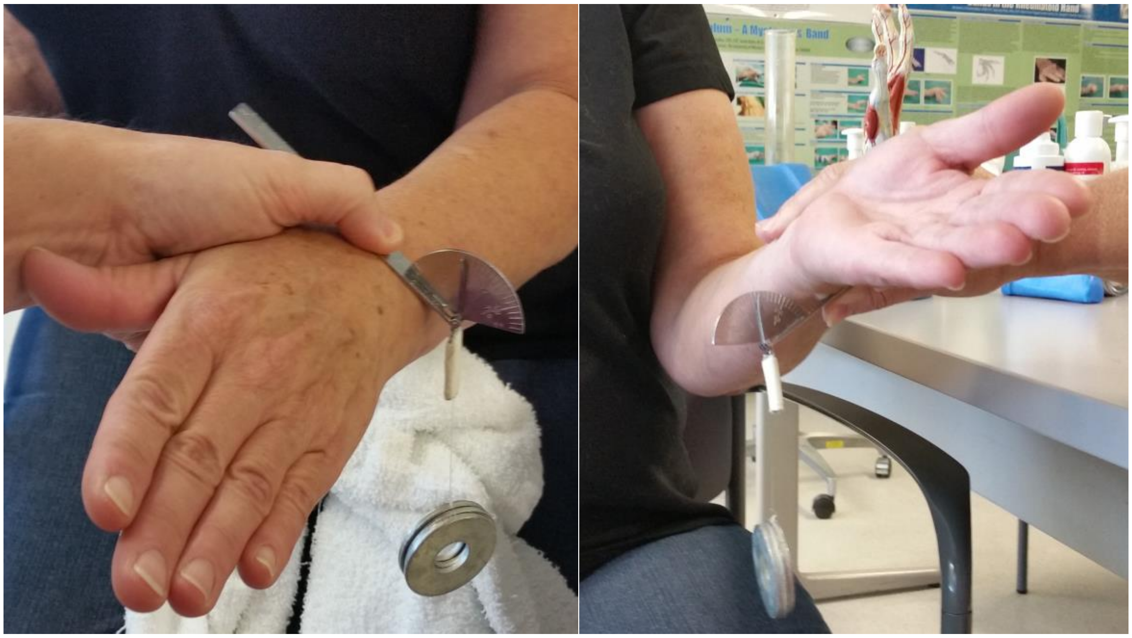

Figure 3. The modified finger goniometer technique for measuring pronation and supination. The assessor maintains pressure to align the goniometer across Lister's tubercle and the ulnar head. The goniometer is simply flipped over for measurement of supination.

2.4 Summary

There is some debate about what type of forearm measurement is most clinically useful. A hand held method assesses the ability to rotate the hand in space while a forearm based measurement focuses on distal radio-ulnar joint motions. It is possible that both approaches have value for different clinical purposes. This article outlines a method of measuring isolated forearm rotation with a tool that is simple to create in the clinic. The technique offers some potential advantages and helps eliminate the conceptual problem of placing a flat edge along a curved surface. The presence of a plumb line, and the use of bony landmarks for goniometer placement, may also present advantages for improving accuracy and decreasing measurement error. Future study is needed to determine the intra-rater and inter-rater reliability of this technique.

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Chapter 3

The Inter-rater Reliability of the Modified Finger Goniometer for Measuring Forearm Rotation

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3.1 Introduction

Limitations in forearm pronation and supination commonly occur following fractures and soft tissue injury to the wrist, forearm, and elbow. [1-3] Goniometric measurement is one of the cornerstones of assessment during rehabilitation of these injuries. The reliability of range of motion (ROM) measurement is important for accurately assessing joint limitations and for documenting change over time. ROM measurements are commonly shared between health care professionals and are a valuable component of the overall status of the patient, provided that the information obtained from the goniometric assessment is the same regardless of the assessor. Computerized tools and inclinometers have been described in the literature for measuring forearm rotation, but the standard goniometer is the most common tool used in the clinical setting.

The forearm may be measured with a standard goniometer using two different approaches. The first approach is often termed functional rotation as it includes measurement of a combination of forearm and inter-carpal rotation, effectively measuring the hand's position in space. One method for this type of measurement, using a hand held cylinder and plumb-line, was initially proposed by Flowers et al. [4] The plumb-line offers an advantage to reproducibility, as finding vertical orientation is taken care of by gravity rather than the assessor's eyes. This method has shown excellent reliability, but this study was small (n=31), was a single session, and measured passive forearm motion only. McRae[5] first measured functional forearm rotation by using a pencil held in the hand. McGarry et al. [6] later studied this technique and found upper limits of the 95% confidence intervals to be 10 degrees for both pronation and supination. Karagiannopoulos et al. [7] compared the pencil technique to the plumb-line method and found similar reliability to this method, but only included 20 injured subjects.

The second approach for measuring forearm rotation is to measure motion occurring directly at the distal radio-ulnar joint (DRUJ). This method does not include accessory intercarpal and metacarpal motion. A standard goniometer is used with the stationary arm held perpendicular to the floor, the axis along the ulnar side of the wrist, and the moveable arm along the volar wrist for supination measurement (Figure 4), and along the dorsal wrist for pronation. This method of measurement, initially proposed by Norkin and White [8], is supported by the American Society of Hand Therapists and standard ROM textbooks [9, 10], and will be referred to as the standard method in this paper.

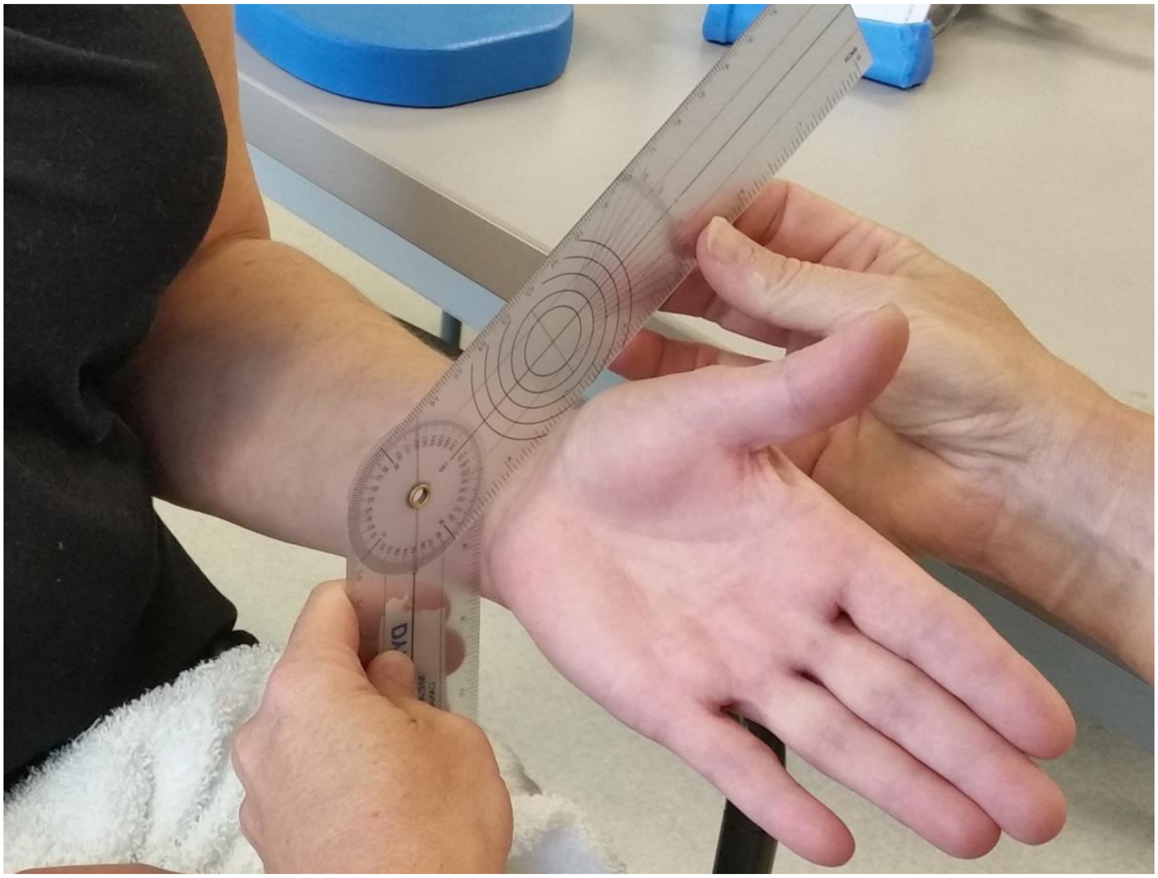


Figure 4. The currently accepted standard technique for measuring isolated forearm rotation.

Both approaches to measurement of the forearm have shown excellent test-retest reliability. Measures of inter-rater reliability, however, have been more variable. In the largest study to date (n=38), investigating the reliability of range of motion measurements of isolated forearm rotation using the standard method, Armstrong et al. concluded that ROM must change greater than 10 degrees for both pronation and supination to be considered meaningful when comparing measurements between testers. [11] This large value for minimal detectable change suggests a lack of precision in measurement, but could have been due to a relatively small number of subjects.

The current method of measuring true forearm rotation involves placing a flat goniometer along the curved surface of the flexion/extension creases of the wrist just distal to the ulnar styloid. The point of contact along the wrist is estimated to be the centre of the wrist. The assessor must also visually estimate vertical for the stationary arm. Inter-rater reliability may be limited as assessors may estimate the placement of the goniometer arms differently depending on their experience, posture, and even their positioning relative to the patient. Recently, a new technique for measuring isolated forearm rotation was introduced.[12] This method potentially reduces visual estimation of goniometer placement and vertical orientation by using bony landmarks for placement and including a plumb-line on the tool to mark vertical orientation.

The purpose of this study was to compare the inter-rater reliability of using a modified finger goniometer (MFG) for the measurement of isolated forearm rotation for patients with distal radius fractures to the currently accepted technique for isolated forearm measurement.

3.2 Methods

3.2.1 Subjects

The data for this prospective cohort study was collected as part of a three year study of patients who had sustained a distal radius fracture and were treated at the Roth McFarlane Hand & Upper Limb Centre. Patients were included in the study if they were over 18 years of age, had been cleared by a hand surgeon to begin ROM exercises for the wrist and forearm, and lived close enough to allow for weekly follow up visits. Exclusion criteria included concurrent diagnosis of complex regional pain syndrome or gross swelling of the hand that precluded the use of superficial heat during therapy. A total of 60 patients (49 females and 11 males) were enrolled in the study. Further demographic data for this cohort are in Table 1. Informed consent was obtained for study participation the rights of the subjects were protected throughout the study.

