

Efficacy of Hand Behind Back mobilisation with movement for shoulder pain and movement impairment: a double blind randomised controlled trial

AUTHORS

Kiran Satpute

Assistant Professor

Department of Kinesiotherapy and Physical Diagnosis

Smt. Kashibai Navale College of Physiotherapy, Pune,

Dr. Prashant Bhandari

Assistant Professor

Department of Orthopedics

Smt. Kashibai Navale Medical College and General Hospital, Pune, Maharashtra, India

Dr. Toby Hall

Specialist Musculoskeletal Physiotherapist

Adjunct Associate Professor

Snr. Teaching Fellow (The University of Western Australia)

School of Physiotherapy and Curtin Health Innovation Research, Curtin University, P.O. Box U1987, Perth, WA 6845, Australia

Corresponding Author

Kiran Satpute

Mailing address: 393 Navi Peth,

Near Vithal Mandir,

Pune-411030

Maharashtra, India

Contact phone number: +91 9604515338

Email address: drkiransatpute@gmail.com

ABSTRACT

Objectives: Shoulder pain and impairment is a prevalent and disabling condition. While some Mulligan mobilization with movement (MWM) techniques have been shown to have beneficial effects, Hand Behind Back (HBB) MWM has not been investigated. The aim of this study was to investigate the effects of HBB MWM on shoulder pain, impairment and disability.

Methods: We conducted a double blind randomized controlled trial in 44 subjects with shoulder pain and movement impairment presenting to an Indian general hospital. Subjects were allocated to receive either MWM and exercise/hot pack (n=22) or exercise/hot pack alone (n=22). The primary outcome was HBB range of motion (ROM). Secondary variables were shoulder internal rotation ROM, pain intensity score, and shoulder disability identified by the Shoulder Pain and Disability index (SPADI). All variables were evaluated by a blinded assessor before and immediately after 9 treatment sessions spread over 3-weeks.

Results: A total of 60 patients were screened and 44 randomized. The average duration of symptoms was 4.1 and 4.7 weeks in the exercise and MWM groups respectively. Paired t-tests revealed that both groups demonstrated statistically significant improvements ($p < 0.001$) with large effect sizes for all variables. However, for all variables the MWM with exercise group showed significantly greater improvements ($p < 0.05$) than the exercise group. HBB ROM showed a mean difference of 9.31° (95% CI 7.38 to 11.27), favoring greater improvement in the MWM with exercise group.

Conclusions: Shoulder HBB MWM with exercise improves outcomes in patients with acute shoulder pain and disability greater than exercise/hot packs alone.

Key words: Manual therapy, shoulder

INTRODUCTION

The annual prevalence and incidence of shoulder pain conditions presenting to primary care in the UK has been documented as 2.36% and 1.47% respectively,¹ and is ranked as the third most frequent musculoskeletal complaint after knee and back pain.^{2,3} Physiotherapists treat a variety of common shoulder disorders including impingement syndrome, glenohumeral instabilities, osteoarthritis, adhesive capsulitis, and bursitis among others.⁴ As an indicator of the severity of the problem, Smith et al.⁵ (2000) reported that 83% of people with shoulder dysfunction were unable to sleep on the involved side due to pain. Furthermore, hyperalgesia and associated movement impairment associated with shoulder disorders imposes functional deficits in daily activities^{6,7} which significantly contributes to the emotional and psychological distress of the patient.⁸ Moreover 41% of patients with shoulder disorders were found to have persistent symptoms on annual follow-up⁹ and up to 30% of workers were availing sick leave due to shoulder dysfunction,¹⁰ thus imposing a substantial financial burden on the individual and society.^{11,8}