Table 1. Demographic Data

		Mean (Range)	
Overall Length of Immobilization		40 days (12-68)	
Age		53.6 years (22-81)	
		Frequency	Percent
Gender	Male	11	18.3
	Female	49	81.7
Dominance	Right	55	91.7
	Left *	5	8.3
Fractured side	Dominant *	31	51.7
	Non -Dominant	29	48.3
ORIF with volar plate		12	20.0
No surgery - closed reduction and cast		48	80.0

* Every left hand dominant person in our study fractured his or her dominant wrist

3.2.2 Measurement

Measurement of active forearm pronation and supination were recorded using two separate measurement techniques described below. Patients were measured at the beginning and end of three consecutive weekly hand therapy visits, once the treating hand surgeon requested wrist and forearm motion. This effectively created six separate time points for measurement comparisons to be analyzed. Two assessors, each with greater than 10 years of hand therapy experience, recorded measurements of active forearm pronation and supination at each time point using the current standard technique, and also with the MFG. Each assessor was blinded to the recorded measurements of the other assessor and also to measurements from previous time points. This resulted in a total of 720 forearm measurements taken during the study (60 patients, 3 visits, 2 measurement times per visit, 2 assessors).

3.2.3 Measurement Techniques

The standard forearm measurement technique has been previously described above and in displayed in Figure 4. As mentioned, as standard goniometer is used with the stationary arm held perpendicular to the floor. The axis is placed along the ulnar side of the wrist with the moveable arm along the volar wrist for supination measurement, and along the dorsal wrist for pronation.

The modified finger goniometer is a standard finger goniometer with a weight attached to the short arm and is depicted in Figure 5. Forearm rotation is measured with the patient seated, their elbow at their side, and the humerus in vertical orientation. Lister's tubercle and the ulnar head are landmarked on the dorsal surface of the wrist, and the flat portion of the goniometer is placed across these bony landmarks. The assessor places slight pressure on the goniometer between these landmarks to keep the goniometer in place. The weighted end of the goniometer sits on the ulnar side of the wrist and is simply flipped over for supination so that the weight can display the measurement angle accordingly (Figure6).

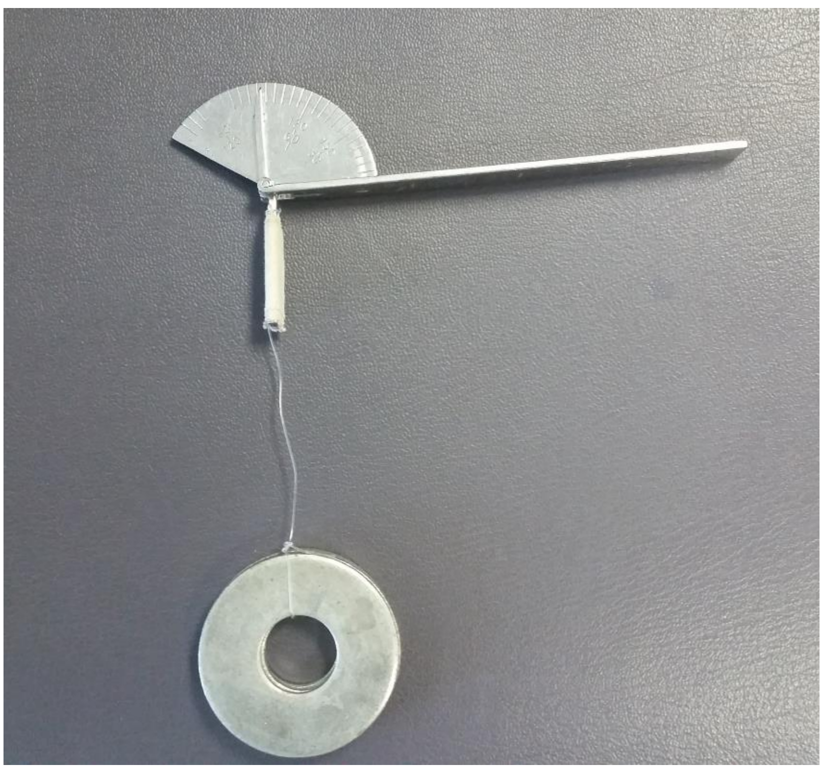


Figure 5. The Modified Finger Goniometer (MFG).

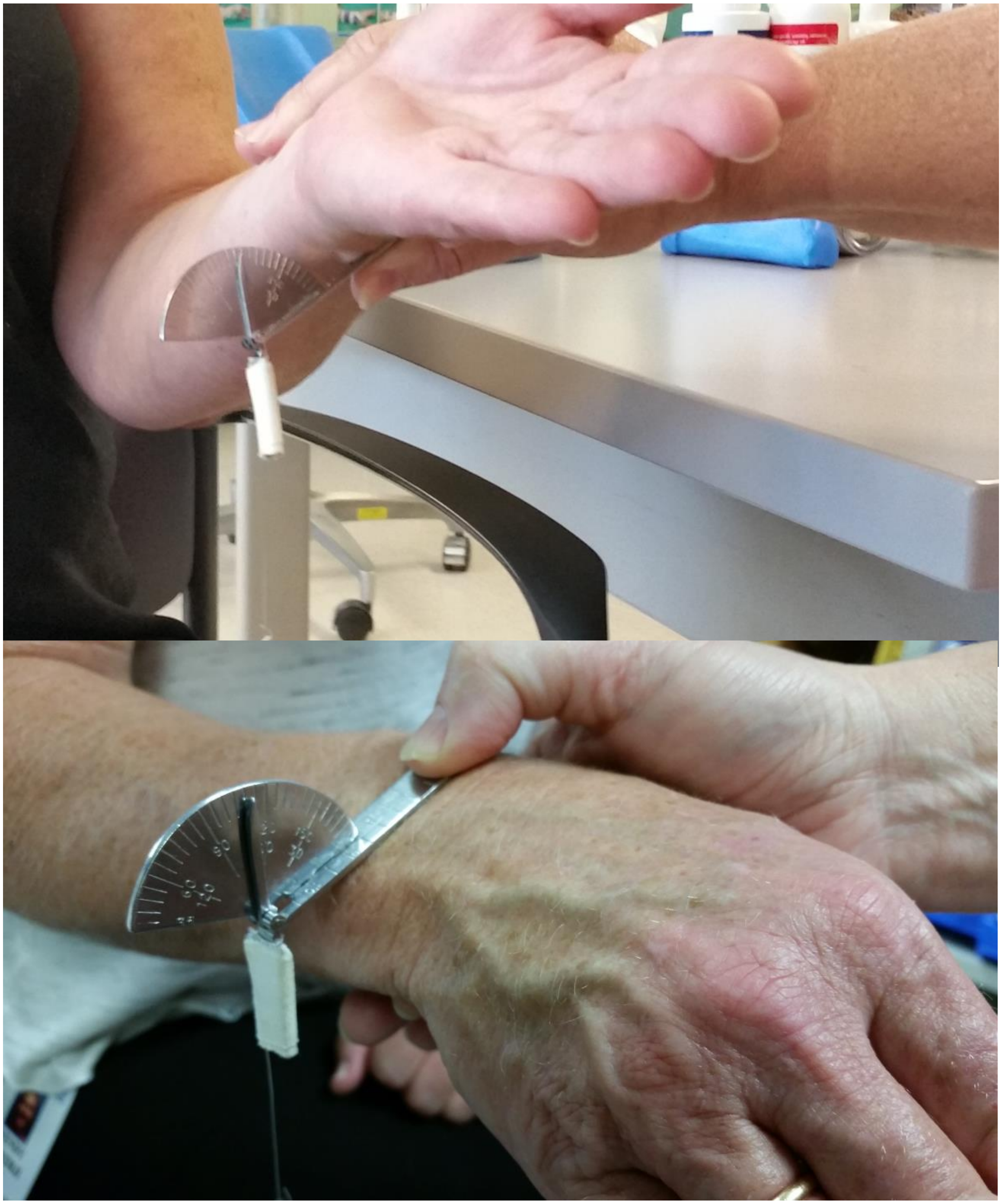


Figure 6. The MFG method for measuring forearm pronation and supination.

3.2.4 Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (Version 20, Chicago, Ill). 2-way, mixed model intra-class correlation coefficients (ICC 2,1) were calculated for both measurement techniques to determine inter-rater reliability of each method.[13] Absolute agreement was analyzed to account for systematic differences in measurement between raters. Since measurements were recorded at six different time points, six ICC's for each measurement type were calculated. To provide a more precise estimate of reliability, the 6 ICC's were averaged to create a "pooled ICC" estimate for each measurement type. The pooled ICC's were considered poor if less than 0.4, moderate between 0.4 and 0.75, and high if greater than 0.75.[14, 15]

The pooled ICC estimates were then used to calculate the standard error of measurement (SEM) and minimal detectable change (MDC) for each measurement technique. Calculation of the MDC for was performed to determine, in degrees, the measurement difference between raters to be considered different from each other. A Bland-Altman plot [16] for each measurement type was also created to determine potential bias and the nature of the limits of agreement. In addition to visual interpretation of the plot, linear regression analysis was used to determine if any systematic differences existed between assessors for each measurement type across the spectrum of forearm rotation.[17] Histograms have been added to each Bland Altman plot to highlight the distribution of measurement error.[18]

3.3 Results

Individual ICC's, along with 95% confidence intervals, are displayed in Table 2. The pooled ICC's, representing the overall average ICC for each measurement type, the SEMs, and 90% MDCs, are in Table 3. In general, the inter rater reliability of the measures were higher for supination than for pronation. The MFG demonstrated a slightly higher point estimate for the ICC than the standard method for pronation (0.86 vs 0.82). For supination, both measurement techniques displayed equally high, pooled ICC's (0.95). The SEMs for the MFG were 2.1 for pronation and 1.2 for supination, compared with 2.9 (pronation) and 1.2 (supination) for the standard technique. These translate into 90% MDCs of 5 degrees and 3 degrees for the MFG pronation/supination, compared to 7 degrees (pronation) and 3 degrees (supination) for the standard technique, respectively.

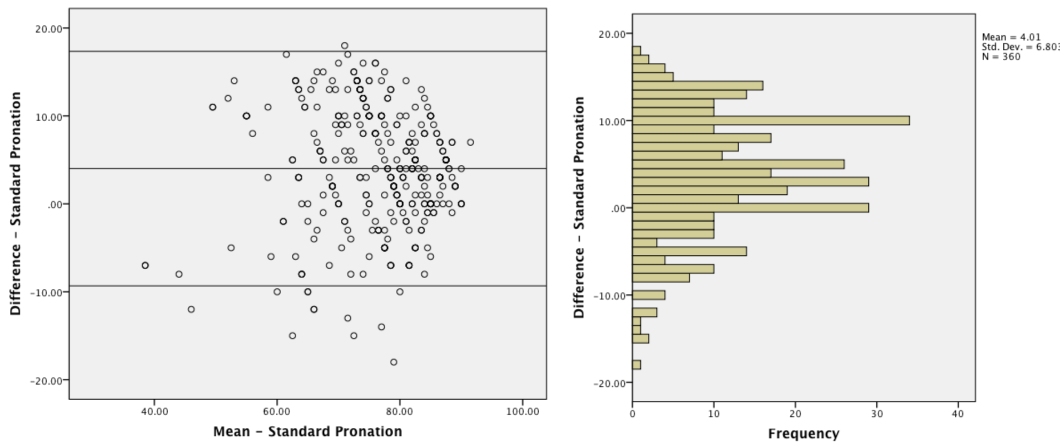
Table 2. Individual ICC's for the 6 separate measurement occasions (labeled ICC1 to ICC6). 95% Confidence Intervals are displayed for the MFG and for the currently accepted method of measuring isolated forearm motion (standard).

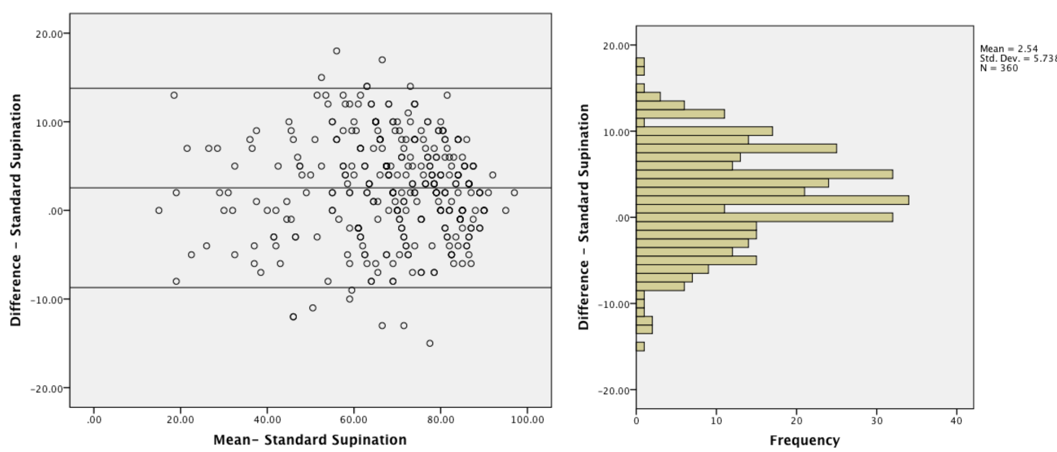
Measure	Method	ICC1	ICC2	ICC3	ICC4	ICC5	ICC6
Pronation	MFG	0.88	0.85	0.86	0.82	0.85	0.82
		(0.61-0.95)	(0.33-0.95)	(0.54-0.94)	(0.30-0.93)	(0.49-0.93)	(0.3-0.93)
	Standard	0.83	0.81	0.85	0.81	0.80	0.76
		(0.70-0.91)	(0.53-0.91)	(0.68-0.92)	(0.54-0.91)	(0.59-0.90)	(0.36-0.84)
Supination	MFG	0.95	0.96	0.95	0.93	0.96	0.96
		(0.91-0.98)	(0.92-0.98)	(0.88-0.97)	(0.89-0.96)	(0.89-0.98)	(0.92-0.98)
	Standard	0.96	0.96	0.96	0.96	0.95	0.93
		(0.94-0.98)	(0.91-0.98)	(0.92-0.98)	(0.90-0.98)	(0.92-0.97)	(0.83-0.96)

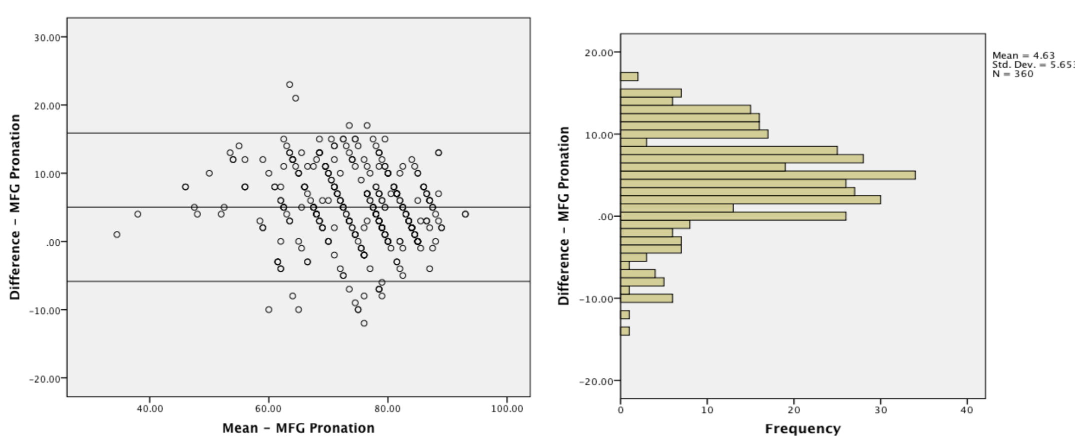
Table 3. Pooled ICC's for the 6 separate measurement occasions. 95% Confidence Intervals are displayed for the MFG and for the currently accepted method of measuring isolated forearm motion (standard). SEM for each technique and 90% MDCs were calculated from the pooled ICC's.

Measure	Method	Pooled ICC (95% Confidence Interval)	SEM	90% MDC
Pronation	MFG	0.86 (0.51-0.94)	2.1	5 degrees
	Standard	0.82 (0.64-0.90)	2.9	7 degrees
Supination	MFG	0.95 (0.92-0.97)	1.2	3 degrees
	Standard	0.95 (0.93-0.97)	1.2	3 degrees

Bland-Altman plots for pronation and supination for both measurement types are displayed in Figure 7. The mean of the difference between assessors along with the upper and lower limit of the 95% confidence interval for these differences are indicated on each plot. The mean difference between assessors was 4 degrees (-9, 17) for pronation and 3 degrees (-9, 14) for supination for the currently accepted measurement technique. For the MFG, the mean difference was 5 degrees (-6, 16) for pronation and 3 degrees (-9, 14) for supination. The histograms are included to illustrate the distribution of measurement error.


Difference – Standard Pronation
Mean – Standard Pronation
Frequency
Mean = 4.01
Std. Dev. = 6.803
N = 360


Difference – Standard Supination
Mean– Standard Supination
Frequency
Mean = 2.54
Std. Dev. = 5.738
N = 360


Difference – MFG Pronation
Mean – MFG Pronation
Frequency
Mean = 4.63
Std. Dev. = 5.653
N = 360

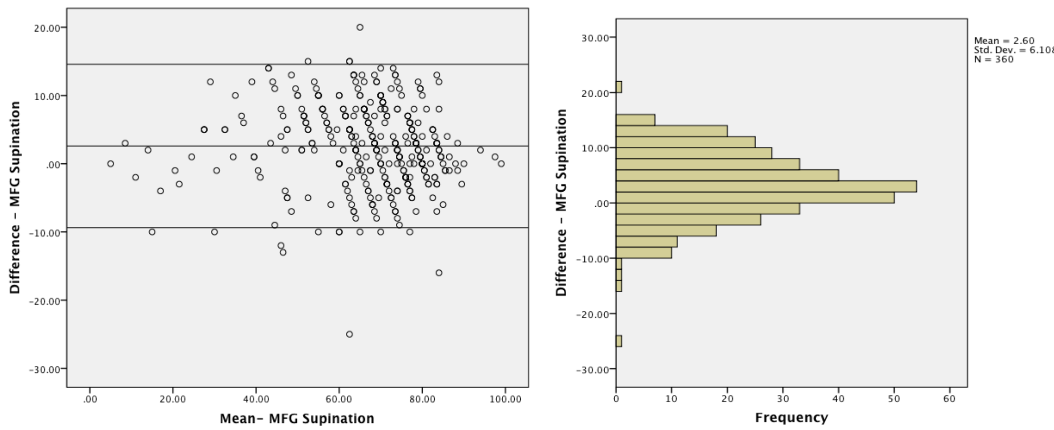


Figure 7. Bland Altman Plots and for pronation and supination for each measurement method, indicating the mean difference between assessors, along with the upper and lower limit for the 95% confidence interval of this difference. Histograms are included to illustrate the distribution of measurement error.

Linear regression analysis was used to determine whether proportional bias (larger proportion and magnitude of values above or below the mean difference score) exists within the Bland-Altman plot, using the difference in measurements between therapists as the dependent variable and mean score for each pair of measurements as the independent variable. Results from this regression analysis suggest there are no proportional biases present for any of the measurement types, as difference scores did not carry significant beta weights for predicting mean scores.

3.4 Discussion

The MFG method of measuring isolated forearm rotation demonstrated excellent inter-rater reliability and slightly narrower confidence intervals than the standard method for measurement. The MFG method offers some advantages over the current measurement technique for measuring isolated forearm rotation as it uses bony landmarks for goniometer placement and uses a plumb-line to determine vertical orientation. These advantages may reduce visual estimation and may make goniometer placement more reproducible. The current standard technique does not use bony landmarks and requires the assessor to place a straight edge on the convex surface of the wrist. By placing the goniometer across Lister's tubercle and the ulnar styloid, the assessor simply applies pressure to hold the goniometer in place while the patient rotates the forearm, effectively eliminating the conceptual problem of placing a straight edge on a round surface.

The pooled ICC's for supination were higher than for pronation. This may be due to potential accessory motions, such as leaning at the torso, and slight abduction of the shoulder and "cheating" the elbow off of the hip, that can occur during pronation despite the therapist's best efforts to minimize these. While supinating, these compensatory accessory motions can be better controlled. Even though the ICC's for pronation were generally lower, the point estimate for the pooled ICC for pronation was higher for the MFG than the standard method. We attribute this to the ease of goniometer placement and the plumb-line. Since the assessor does not need to focus on where to place the goniometer or aligning the second goniometer arm with vertical, they can potentially focus attention on minimizing the accessory motions that can occur during pronation. While the point estimate for the MFG is higher than the standard method, the confidence intervals for the ICC's overlap, indicating that the MFG is at least equivalent to the standard method in terms of inter-rater reliability.

Our MDC for both methods were slightly less than previously reported in the literature.[11] One potential reason for our reduced MDC is that it is based on a pooled ICC estimate. Other possible reasons for this are that the sample size is larger than previously used, and the all of the therapists performing the measurements had greater than 10 years experience with the standard method. In fact, the MFG was a new method introduced into the hand therapy clinic for the purpose of research and was not used clinically prior to this study. One weakness of our study is that this likely artificially reduced the potential superiority of the MFG method, since all of the assessors had multiple years experience using the standard technique and limited experience with the MFG.

The MFG technique may be beneficial for assessors with less experience, as it may be more intuitive. Reduction in visual estimation for the MFG method may have increased advantages in terms of reliability for those with less experience and further study is warranted. As mentioned, the assessors in our study were very experienced hand therapists who had measured forearm rotation nearly every day for over 10 years. The MFG technique may also prove beneficial for multi-centre trials where assessors may have variable experience.