Physiotherapy is often the first approach used in the conservative management of people with musculoskeletal dysfunction of the shoulder. This may include manual therapy techniques in conjunction with stretching and strengthening exercises, and electrotherapeutic modalities.¹² There is growing evidence of the need for treatment techniques to restore normal range and functional ability in these patients and joint mobilization techniques may be able to help in this regard.^{13,14,15} However some studies demonstrate benefits for manual therapy in terms of reducing pain and improving shoulder mobility, but with questionable improvements in function and quality of life.¹⁶ Other recent studies have demonstrated that advice and exercise alone are sufficient to manage chronic shoulder dysfunction without the addition of passive joint mobilization.^{17,18}

An array of different patterns of movement impairment and poor motor control are seen in patients with shoulder dysfunction and require careful assessment.^{19,20} This variation in movement impairment may be due to the different structures sensitized around the shoulder. For example, shoulder internal rotation is an important functional movement that is often compromised in patients with poor shoulder girdle motor control.²⁰ This movement is often restricted, particularly in abduction, due to tightness of the posterior band of the inferior glenohumeral ligament complex and capsule.²¹ Thus, patients with sensitivity or tightness of these connective tissues may have specific restriction of reaching across the chest and reaching their hand up behind their back (shoulder internal rotation/adduction with elbow flexion), causing substantial functional disability. Hence, restoration of functional internal rotation movement should be considered as an important aspect of a comprehensive management plan.

Mobilization with movement (MWM) is a relatively new concept of manual therapy that involves the application of sustained gliding force applied by a therapist (passive mobilization component) with a concurrent active movement performed by the patient (active movement component). It is important that the painful impaired movement is rendered pain-free by the addition of the glide force.²² Specific guidelines have been set-down for the successful use of MWM.²³ The technique, "hand behind back" (HBB) MWM has been described to increase restricted range of internal rotation of the shoulder.²⁴

Previous research supports the use of exercise and manual therapy for shoulder disorders.²⁵ There is also preliminary evidence for benefits of MWM for shoulder pain associated with limitation of elevation and abduction.^{26,27} To date, no randomised controlled trial (RCT) has investigated the efficacy of HBB MWM techniques for people with shoulder pain and restricted range of motion (ROM) and subsequent disability.²⁸ Hence, the purpose of this study is to evaluate the efficacy of HBB MWM techniques on shoulder internal rotation ROM, pain, and function.

METHODS

A 2 group, with equal allocation, repeated measures, double-blind RCT was conducted to investigate the efficacy of shoulder HBB MWM on shoulder internal rotation ROM, HBB ROM, pain, and disability. Approval for this study was granted by the ethical committee of Smt. Kashibai Navale Medical College and General Hospital, Narhe, Pune, India. The trial is registered with the clinical trial registry India (CTRI) Ref. No. CTRI/2014/05/004624.

We investigated short-term (3-weeks) treatment efficacy for pain, shoulder ROM and disability. Prior to recruitment consecutive subjects presenting with shoulder pain at the orthopaedic and physiotherapy outpatient department of Smt. Kashibai Navale Medical College and General Hospital between May and November 2013, underwent physical screening of the affected shoulder by an orthopaedic surgeon. Evaluation involved assessment of shoulder active movements. Subjects identified by the surgeon with shoulder pain and movement impairment were then invited to take part in the study. Sixty participants expressed interest and were evaluated by a physiotherapist for potential inclusion. Participants aged between 18 and 65 years were screened for suitability according to the following inclusion and exclusion criteria. Subjects had to be able to reach the dorsum of their hand on the affected side at least to the buttock (but not above the iliac crest), be able to lie on the affected side for internal rotation measurement which should not be more than 25°,²⁹ and have at least 90° shoulder abduction. The primary exclusion criteria were shoulder stiffness due to immobilization secondary to traumatic fractures, dislocations or soft tissue injuries around the shoulder complex and those who received physiotherapy or intra articular steroid injections within the previous 3

months. Other exclusion criteria were history of myocardial infarction or cardiac surgery, cervical spine surgery within the last 6 months, cervical radiculopathy, neuromuscular disorders affecting the shoulder, and bilateral shoulder involvement. In addition, participants with contraindications to manual therapy, and who were unable to understand and follow instructions, were also excluded. Figure 1 details the flow of subjects through each phase of the study.