Another potential weakness of our study was that the analysis included each of the six separate measurement sessions as independent measures. We effectively reproduced the experiment six times on the same group of patients. Even though treatment was conducted at each visit, at least one week passed between each visit, and the ROM of patients changed both during the treatment visits and from week to week, this may have reduced variability in the sample and artificially reduced our confidence intervals for both techniques. Measurements also occurred at the beginning and end of each session. Even though assessors were blinded to their previously recorded measurements and at least 30 minutes of time passed between measurements, they may have remembered the numbers from the pre-treatment measurement, thus introducing potential systematic error.

There is some debate in the literature with respect to whether measuring functional forearm rotation or isolated forearm rotation is more clinically useful or relevant. We believe it is important to know both measurements. Berger and Dobyns reported that up to 40 degrees of rotation can occur at the radio-carpal and mid-carpal joints.[19] If some people have a "lax" wrist, but stiff DRUJ, they may still have reasonably good overall rotation. The stiffness within the DRUJ might lead to stress on the carpus during functional activity and cause other long term issues with the triangular fibrocartilage complex or other extrinsic wrist ligaments. Measuring only functional forearm rotation might miss these patients. An interesting future study would be to develop a clinical ratio for the two measurements related to the contralateral side. This ratio may have prognostic ability to determine the potential for future ulnar sided wrist pain that occur after wrist injury.

In summary, this study was the largest of its kind for determining the reliability of forearm measurement. While the point estimates for the ICC's of the MFG method are equal or higher than the standard method, the confidence intervals for the ICC's overlap, indicating that the MFG is at least equivalent to the standard method in terms of inter-rater reliability. The MFG is a simple, reliable technique for measuring isolated forearm rotation, and has some potential advantages in terms of reducing visual estimation and simplifying goniometer placement.

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Chapter 4

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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https://us.sagepub.com/en-us/nam/journals-permissions

4.1 Introduction

Distal radius fracture (DRF) is the most common fracture in the upper extremity[3], with reported incidence being as high as 4 in 1000.[8] 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.[7,16] In a systematic review, Valdes et al.[19] 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 towards the efficacy of therapy interventions could be a wide variety of practice patterns used by therapists during rehabilitation.

In a survey of over 240 therapists, Michlovitz et al. [10] 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 post-immobilization 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 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 pack, but not for the upper extremity. In the lower extremity, hot pack has been studied with mixed results. Petrovksy et al.[13] found that the use of hot packs for 20 minutes decreased the amount of force required to move the knee by 25% when compared to cold application. Looking at hamstring flexibility, Sawyer et al.[14] did not find any changes in flexibility after hot pack application, while Funk et al.[4] 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 al. [9] used a linear regression analysis to determine that volume increased by 5 ml for every degree past 94 degrees Fahrenheit, 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 mid-humerus level, with total arm volumes of approximately 3000 ml. A 50 ml change in volume (an average change with immersion at 104 degrees Fahrenheit) represents only a one 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 since a prolonged increase in hand edema is 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 post-immobilization 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 if any changes in volume between these modalities was still present 30 minutes after heat application, and if there were any differences in volume change between groups after three repeated therapy visits.

4.2 Methods

4.2.1 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 over age 18, lived in a geographic region close enough to the Health Centre that allowed for three 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 centre, 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 found in Table 4. All patients that had surgical intervention had a volar locking plate for fixation. At the time of enrollment, all patients had a clinically healed distal radius fracture that was confirmed by radiographs, and were cleared to begin motion by their hand surgeon. Patients were enrolled in the study and were seen in hand therapy the same day the decision was made to discontinue immobilization.

Table 4. Patient Demographics. Mean values are shown with standard deviations.

	Hot Pack Group	Whirlpool Group
Days between fracture and study enrollment	39.3 days (13.2)	40.0 (11.8)
Age	54.4 years (11.3)	52.7 (16.1)
Gender Male	7	4
Female	23	26
Surgery (ORIF with volar plate) Yes	7	5
No	23	25
AO CLASSIFICATION TYPE A	18	18
B	5	3
C	7	9
Mean Volume Before Heat on 1st Visit	481.7 ml (90.5)	449.7 ml (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)

4.2.2 Interventions

A flow diagram of the interventions and measurements is in Figure 8. At randomization, patients were allocated into one of two groups (each group receiving a different form of superficial heat application) and were seen for three consecutive, weekly therapy visits. After 3 visits, patients were discharged from the study. During each of the three 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 nine 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.

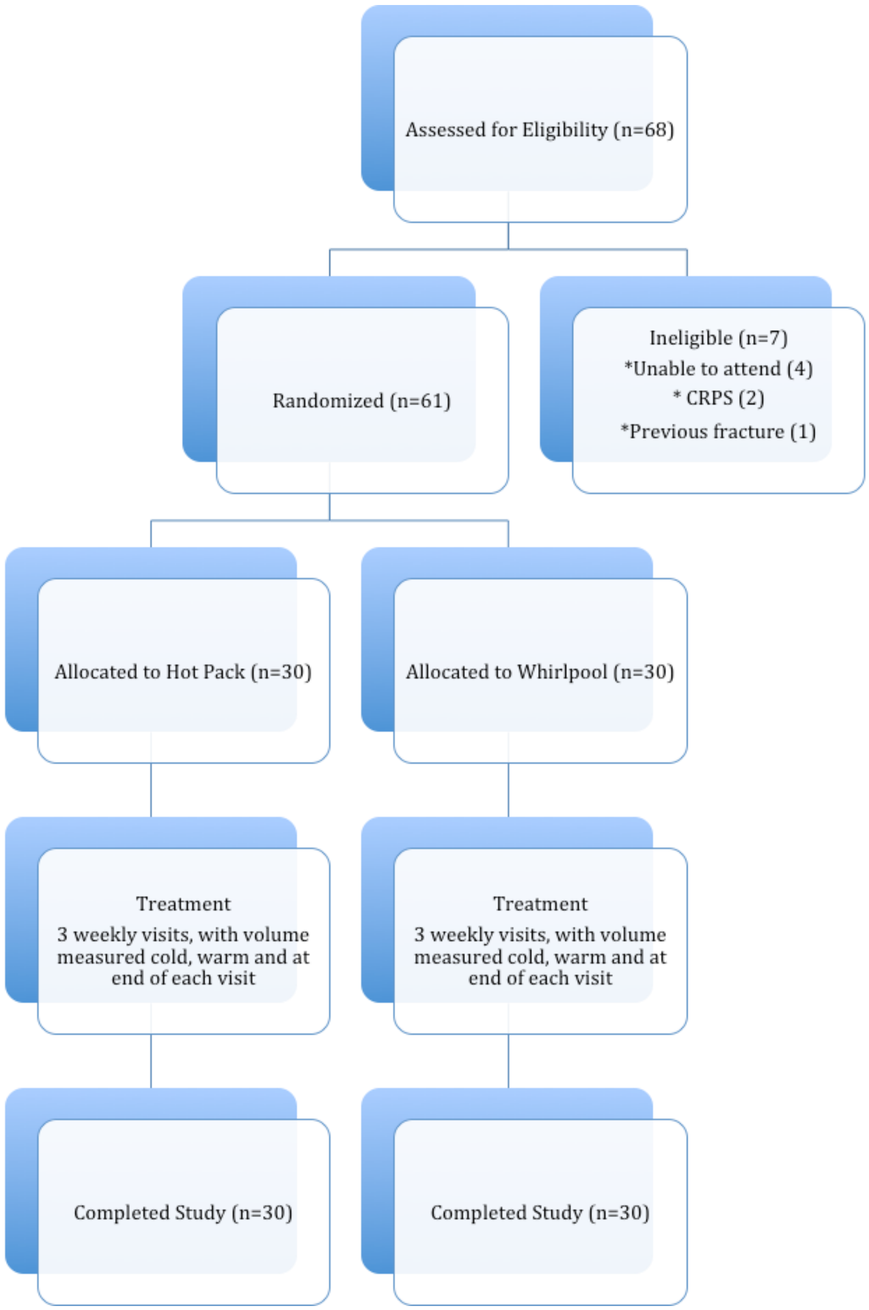

Figure 8. Study design and patient flow.

For each of the three 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 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 degrees Celsius. A standard hot pack cover and two layers of towel were used to prevent overheating (Figure 9). Patients in Group 2 immersed the upper extremity in a whirlpool bath in a semi-dependent position, with the hand as close to the surface of the water as possible and the elbow flexed (Figure 10). The temperature of the whirlpool was 40 degrees Celsius. 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 exercises 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 post-heat volumetric measurements. This was then followed by a 30 minute hand therapy session and a final volumetric measurement prior to departure.

Figure 9. Hot Pack application.

Figure 10. Whirlpool application. Arm is immersed with the elbow at 90 degrees flexion with hand along the surface of the water.

4.2.3 Outcomes

A separate certified hand therapist with at least 10 years experience who was blinded to group allocation measured all patients. 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. This method of measuring volume has excellent reliability.[2,15] For each of the three visits, volume was recorded prior to heat application, immediately following 15 min heat application, and at the end of the 30 minute therapy visit.

4.2.4 Statistical Methods

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

Two separate one-way ANOVA analyses were used to determine if 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. Cold measurement time points were chosen in order 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.

4.3 Results

68 consecutive patients were assessed for study eligibility. 61 of those who met the study eligibility criteria were enrolled. A total of 60 patients with DRF completed the study. One patient was excluded from the analysis. This patient was enrolled in the study but did not return for any follow-up therapy sessions and no data was recorded for this patient (Figure 8). 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 that 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 found in Figure 11. The mean group difference for volume change at this time point, with 95% confidence interval, was 4.9ml (2.5, 7.4). The average increase in volume immediately after heating for those in the hot pack group (with 95% confidence interval), was 3.6ml (2.1, 5.0), while the average volume increase for those in the whirlpool group was 8.5ml (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.