Participants were randomised into 2 equal groups with the help of a computer generated randomisation sequence, with allocation placed in sequentially numbered opaque sealed envelopes. The receptionist of the physiotherapy department provided consecutive patients with a single sealed envelope opened by participant, which directed the group allocation. Participants were informed that they would receive 1 of 2 forms of physical treatment, but they were unaware of the form that would take and so were essentially “blind” to the intervention.

Outcomes

Outcome measures were evaluated by a qualified physiotherapist blinded to the allocated treatment condition. The primary outcome measure was range of a pain-free functional measure of HBB. The secondary outcome measures were pain-free passive glenohumeral internal rotation ROM in side lying, pain severity determined by a visual analogue scale (VAS) score during maximal HBB movement and pain and disability score assessed by the Shoulder Pain and Disability Index (SPADI).

A universal goniometer with 1° increments was used to measure pain-free glenohumeral internal rotation ROM in side lying. Initially the participant lay supine with 90° shoulder abduction. They were then asked to roll onto their affected side to place the shoulder in 90° flexion, this position effectively stabilized the scapula so that no manual scapula stabilization was required. The elbow was flexed to 90° with the olecranon process kept at the edge of the plinth which was used as the fulcrum. The goniometer stationary arm was aligned with the plinth edge, and the movable arm aligned with the ulnar border. Passive internal rotation ROM was measured just prior to the onset of pain. This measurement method (figure 2) has excellent intrarater reliability (ICC = 0.94-0.98) and good to excellent interrater reliability (ICC= 0.88-0.96) with the minimum detectable change (MDC) of 6.1° for people with shoulder pathology.²⁹

A functional measure of HBB was recorded. While standing, the subject was asked to keep their hand behind the back with the dorsum of hand touching the back and thumb close to the palm. The distance between the tip of their thumb and the mid-line between the 2 posterior superior iliac spines (PSIS) was measured using a tape measure. Results were recorded in centimeters above the line (a positive measure) or below the line (a negative measure). The intra-rater (ICC = 0.95) and inter-rater (ICC = 0.96) reliability of this method is excellent with MDC 12.8 mm and standard error of measurement (SEM) 4.3 mm for intra-rater reliability.³⁰

Functional disability and pain over the previous week was assessed by the SPADI questionnaire, which is a self-administered questionnaire consisting of 2 dimensions, of which 5 questions are for pain and 8 are for functional activities.³¹ The numerical rating scale (NRS) version of SPADI was used.³² The SPADI questionnaire is a shoulder specific, responsive and valid measure of shoulder pain and disability.^{33,34,35} When the SPADI questionnaire is used prior to treatment and then at discharge, the MDC is 18 points.³⁶

A single-item 10 cm horizontal VAS³⁷ was used to record pain intensity during maximal HBB movement. The minimal clinically important difference for VAS pain

score is 1.4 cm for patients treated for shoulder rotator cuff disease³⁸ which is lower than reported for musculoskeletal disorders affecting other body regions.³⁹

Treatments

All the subjects diagnosed with shoulder pain and movement impairment were assessed for their suitability for inclusion by the examining physiotherapist who was blinded to randomization. This physiotherapist also carried out the assessment of shoulder movement, pain scores and SPADI measurements. Those who fulfilled the relevant criteria and were willing to participate were enrolled after providing written informed consent. Subjects were given the right to withdraw from the study at any time.

All patients attended a physiotherapy department for each treatment session carried out over 3 consecutive weeks, with 3 sessions per week. Reassessment occurred at the end of the final treatment session in the third week. All participants, in the MWM with exercise as well as the exercise group were given structured exercises and a hot-pack during each treatment session. In addition to this, subjects in the MWM with exercise group also received HBB MWM.