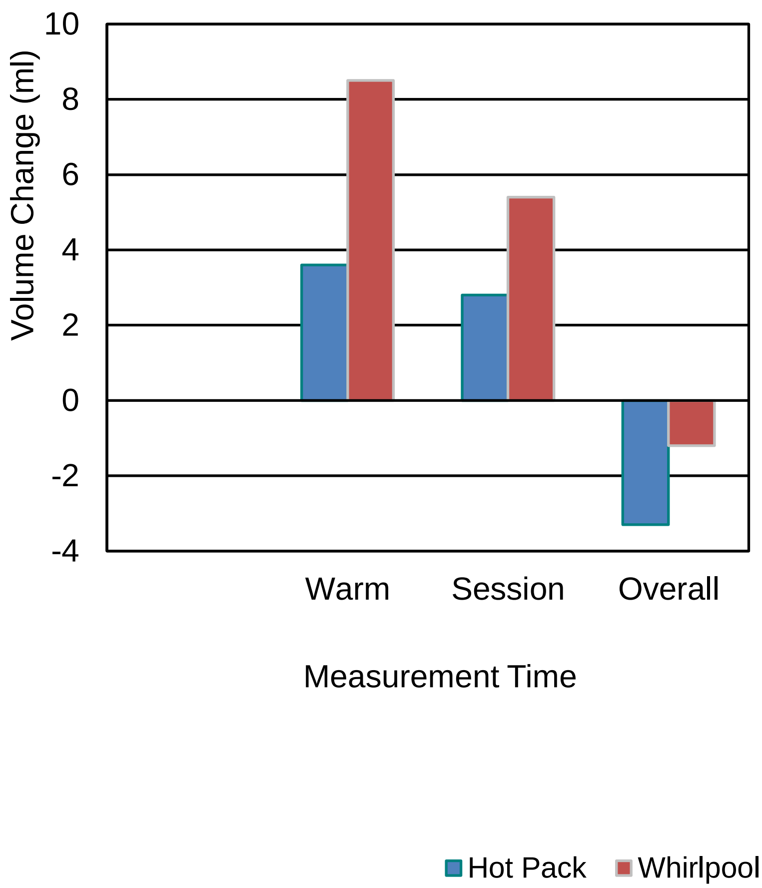

Figure 11. Summary of volumetric changes (ml) with hot pack application and whirlpool. Time points are mean volume change immediately after heat (warm), mean volume change at the end of each therapy session (session), and final cold volumetric measurement at study completion 3 weeks after enrollment (overall). The difference between hot pack and whirlpool is only statistically significant at the warm measurement time.

When re-measured after a hand therapy session approximately 30 minutes later, this group differences in volume change was no longer significant [$F(1,58)=2.72$, $p=0.11$)]. 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 2.6ml (-0.6, 5.7). Patients in the hot pack group had an overall volume change of 2.8ml (1.1, 4.6), and the whirlpool group was 5.4ml (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 [$F(1,59)=0.27$, $p=0.61$]. The mean difference for volume change between groups, with 95% confidence interval, was 2.0ml (-5.6, 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.

4.4 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.[17] 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 6ml, 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 re-measured 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 if there were differences in volume change between those receiving hot pack versus whirlpool over a 3 week time period. There were no statistical 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 al.[17] , 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 to 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 to 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 to 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 (i.e. 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 to dry.[12] 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. [5,11,12,18]

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 4).

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 post-heat 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 for improving range of motion. For patients with distal radius fracture, 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 to 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 distal radius fracture. Future study investigating the relative changes in range of motion with the use of these modalities would be beneficial.

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Chapter 5

The Short-Term Effects of Hot Packs Versus Therapeutic Whirlpool on Active Wrist Range of Motion for Patients with Distal Radius Fracture: A Randomized Controlled Trial

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5.1 Introduction

Although distal radius fractures (DRF) are among the most common fractures treated by hand therapists, a fairly recent Cochrane review indicated that “the available evidence from randomized controlled trials is insufficient to establish the relative effectiveness of the various interventions used in the rehabilitation of adults with fractures of the distal radius”.[1] Practice patterns vary widely in rehabilitation of DRF[2]; and commonly include the use of superficial heat prior to stretching and exercise as a means of maximizing recovery of joint motion in fracture rehabilitation. The use of superficial heat can often take nearly half of the therapy visit time and is a billable practice in the private sector in Canada and in the United States. Hence, there are potentially millions of taxpayer and insurance dollars spent using this modality each year, even though the level of benefit derived from their use for improving range of motion after injury has never been quantified for the upper extremity.

Superficial heat modalities are commonly used for preconditioning joints to increase joint range of motion (ROM) during the mobilization stage following wrist fracture.[2] A recent systematic review concluded that superficial heat immediately increased ROM at a variety of joints, and that a combination of heat and stretching is more effective than just stretching alone.[3] However, most of the studies in this systematic review focused on the knee, ankle, hip, and shoulder. While it is generally accepted that heat is beneficial for improving ROM of joints, the mechanism of action is not clearly understood, and the optimal method and actual benefit of heat application has not been established, especially for the upper extremity.

There are several methods of superficial heat application used for the upper extremity including moist hot packs, whirlpool baths, paraffin wax baths, and Fluidotherapy ™. Of these, hot pack application is likely the most common as it is inexpensive and can be repeated in the home environment. Therapeutic whirlpool has traditionally not been recommended for upper extremity use due to concerns about increasing edema[4], however recent work has shown this to be a transient effect.[5] Given that increases in edema may not be of concern for the long term, whirlpool may have an advantage over hot pack for increasing ROM due to the ability to perform motion during the heating process. The purpose of this study was to investigate the immediate, short-term effects of using a hot pack versus therapeutic whirlpool for improving wrist ROM during a therapy session for patients with distal radius fracture. A secondary purpose of this study was to determine if there were any group differences in ROM change after three repeated therapy visits.

5.2 Methods

5.2.1 Participants

Ethics approval was received for this study by the local institutional ethics review board. Patients who had recently sustained a DRF and were treated at a large tertiary Hand Therapy Centre between 2011 and 2014 were eligible for enrollment in this study. Patients were included in the study if they had been cleared by a hand surgeon to begin ROM exercises for the wrist and forearm, were over 18 years of age, and were able to attend weekly follow up visits. Exclusion criteria consisted of a concurrent diagnosis of complex regional pain syndrome, gross swelling of the hand that precluded the use of superficial heat during therapy, open wounds, and a pre-determined inability to attend follow up sessions. Patients were seen on the same day that the Hand Surgeon decided to allow wrist ROM. Relevant demographics, including time of immobilization prior to study enrolment, age, sex, AO fracture classification, and surgical intervention are found in Table 5. Volar locking plates were used for all patients that required surgery to obtain fracture reduction.

Table 5. Demographics.

	Hot Pack Group	Whirlpool Group
Days Immobilized (from fracture to enrolment)	39.3 days (13.2)	40.0 (11.8)
Age	54.4 years (11.3)	52.7 (16.1)
Gender (Female/Male)	23/7	26/4
Number having ORIF with volar plate	7	5
AO Fracture Type A	18	18
B	5	3
C	7	9

5.2.2 Interventions

Upon enrolment, patients were randomized into two groups using a random number sequence by a therapist not involved in data collection. All patients had active ROM of their wrist measured before and immediately after heat application for three consecutive therapy visits. Patient flow through the study is found in Figure 12. The therapist measuring ROM was blinded to group allocation. To ensure successful blinding, heat application occurred in a separate room and all patients were required to wash their hands before and after heat application to prevent moist skin from being a clue to group allocation once heating was complete.

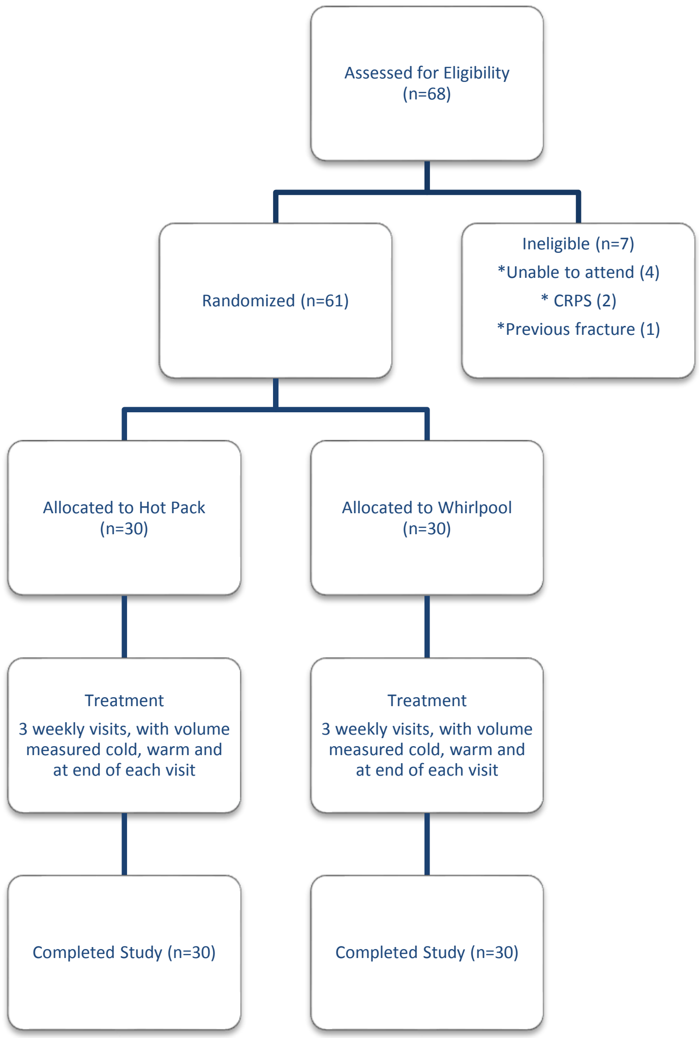

Figure 12. Patient flow through the study.

Patients in group one were placed in a moist hot pack. The hotpack came from a hydrocollator with a water temperature of 73 degrees Celsius, and wrapped with a cover and towels as shown in Figure 13. The hand and wrist were placed in the hot pack for exactly 15 minutes using a minute timer. Patients in group two had their arm placed in a whirlpool bath at 40 degrees Celsius. The arm was submersed to the level of the mid humerus, with the elbow flexed and the hand held at the surface of the water to maximize hand elevation and minimize edema (Figure 14). These patients were asked to perform active wrist flexion, extension, radial deviation, ulnar deviation, pronation and supination exercises while in the bath. Exercises were completed in the order outlined above, repeated 10 times for each direction, with each stretch held for 10 seconds. Patients came out of the whirlpool at exactly 15 minutes as indicated by a minute timer. All patients then washed their hands briefly in warm water and the blinded assessor immediately recorded heated ROM measurements. This process occurred for three consecutive therapy visits.

Figure 13. Hot pack application.

Figure 14. Whirlpool treatment. Hand is maintained near the surface of the water to minimize volumetric change in the hand.

5.2.3 Outcomes

Measurements of ROM were taken by a Hand Therapist with greater than 10 years experience who was blinded to group allocation. Patients were instructed not to tell the examiner what type of heating they received. Active wrist flexion, extension, radial deviation, ulnar deviation, forearm pronation, and supination were measured. These measurements were taken before and immediately after the heating sessions for three consecutive weekly therapy visits. Measurement techniques for wrist flexion/extension, radial/ulnar deviation were completed as recommended by the American Society of Hand Therapists using a standard goniometer.[6] For measurement of active forearm rotation, the modified finger goniometer technique was used.[7, 8]

5.2.4 Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (Version 20, Chicago, Ill). Since there were multiple ROM variables measured, a MANOVA was used to determine if the canonical variate for these multiple dependent variables was significantly different between groups. All dependent variables were analyzed for normality, skewness, and kurtosis to ensure fit within the model. Mahalinobis distance scores were used to assess for outliers.[9]

Homogeneity of variance was also assessed, although liberally, as group sizes were equal.

Our primary research question was to determine which modality offered the greatest short-term improvement in ROM during a therapy session. Thus, change scores for each ROM measurement were calculated for each therapy visit by subtracting the ROM before heat application from the ROM immediately after heat was applied. The average change per visit for each measurement was then calculated and used as the dependent variables in the MANOVA analysis. Once the MANOVA analysis was complete, several one-way ANOVAs were conducted to determine if there was a group difference in ROM changes for each measurement of the wrist, based on whether patients had hot pack treatment or whirlpool bath. Estimated marginal means for change scores of each of the measurements were also calculated along with 95% confidence intervals.

A secondary purpose of this study was to determine if there were any group differences in ROM change after three repeated therapy visits. Overall change in ROM was calculated by subtracting the initial cold ROM values from the cold values on the 3rd visit. The cold measurements were chosen to remove any short-term ROM changes caused by the heating session during the last visit. A second MANOVA was completed using these numbers to determine if the canonical variate for ROM was significantly different after three weeks of therapy depending on group assignment.

5.3 Results

A total of 61 patients were enrolled in the study. One patient did not return for any follow up sessions and was excluded, leaving 60 patients for final analysis. Data was assessed for normality to ensure fit within a MANOVA model. Shapiro-Wilks W test [10], was not significant for any of the dependent change variables, indicating that change scores were normally distributed. To detect for multivariate outliers, the maximum Mahalanobis distance score was calculated. The maximum Mahalanobis distance score in our data was 17.7. The critical value of the Chi-Square for six comparisons, with alpha=0.001, is 22.46. Therefore no outliers were present in our data.

The MANOVA analysis demonstrated that the canonical variate for ROM was significantly different between groups [$F(6,53) = 6.01$, $p<0.05$], indicating that patients in the whirlpool group had a significantly larger increase in ROM than patients receiving hot pack application. Partial eta-squared for the analysis was 0.41, indicating that 41 percent of the variance in ROM was explained by the chosen method of superficial heat. When assessing individual motions, patients in the whirlpool group had a greater improvement in wrist extension [$F(1,58) = 26.05$,

$p<0.05$, eta squared 0.31] and wrist flexion [$F(1,58) = 15.56$, $p<0.05$, eta squared 0.21]. There was no significant difference in ROM change between the whirlpool group and hot pack group for forearm rotation or radial/ulnar deviation of the wrist.

Estimated marginal means for the change scores are found in Figure 15**.** Improvement in wrist extension, with 95% confidence interval, was 3.0 degrees (2.4, 3.5) during the whirlpool sessions. Wrist flexion improved 3.3 degrees (2.5, 4.0) with whirlpool. These were significantly different from changes in extension and flexion during hot pack, which were 1 degree (0.5, 1.6) and 1.1 degrees (0.4, 1.9), respectively. There were no significant differences between whirlpool and hot pack for the other ROM measurements. Both hot pack and whirlpool had a positive effect on ROM for these measurements, as the lower end of the 95% confidence intervals were greater than zero for all measurements.

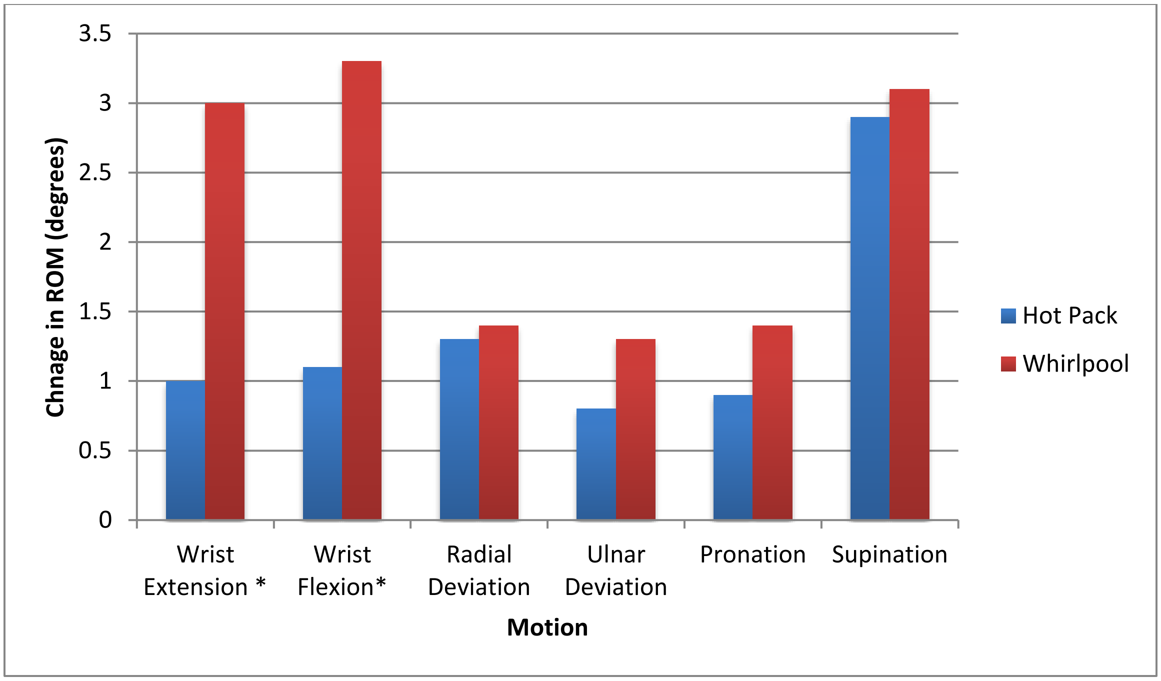

Figure 15. Changes in ROM (degrees) during hot pack application and whirlpool. (* indicates a statistically significant difference between groups)

A second MANOVA was completed to determine if there were group difference in ROM change from enrolment to discharge from the study 3 weeks later. The MANOVA was not significant [F(6,53) = 0.288, p=0.94, eta squared = 0.03], indicating that there was no significant difference between whirlpool and hot pack application for overall changes in ROM over a three week period of time.

5.4 Discussion

Whirlpool has traditionally been avoided as a superficial heating modality for the upper extremity due to concerns about the potential for increasing edema.[4] However, recent work has shown volumetric changes to be transient[5], prompting this research to compare the effect of whirlpool and hot pack on wrist ROM. The most important finding in this study was that a greater increase in ROM was observed with whirlpool than with hot pack application. This finding may impact the choice of superficial heat modality for the purpose of improving wrist ROM. Our results suggest that whirlpool should be considered as an in-clinic option when attempting to pre-condition the wrist prior to other therapy interventions.

The change scores for individual motions at the wrist showed that individuals in the whirlpool group had greater changes in wrist flexion and extension than with hot pack. One advantage of whirlpool is that motion can be performed during the heating process. Therapists choose heating modalities in the clinic for many different reasons, with improving ROM one of the most likely. The added advantage of performing motion during the heating process may be the reason that individuals who receive whirlpool had a greater improvement in flexion/extension than with hot pack. Changes in radial and ulnar deviation and pronation supination were not different between groups. One possible explanation for this is that the patients in the whirlpool group spent more time in the whirlpool working on flexion and extension. Patients were not supervised while in the whirlpool, and could have spent more time moving through wrist flexion and extension since these were the first exercises they were instructed to perform. Furthermore, the absolute amount radial deviation/ulnar deviation was relatively smaller, potentially making differences more difficult to measure and detect.

The final purpose of this study was to determine whether there were group differences in ROM changes after three weeks of therapy. Overall wrist ROM improved from visit one to visit three, but we did not detect a statistically significant difference between groups over this time period. Since both groups had improvements in ROM over the course of the study, both remain considerations for clinical use as superficial heat modalities. While the whirlpool group had a greater increase in wrist ROM than those receiving hot packs during a single therapy session, these benefits did not carry over from one therapy visit to the next.

In vitro studies looking at the effect of heat on soft tissue have shown that increase in temperature corresponds with an increase in tissue elasticity.[11-13] The original rationale for using superficial heat clinically was to improve ROM through this mechanism. Follow up studies have failed to support this mechanism of action for improving ROM through the use of superficial heat, as the actual rise in tissue temperature is minimal compared to in vitro studies and therefore unlikely to increase elasticity in the target tissue.[14, 15]

One theory, arising from a systematic review of the literature on thermal agents' effect on soft tissue, is that temperature change reduces the pain response, thus allowing patients to move through greater ROM without eliciting a protective response and co-contraction.[3] This systematic review showed variable results for cooling modalities, but consistent improvement in ROM with the use of heat. Our results mirror this, where superficial heat was beneficial for improving ROM for both of our treatment groups.

5.4.1 Study Limitations

This study population consisted of mostly female patients with fairly recent DRF who were recently cleared to begin ROM of the wrist. This population was chosen due to the high incidence of DRF and the frequency of this diagnosis in hand therapy practice. By choosing only one diagnosis to study, the results of our study have limited generalizability. Clinicians should be cautioned when applying the results of this study to other musculoskeletal injuries in the upper extremity as they may not apply to these populations.

Another limitation of our study is that we only measured active ROM (AROM) and not passive ROM (PROM) as PROM was contraindicated in some of our subjects due to fracture acuity. While this type of measurement provides a picture of functional use and mobility of the wrist, it does not provide information about maximal joint motion. Variability in ROM could have easily been affected by pain tolerance, muscle/tendon adherence or weakness, and overall effort.

Another limitation of our study is that we did not include a third group to act as an exercise control. In our current design, we are effectively comparing the ROM improvement caused by the heat of the hot pack against the improvement of the heat plus ROM exercises allowed by the whirlpool. While this is pragmatic in nature and illustrates the benefit of the whirlpool in allowing motion during the heating process, we cannot determine how much of the benefit could have come from exercise alone. Several other studies have shown that a combination of heat and stretch is superior to stretching alone for improving ROM of other joints during a single treatment session, but these have been primarily for the lower extremity.[16-19] Future studies should include a control group that does not receive any heat application, but has wrist ROM measurements taken before and after exercise to determine if this may be a reason for the change. It is unlikely that exercise alone accounts for all of the change, as the individuals in our study that received hot pack also had a statistically significant improvement in ROM from baseline, but it may account for some of the difference between hot pack and whirlpool.

5.5 Conclusions

The point estimates for change in ROM for the flexion/extension arc was just over six degrees for whirlpool and two degrees for hot pack. While the difference between these modalities was statistically significant, it could be argued that neither change is clinically relevant. Despite the small magnitude of change, it is important to remember that the purpose of a superficial heat modality is simply to precondition the joint for therapeutic stretching. Given the small amount of effort needed, the minimal risk, and potential for magnifying these changes with stretching once the heating is complete, any amount of improvement is seen to be clinically important.

One of the biggest disadvantages of whirlpool is that they are expensive and difficult to replicate in the home environment. This is true for actual whirlpools where the water is agitated with a motor, but further study is warranted to see if the agitation is necessary. It is possible that the combination of heat plus exercise is truly the most important factor to consider when pre-conditioning patients prior to other interventions in the clinic. Future study could look at ROM changes in simple hot water baths without agitation to allow for improved reproducibility in varied settings (like a sink at home), where an agitator is not available. Trials that include functional tasks, like washing dishes in hot water, may also have value.