Moist steam hot-packs were first applied to the shoulder region for 10-minutes prior to exercise. Following this the structured exercise protocol was performed under the supervision of the treating physiotherapist. Resistance bands were used for strengthening exercises. Patients were asked to stretch the band within the limits of pain and hold that position for 10 seconds. Deterioration in movement quality or pain was avoided during all strengthening exercises by either reducing the level of resistance or modifying the ROM. The level of resistance was increased as strength improved. The isometric strengthening protocol was as follows: Shoulder flexion in supine (3a); Scapular retraction in prone (3b); Scapular retraction in standing (3c); Shoulder internal (3d) and external (3e) rotation with the arm by the side; and 4. Scapular protraction in standing (3f). Each exercise was performed 10 times with a 10 second hold, followed by a 5 second rest. Stretching exercises targeted the shoulder posterior capsule. The first exercise (3g) was performed by lying on the affected side, elbow flexed to 90°, while the shoulder was flexed to 90° and internally rotated. This position was held for 30 seconds, repeated 5 times, with rest interval of 10 seconds.⁴⁰ The second stretch was HBB with assistance from the patient's opposite hand (3h). This was maintained for 30 seconds, repeated 5 times, with a rest interval of 10 seconds (Figure 3).

A home exercise program was also given to all subjects, which included the above set of exercises without the use of resistance bands. All subjects were provided with written handouts explaining each exercise. Subjects were asked to perform the home exercise program once on treatment days and twice on non-treatment days during the 3-week intervention period.

HBB MWM was carried out by a physiotherapist (KS) with a post-graduate degree in musculoskeletal physiotherapy who was also a certified Mulligan practitioner with 6 years clinical experience in using the Mulligan Concept. The physiotherapist stood beside the seated patient's affected shoulder during the procedure (Figure 4). The patient reached up behind their back as far as possible. While maintaining this position, the physiotherapist provided a caudally directed glide along the line of the humerus, with 1 hand placed on the forearm just distal to the elbow crease, at the same time the scapula was stabilized by the physiotherapist's other dorsally placed hand. The patient was encouraged to move their arm actively behind their back, with assistance from the therapist's abdomen against the patient's humerus.

Overpressure to the movement was applied by the patient's other hand assisting their affected shoulder further into the pain-free range. Three sets of 10 repetitions

were applied with a rest interval of 60 seconds between each set. The patient was instructed that the MWM procedure should be pain-free, and to indicate immediately if any pain was experienced during the MWM application.⁴¹

Data Analysis

The Statistical Package for Social Sciences (SPSS 19) software was used for statistical analysis. Sample size calculation was based on data from Teys et al.²⁶ A sample size of 18 was required based on 80% power to detect a mean difference of 12° (standard deviation 12, alpha = 0.05) in ROM between interventions.^{26,42} The sample was increased to 22 to allow for 20% drop out.

The independent variables were treatment group (MWM with exercise/hot pack or exercise/hot pack alone) and time (before and after 3 weeks of intervention). Dependent variables were internal rotation ROM, HBB ROM measure; VAS score during maximal HBB movement and SPADI total pain and disability score. Mean baseline demographic values were calculated for continuous variables. Frequencies were calculated for categorical variables. Preliminary analysis (Kolmogorov-Smirnov test) revealed that data was normally distributed ($p > 0.05$). Similarity of baseline measures between groups was assessed using t-tests. (Table 1) Comparisons within and between each group were assessed by t-tests (pre to post intervention) with Bonferroni correction to reduce the chance of type 1 error.

The effect sizes (Cohen's d) within each group (pre to post intervention) and between groups were also calculated. The effect sizes are presented with their 95% confidence interval (CI). A score below 0.4 represents small effect, between 0.4 and 0.8 a moderate effect, and over 0.8 a large effect.