Whirlpool and hot pack treatments both improved wrist ROM during therapy sessions in this study, making both of these acceptable options for clinical use when the goal is to pre-condition a patient for other treatments. Individuals who received whirlpool showed a statistically greater increase in wrist ROM than those receiving hot pack during a therapy session. This may be due to the added benefit of being able to perform exercise during the heating session. Since whirlpools are expensive, further study should investigate hot water soaks without water agitation to allow reproducibility in clinics without access to a whirlpool or in the home environment.

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Chapter 6

General Discussion and Future Directions

6.1 Thesis Overview

The overall objective of this thesis was to contribute to the optimization of the composition and delivery of assessment and treatment for patients with distal radius fracture (DRF). To accomplish this, one aspect of therapy assessment and one aspect of treatment were studied. The assessment component of this thesis included the introduction of a new method of measuring forearm rotation[1], followed by an inter-rater reliability study[2] to determine how this new method compared to the currently accepted method for measurement.[3] The treatment component of this thesis focused on a comparison of the effect of hot packs and whirlpool on volume of the hand[4] and ROM of the wrist and forearm after DRF.

This thesis demonstrated that the MFG method of forearm measurement is has equivalent inter rater reliability to the currently accepted method of measurement for patients with DRF. The hypothesis was that the MFG method would show improved reliability over the currently accepted method due to the ease of landmarking and decreased visual estimation required for the MFG technique. While the point estimates for the ICC's were equal or higher for supination and pronation, the confidence intervals overlap, so it was concluded that the MFG method is at least as reliable, and should be considered an option for clinical measurement.

The treatment phase of this study focused on the volumetric effects and ROM effects of hot packs and whirlpool for patients with DRF. There was a statistically significant difference in hand volume between groups immediately after heat, with patients in the whirlpool group having a larger increase in volume. When this volume change was re-measured at the end of the therapy visit, there was no significant difference between groups. This means that whirlpool may be an option for use in therapy, especially considering that patients who had whirlpool treatment had a statistically larger increase in wrist ROM than patients who had a hot pack during therapy.

6.2 Implications of Thesis Findings

The findings of this thesis have implications for clinicians who assess and treat patients with DRF. As mentioned, the assessment portion introduced a new measurement technique that provides intuitive land marking and requires less visual estimation for goniometer placement than the currently accepted method. Previous reliability studies looking at goniometric measurement have shown forearm measurement to have less reliability than other measurement of the wrist and elbow.[5, 6] Our findings show that the MFG method is at least as reliable as the currently accepted measurement technique and can be used for assessment of patients with limited forearm motion.

Previous work has shown that whirlpool treatment led to an increase in swelling in the hand.[7] Because of this study, whirlpool has not traditionally been used for treatment of upper extremity conditions. This study included just 20 patients, only investigated the immediate effects on volume, and did not look at volume trajectory over time. They also placed the arm in the whirlpool for 30 minutes, used a vertical position in the whirlpool, and did not include any exercises during heat. Positioning the arm vertically and keeping the arm still may have artificially increased upper extremity volume.

Given the limitations of the aforementioned upper extremity study, the first step of the treatment phase of this thesis was to re-investigate the volumetric effects of whirlpool on volume of the hand. Our findings contradicted this previous work. This is possibly because of differences in sampling, but also likely due to decreased treatment time, different positioning, and the use of exercise during heat. Previous studies have shown that whirlpool has beneficial effects on ROM for the lower extremity, while not having a significant impact on volumetric change.[8 9] Our findings mirror the effects of the studies for the lower extremity and show that whirlpool may be an effective option for superficial heat for upper extremity conditions. This has implications for upper extremity therapists for validating this modality for clinical use. In addition to the positive effect from whirlpool, patients who received hot pack treatments also had statistically significant increases in ROM from baseline. While these increases were not as large as whirlpool, they help to validate the use of hot pack as a superficial heat modality for rehabilitation of DRF.

6.3 Limitations

This thesis has limited external validity due to the population studied. Patients who were enrolled in this study were treated by highly skilled Hand Surgeons in a tertiary care centre, with advanced training in management of wrist fractures. Patients from different settings may have different variability in ROM, pain levels, and volumetric response to heat due to differences in patient care. While DRF is a logical choice for study due to the fact that many patients with DRF have limitations in both wrist and forearm motion, generalizing the findings of this thesis to other populations of individuals with limited wrist motion may not be valid.

For the assessment portion of this thesis, the primary weakness was that the analysis included each of the six separate measurement sessions as independent measures. We effectively reproduced the experiment six times on the same group of patients. This may have inflated the ICC estimates and artificially reduced the confidence intervals for both measurement techniques due to the decreased variability in subjects. Another threat to the internal validity of this portion of the thesis is that measurements occurred at the beginning and end of each session. Even though assessors were blinded to their previously recorded measurements, at least 30 minutes of time passed between measurements, and changes in ROM were expected, they may have remembered the numbers from the pre-treatment measurement, thus introducing potential systematic error.

Another limitation of this portion of the thesis is that only inter-rater reliability of each method of forearm measurement was studied. It would have been valuable to also measure intra-rater reliability of the MFG method and included this in the thesis. Unfortunately, this was not possible to accomplish as treatment was performed during each visit, and changes in ROM were expected during each visit and during the time frame in between weekly visits.

The biggest limitation for the superficial heat portion of this thesis was the exclusion of a third group that received only exercises without any heat. This would have been beneficial for determining how much of the volumetric change and ROM change was due to heat versus how much these variables may have changed due to exercise alone. This limitation was noted prior to the initiation of data collection. Due to time constraints and available patients for data collection, it was decided to proceed with two groups. In summary, the data for volumetric change (Chapter 4) and ROM change (Chapter 5) are really a comparison of hot pack heat versus heat plus ROM exercises allowed by whirlpool treatment. Several studies have previously shown heat plus exercise to be more effective than exercise alone.[10-12] For this reason, it was decided to continue with a pragmatic study of how the two superficial heat modalities compare clinically rather than try to differentiate how much change was due to heat versus exercise.

There were other limitations that threatened the internal validity of the papers in the treatment portion of this thesis. For the volume study, we did not control the timing or the treatments during the therapy session. Differences in this variable may have affected volumetric change during the sessions. Furthermore, we did not have anyone supervise the exercises done in the whirlpool. Despite verbal instructions prior to treatment, and written instructions posted on the wall, patients may have not exercised as recommended. We did not test their comprehension or performance of these exercises during their time in the whirlpool. Variability in exercises during the whirlpool sessions may have impacted both volumetric and ROM change during the sessions.

6.4 Recommendations for Future Studies

The overall objective of this thesis was to contribute to the optimization of assessment and treatment for patients with DRF. This thesis did meet this objective, however, several knowledge gaps remain. Further study is warranted, not only for goniometric assessment of the forearm and effect of superficial heat modalities, but also for many other aspects of treatment for this population. Since controversy exists over the efficacy of therapy for this population, the exact subset of the population of DRF that may require and benefit from therapy should be defined.

To expand the generalizability of the findings within this thesis, further study should investigate the use of the MFG and the use of hot/pack whirlpool for other populations where forearm ROM limitations occur or where wrist ROM is limited. These populations may include patients with wrist sprains, triangular fibrocartilagenous complex (TFCC) pathology, scaphoid fractures, radial head fractures, and injuries affecting both bones in the forearm such as Galeazzi fractures, Monteggia fractures, or proximal radio-ulnar synostoses.

Intra-rater reliability should be determined for the MFG. This will require measuring forearm motion in a stable population where forearm motion does not change over time. Ideally, this population would include older injuries where motion has plateaued. This would be preferable to a normal population as there would be greater variability in measurement to ensure that the MFG demonstrates acceptable reliability across the spectrum of available ROM of the forearm.

Since there are two distinct ways of measuring the forearm (one at the DRUJ and functional ROM looking at the hand's position in space), a future study that compares measurement values of these two measurements may have diagnostic value. If a comparison of "normal" wrists shows a different ratio between DRUJ ROM and functional ROM than those with known laxity within the carpus, this ratio could then be used to measure carpal laxity and also to predict ulnar sided pathology of the wrist.

For the treatment component of this thesis, we used "standard" hot pack and whirlpool temperatures. We also selected a fairly arbitrary 15-minute treatment time for each superficial heat modality. This was based on previous studies that have investigated similar outcomes for the lower limb,[13, 14] however, optimization of dosage is very important and has not been established. Future study on superficial heat modalities should investigate treatment effects for variable temperature and treatment time in order to maximize benefits for their use.

This thesis only compared two superficial heat modalities to each other. Other heat modalities that are used by therapists clinically include paraffin wax baths and Fluidotherapy. Each modality has pros and cons, so further study looking in to the effects of these modalities for improving motion is needed. Establishing a hierarchy of the best method of heat depending on treatment goals would assist the clinical decision making process, and help therapists standardize treatment across centres. A reduction in the variability of treatments used by therapists may help to show that therapy is beneficial for treatment of a subset of the DRF population.

As mentioned in Chapter 1 of this thesis, the main goal of therapy after DRF is usually to recover functional use of the upper extremity. Since ROM has been established as necessary to complete many functional tasks, therapists often focus on improving motion as a surrogate measure for function. While superficial heat has been shown in the literature and in this thesis to help improve motion, the mechanism of how this occurs is not fully understood. Understanding the relative effects of exercise and heat may help with understanding this mechanism. If further investigation of the mechanism of how heat helps to improve motion were undertaken, it would be important to control for the effects of exercises. To do this, addition of a third group that receives only exercise would be needed. Another option would be to do a study on only whirlpool, where half of the patients performed exercises and the other half did not. This may help to control for the effect of exercise during whirlpool sessions.

A final recommendation for further study is to investigate the effect of water agitation. One of the biggest disadvantages of whirlpool is that they are expensive and have a motor that requires maintenance and can break down over time. Further study should look at whether agitation of the water is needed. If exercise in a still hot water bath is as effective as in an actual agitated whirlpool, then this type of modality can be easily repeated in the home environment.

6.5 References

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Appendices

Appendix 1 -Ethics

Western

Research Ethics

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Mr. Mike Szekeres
File Number:6712
Review Level: Delegated
Approved Local Adult Participants:64
Approved Local Minor Participants:0
Protocol Title: The Short Term Effects of Hot Packs Versus Whirlpool and Exercise for increasing Total Active Motion at the Wrist - 16696E
Department & Institution: Health Sciences\Occupational Therapy,St. Joseph's Health Care London
Sponsor:
Ethics Approval Date: December 14, 2012 **Expiry Date:**June 30, 2014
Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Revised Study End Date	The study end date has been extended to June 30, 2014 to allow for continuation of the project.	

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the University of Western Ontario Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

This is an official document. Please retain the original in your files.