RESULTS

Forty-four participants (23 right and 21 left side symptoms) were recruited for this study. Demographic details are shown in Table 1. No significant difference in outcome measures were found at baseline between groups ($p > 0.05$), as shown in Table 1. There was no loss at follow-up from the experimental group receiving HBB MWM with exercise. Two participants from the control group were lost to follow-up after the first week due to difficulty in commuting to the hospital. As drop-outs were very low, according to intention-to-treat analysis, means from the remainder of the control group were used for these 2 missing values.⁴³ There was no report of worsening of symptoms in either group after the interventions.

Table 2 presents the mean values with SD and 95% CI for pain, ROM and disability variables. Significant time effects ($p < 0.001$) were detected for pain, ROM, and disability scores. A series of paired t-test demonstrated statistically significant improvements with large effect sizes (Cohens d) between assessment points in all the dependent variables in both groups as shown in Table 2. However, independent sample t-test revealed significantly greater improvement in participants receiving HBB MWM with exercise when compared to those only receiving exercise and hot pack ($p < 0.001$). These findings, together with mean (SD and 95% CI) values and effects sizes for pain, ROM and disability variables are shown in Table 3 and supported by Figure 5.

DISCUSSION

In this RCT, both groups showed significant improvements in pain, shoulder ROM and disability. However, the group receiving Mulligan's HBB MWM with exercise/hot packs showed significantly greater improvement than the group receiving exercise/hot packs alone. The effect sizes for these differences were large for all the

outcomes measured at the follow-up point. It should be noted that the effect was not only statistically significant but also clinically meaningful as it exceeded the minimum clinically important difference of 1.4cm on the VAS,³⁸ the MDC of 6.1° for shoulder internal rotation ROM,²⁹ and the MDC of 18 points for the SPADI score.³⁶ Further, even the lower bound estimates for the 95% CIs fall above the minimum clinically important difference for VAS pain score, MDC for internal rotation ROM and SPADI score for the MWM with exercise group. This provides evidence that the Mulligan MWM technique combined with exercise and hot packs may be beneficial in the management of patients with shoulder pain, disability and limitation of shoulder HBB ROM.

Significant improvements in pain, ROM and disability over the intervention period in both groups may be explained to some degree by natural resolution and/or that exercise/hot packs were the driver for change in this 3-week intervention period. One potential mechanism for this improvement may be that exercise improves joint function by improving muscle strength and control of the scapular and glenohumeral joint stabilizers as well as improving extensibility of shortened ligamentous and capsular tissues.^{46,47} Previous studies have found that 9-12 treatment sessions of passive joint mobilization has no additional benefit over exercise and advice in the short or long term, for improving function in patients with painful restricted shoulders of more than 1-months duration.^{17,18} Similarly, the subjects in our study had symptoms for a similar time-frame, but the manual therapy treatment (MWM) comprised an active and passive movement component combined.²⁴ This approach was clearly more effective in the early management of our subjects with painful stiff shoulders. In accordance with our findings a previous study found that a posterolateral glide MWM techniques was more effective than other forms of shoulder mobilisation for improving movement control and dysfunction in patients even with long-standing shoulder dysfunction.¹⁵

The mechanisms of action for MWM have been investigated⁴⁶ and summarized in detail in Vicenzino et al.²² It is suggested that MWM evokes a non-opioid descending pain inhibitory system (non-endorphin based) inducing mechanical hypoalgesia. The mechanical stimulus provided by MWM may trigger central nervous system descending pain inhibitory system's causing hypoalgesia. MWM also potentially modulates mechanical local hyperalgesia, which results from the sensitized peripheral nocicepters within the area of dysfunction.^{47,46} Further potential mechanisms of action could be through sympathoexcitation, which has been shown to occur following MWM in the lumbar spine.⁴⁸ In addition to neurophysiological effects, it is also suggested that MWM has mechanical effects by restoring the normal biomechanics to the dysfunctional joint, reducing a positional fault allowing greater range of pain-free movement.²⁴ There is evidence of positional faults occurring in musculoskeletal pain disorder, for example at the inferior tibiofibular joint following ankle sprain^{49,50} and at the patellofemoral joint.⁵¹ There is also evidence of a positional fault at the shoulder in some shoulder pain disorders.^{52,53,54}

In addition to the effects on pain, there were significant improvements in shoulder internal rotation ROM of 16.86° in the MWM with exercise group in contrast to 7.38° in the exercise group. The additional beneficial effects of MWM on shoulder ROM is in accordance with previous studies of MWM for shoulder pain and impairment.^{26,42} In those studies a posterolateral glide MWM induced significantly greater improvement in shoulder flexion ROM when compared to placebo and control interventions which was sustained and further improved when used in conjunction with rigid sports tape applied to the skin to maintain the repositioning of the humeral head consistent with the MWM technique. Another study²⁷ found significant improvement in both active and passive ROM of all shoulder movements following a treatment program incorporating MWM applied in flexion, elevation and internal rotation.

Shoulder internal rotation ROM improved in both groups more than the MDC for that movement indicating a clinically relevant change. Despite this, the group receiving MWM with exercise exhibited greater improvement than those receiving exercise/hot pack, reaching 34.55° that approximates the mean normal range of 39.7° when measured in side lying²⁹ indicating clinically significant improvement. Borstad et al⁵⁵ reported that a change of 19° in shoulder internal rotation ROM can be considered as a true change in shoulder posterior capsule flexibility. The improvement seen in both groups was greater than this ROM.

Improvement seen in shoulder internal rotation and HBB ROM may be explained by reduction in pain, but also by increased flexibility of the posterior capsule⁴⁰ as well as shoulder external rotator muscle length along with strengthening of the shoulder internal rotators. Improved ROM associated with MWM may also be explained by a correction of a positional fault. Shoulder positional faults have been demonstrated,²⁸ with a study reporting that the humeral head migrates superiorly with respect to the glenoid, secondary to tightness of the posterior capsule.⁵⁶ The MWM technique aims to correct the position of the humeral head in the glenoid fossa, to restore normal pain-free movement.²⁴

Shoulder HBB movement is required in functional activities such as removing something from a back pocket, dressing, undoing a bra clasp, washing the back etc. There was a mean improvement in HBB ROM of 16.32 cm in the MWM with exercise group compared to 6.83 cm improvement in the exercise group. This HBB movement can be considered an active measure of shoulder internal rotation. This greater improvement in active range in the MWM with exercise group may be due to a number of factors including post exercise facilitation. This can be described as an increase in the excitability of motor pathways⁵⁷ innervating the internal rotators of shoulder following painless active HBB movement. Additionally, the painless movement achieved through the application of MWM also provides a stimulus for motor learning.²² Furthermore, the acquired adverse pain memories, which were developed while using the arm in daily function, may be reduced by repeated application of MWM thus helping to gain new pain-free HBB movement.⁵⁸ At the end though, mean range of 16.20 cm of HBB movement found in the MWM with exercise group may not compare favourably with the range of 33.6 to 34.4 cm found in asymptomatic people. Despite this difference, it is important to understand that there is high variability in the normal range of HBB movement.³⁰

Reduction in pain, improved ROM and changes in muscle function may be responsible for the improvement we found in shoulder pain and function⁵⁹ when measured with the SPADI questionnaire. A greater reduction in disability scores was seen in the MWM with exercise group, which supports the results of previous studies investigating posterolateral glide MWM for shoulder disability.^{60,15,27}