Western University, Support Services Bldg Rm. 5150 London, ON, Canada N6A 3K7
t. 519.661.3036 f. 519.850.2466 www.uwo.ca/research/ethics

Appendix 2 – Study Letter of Information

ST JOSEPH's HEALTH CARE LONDON

Study Title: The Short Term Effects of Hot Packs Versus Whirlpool and Exercise for Increasing Total Active Wrist Motion

Investigators: Mike Szekeres, OT Reg (Ont.), CHT
Joy MacDermid, PhD, PT
Emily Seeley, OT Reg (Ont.), CHT
Joanne Rooney, PT

Place of research: St. Joseph's Health Care, London, Ontario
Hand and Upper Limb Centre

As an individual who has recently sustained an injury to your wrist, you are being **invited** to take part in a research study that may help us determine the impact of using heat prior to exercises. We typically use some form of heat on your wrist during each therapy visit. The best method of heat **application** has not yet been established in the literature.

Should you agree to participate in the study, you will be placed into one of two groups by the flip of a coin. Each group will have their wrist motion measured prior to each treatment session **in the hand therapy department**. Group 1 will place their hand in a hot pack for 15 minutes and have their wrist motion re-measured. Group 2 will perform active range of motion exercise for their wrist in a warm whirlpool and then have their wrist motion re-measured. This process will take place weekly for you over the next 3 weeks, at which point you will be finished with our research study and will continue with regular treatment sessions as necessary. **64 patients will be enrolled in this study.**

If you should agree to participate in this study, you will be asked to complete two (2) questionnaires in our hand therapy department, the DASH (Disabilities of the Arm, Shoulder and Hand) the PRWE (Patient-rated Wrist Evaluation). The DASH is a four-page questionnaire that helps assess your upper limb function. The PRWE is a two-page questionnaire that helps assess your wrist function. In addition, there is a scale, the VAS (Visual Analog Scale) to mark the level of pain you are experiencing in your wrist. It should take approximately 15 minutes in total to complete both questionnaires and the pain scale. The questionnaires are administered upon your initial visit and at the end of your participation in the study 3 weeks from now.

Throughout your rehabilitation, regardless of which group you are involved in, we will measure the range of motion of your fingers, wrist, forearm, elbow and shoulder. The measurements will take approximately 5 minutes to complete. These measurements will be taken approximately once a week during therapy visits. We will also measure the volume of your hand before and after each session.

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future care. If you decide not to participate in this study, you will still receive treatment based on our standard treatment protocol for wrist fractures. **The type of heat you receive in hand therapy will not be randomized and will be left to the discretion of your treating therapist.**

Risks: **Your hand therapy chart will be accessed by the principal investigator for the collection of data within the hand therapy department. The heat used during treatment is not sufficient to cause burns.** There are no other known risks to you for participating in this study as both methods of treatment are currently used within the hand therapy department as part of your regular treatment.

Confidentiality will be protected by keeping all research data on a password protected file on a laptop **under a unique study ID.** Your name is not entered on the laptop, just **this ID number**. If the results of this study are published, your name and any identifying personal information will not be used. **All records of your personal data will be deleted from the laptop once the study is accepted for publication. Representatives of the University of Western Ontario Health Sciences Research Ethics Board may contact you or require access to your study-related records to monitor conduct of the research.**

This letter is yours to keep for future reference. **You do not waive any legal rights by signing the consent form.**

If you have any questions about the conduct of this study or your rights as a research subject you may contact **Dr. David Hill, Scientific Director, Lawson Research Institute at 519-667-6649.**

If you have any questions at any time during the study, please contact the principal investigator, Mike Szekeres, at (519) 646-6000 extension 64799. If you are already participating in another research study, at this time please discuss this with the investigator.

Sincerely,

On Behalf of the Investigators

Curriculum Vitae

Mike Szekeres PhD(c), OT Reg (Ont.), CHT

EDUCATION

2012-Present	**WESTERN UNIVERSITY** **London, ON** PhD Candidate, Rehabilitation Science
1995-1998	**WESTERN UNIVERSITY** **London, ON** Bachelor of Science in Occupational Therapy

POSITIONS- University Appointments

2013-Present	**WESTERN UNIVERSITY** **London, ON** Sessional Faculty – Intensive Course on Upper Extremity Rehabilitation
2005-Present	**WESTERN UNIVERSITY** **London, ON** Non-Core Member, Faculty of Graduate Studies

POSITIONS – Professional Development

2015-Present	**JOURNAL OF HAND THERAPY** Assistant Editor
2006-Present	**HAND THERAPY CANADA** President, Conference Chair for the Canadian Hand Therapy Conference
2010	**AMERICAN SOCIETY OF HAND THERAPISTS** Director, Education Division
2009	**AMERICAN SOCIETY OF HAND THERAPISTS** Vice-Director, Education Division
2009-Present	**REVIEWER, JOURNAL OF HAND THERAPY** Scientific/Clinical Manuscript Peer Reviews

2008 **HAND THERAPY CERTIFICATION COMMISSION**
Certified Hand Therapist Designation

1999-Present **LONDON AND AREA HAND INTEREST GROUP**
Past Chairman, current member

REFEREED SCIENTIFIC PUBLICATIONS

Szekeres, M, MacDermid, JC, Birmingham T, Grewal R, Lalone, E. The Effect of Therapeutic Whirlpool and Hot Packs on Hand Volume During Rehabilitation After Distal Radius Fracture: A Blinded Randomized Controlled Trial. Hand. Pre-published Online, August 2nd, 2016.

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PRESENTATIONS, PAPER & POSTER ABSTRACTS

2016 ASHT Meeting. Washington DC. The Short Term Effects of Hot Packs vs Whirlpool on Range of Motion of the Wrist. Scientific Paper Session Podium Presentation

2016 ASHT Meeting. Washington DC. International Invited Panelist. Journal of Hand Therapy Articles of Impact.

2016 Evaluation of the Stiff Hand. One hour Video Course. Occupationaltherapy.com

2016 Assessment and Rehabilitation of the Unstable Elbow. One hour Video Course. Occupationaltherapy.com

2015 Treatment Principles for Five of the Most Common Upper Extremity Conditions. One hour Video Course. Occupationaltherapy.com

2015 Upper Extremity Assessment – Elbow to Hand. Two hour Video Course. Occupationaltherapy.com.

2015 The Wisconsin Hand Experience. Milwaukee, WI. Invited lecturer. Elbow rehabilitation after trauma: A spectrum of stiffness.

2015 The Wisconsin Hand Experience. Milwaukee, WI. Invited lecturer. Hands on Elbows 5 hour workshop.

2014 American Association for Hand Surgery Annual Meeting. Course Co-Chair of Therapist Development Workshop

2014 American Association for Hand Surgery Annual Meeting. Invited Panelist for Scientific Session on Arthritis and Trauma

2013 ASHT Meeting, Chicago, IL. Life-long pursuit of the evidence to enhance profession and clinical decision making skills.

2013 4th Annual Hand & Upper Limb Centre Symposium. Anatomy of the Upper Extremity.

2012 The Philadelphia Meeting. Invited Faculty Member. Shoulder and elbow arthroplasty.

2012 The Philadelphia Meeting. Invited Faculty Member. Complex elbow problems.

2012 The Philadelphia Meeting. Invited Faculty Member. Clinical assessment of the elbow.

2011 American Association for Hand Surgery Annual Meeting. Instructional course: Challenges of orthotic selection.

2011 The Philadelphia Meeting. Invited Faculty Member. Optimizing range of motion after elbow instability.

2011 The Philadelphia Meeting. Invited Faculty Member. Rehabilitation after total elbow arthroplasty.

2010 ASHT Meeting, Orlando, FL. Instructional Course Lecture. Hands on orthotics.

2010 1st Annual Hand & Upper Limb Symposium. Rehabilitation after elbow instability.

2009 Evidence Based Practice for Hand Therapists, Syracuse NY. Invited Faculty

2009 ASHT Meeting, San Francisco, CA. Instructional Course Lecture with Dr. Graham King. The unstable elbow – A broken bridge between the hand and shoulder.

2009 ASHT Meeting, San Francisco, CA. Instructional Course Lecture. Web site building and management for surgeons and therapists.

2009 Fowler Kennedy Sports Medicine Symposium. Invited Lecture. Management of medial collateral ligament reconstruction at the elbow.

2009 Splinting Essentials. Course Faculty. London, ON.

2009 ASHT Times Invited Article (co-author) – Orthotic options for radial nerve palsy.

2008 Jacksonville Upper Extremity Conference. Invited Lecture. Rehabilitation after total elbow arthroplasty and posterolateral rotatory instability of the elbow.

2008 Jacksonville Upper Extremity Conference. Invited Lecture. Management of distal radius fractures and ulnar sided wrist pain and clinical evaluation of the wrist.

2007 Hand & Upper Limb Centre. Faculty Member. Rehabilitation of the Wrist and Elbow.

2007 ASHT Meeting, Phoenix, AZ. Posterolateral rotatory instability of the elbow – biomechanical considerations and rehabilitation

2007 ASHT Meeting, Phoenix, AZ. A tenodesis extension assist for radial nerve palsy.

2006 ASHT Meeting. San Antonio, TX. The elbow turnbuckle versus the static progressive elbow flexion cuff

2005 Canadian Orthopaedic Nursing Association. Invited Lecture. Rehabilitation of wrist fractures.

2004 Sarnia ON. Faculty member. A review course in Hand Splinting. 1 day workshop.

2004 IFSHT Meeting, Edinburgh, Scotland. A Biomechanical analysis of static-progressive elbow flexion splinting. Scientific Paper Session.

2003 ASHT Meeting, Hollywood CA. Co-Presenter. Extensor Tendon Biomechanics. 2 Hour instructional course.

2003 ASHT Meeting, Hollywood CA. A low tech alternative to static progressive wrist extension splinting: the wrist extension strap.

TEXT BOOK CHAPTERS

2016 Szekeres M, King GJ. Total Elbow Arthroplasty, in Green, A, ed: Postoperative Orthopaedic Rehabilitation (in press)

2012 Freure J, Szekeres M: Flexor tendon rehabilitation, in Bhandari M, ed: Evidence Based Orthopaedics. Wiley-Blackwell, 2012, pp 998-1012.

AWARDS & FUNDING

2016	Ontario Graduate Scholarship - $15000
2015	Ontario Graduate Scholarship - $15000
2014	Ontario Graduate Scholarship - $15000
2013	Ontario Graduate Scholarship - $15000
2012	President’s Award for Innovation. Awarded $8000 to develop a web portal for client education programs.

CLINICAL EXPERIENCE

2008-Present	**HAND THERAPY CANADA** **London, ON** President, Hand Therapist
1998-2014	**ST. JOSEPH”S HEALTH CARE** **HAND & UPPER LIMB CENTRE** **London, ON** Hand & Upper Limb Centre Staff Therapist
1998	**LONDON HEALTH SCIENCES CENTRE** **London, ON** Inpatient General Medicine