There are some limitations to this study's findings. Firstly, subjects were patients attending the Orthopaedic and Physiotherapy departments of a general hospital, with a specific limitation of HBB, hence results may not be generalized to all shoulder impairments and disorders. Secondly, a control group was not included so it is not possible to identify whether improvements in the exercise/hot pack group were due to natural resolution. However, as the MWM group also received this treatment the additional improvements seen in this group over the exercise group can be attributed to MWM. Thirdly, subjects were followed up for 3 weeks only. Long-term follow up is required to evaluate the sustained effects of this intervention. Despite this, we found that subjects were able to achieve substantial improvements in movement, achieving functional range of internal rotation in the MWM with exercise group. This bodes well for the patient in achieving maximum recovery. Fourthly, the final assessment was

carried out immediately after the last treatment session, possibly influencing improvements. Hence, it may be difficult to separate the immediate effects of the final treatment for the VAS pain score and ROM measurements. A final potential limitation is that subjects were only included if they could put their hand behind their back as far as their ipsilateral buttock and who also had at least 90° shoulder abduction. Thus, the results of this study may be different in subjects with more severe loss of ROM. A multi-center, placebo controlled trial with long-term follow up is recommended to improve the external validity of these results.

CONCLUSION

The results of this RCT indicates that Mulligan's manual therapy technique HBB MWM provides benefits in terms of improved shoulder internal rotation and HBB ROM, pain and disability when added to exercise/hot packs when applied over a 3-week intervention period.

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TABLES

Table 1: Characteristics of participants

	GROUP MWM& Exercise/hot packs		GROUP Exercise/hot packs		Sig
	n= 22		n= 22		
	MEAN	Sd	MEAN	Sd	
AGE (years)	53.41	7.08	52.41	7.06	0.64
Symptom duration (weeks)	4.14	1.28	4.73	1.93	0.09
IR ROM (degrees)	17.68	3.51	19.41	2.79	0.08
HBB measure (cm)	-0.11	1.88	0.07	1.79	0.74
VAS with maximal HBB(cm)	8.10	0.69	7.95	0.78	0.50
SPADI score	64.50	6.69	65.23	4.87	0.68
Male count (%)	10 (45%)		15 (68%)		NA
Female count (%)	12 (55%)		7 (32%)		NA

IR: Internal rotation. ROM: Range of motion. HBB: Hand behind back. VAS: visual analogue scale pain score during maximal HBB.SPADI: Shoulder pain and disability index (minimum score 0, maximum 130). NA: not applicable

Table 2: Within group analysis before and after intervention with paired t-test (pre- and post-intervention) for pain, range of motion and disability with effect size

	MWM & Exercise/hot packs (n=22)			Exercise/ hot packs (n=22)		
	Mean of difference (SD) 95% CI	p-value	Cohens d (95% CI)	Mean of difference (SD)95% CI	P-value	Cohens d (95% CI)
VAS pain HBB	5.31(1.80) 5.06,5.57	<0.001*	8.41 (8.21,8.59)	3.39 (0.72) 3.08, 3.71	<0.001*	4.61 (4.38,4.82)
IR ROM	-16.86(3.04) -18.21,-15.51	<0.001*	4.74 5.80, 3.70)	-7.38 (2.08) -8.30, -6.46	<0.001*	2.65 (3.48:1.83)
HBB ROM	-16.32 (3.38) -17.82, -14.82	<0.001*	5.35 (6.25, 4.45)	-6.83 (2.66) - 8.01,-5.64	<0.001*	3.52 (4.10,2.95)
SPADI score	40.63 (6.47) 37.76, 43.51	<0.001*	6.52 (4.68, 8.36)	19.19 (5.50) 16.75, 21.62	<0.001*	3.85 (2.37, 5.32)

VAS pain HBB: VAS pain score during maximal HBB

MWM: Mobilization with movement. IR: Internal rotation. ROM: Range of motion. HBB: Hand behind back. SPADI: Shoulder pain and disability index. CI: confidence interval

- Significant difference between groups $p < 0.0125$ (Bonferroni adjustments: significance level $< 0.05/4$).

Cohen's d: Within groups effect size, standardized mean difference

Table 3: Between groups analysis with independent samples t-test for pain, range of motion and disability with effect size post intervention

	Mean (SD)	Mean difference scores (95% CI)	Cohen's d (CI 95%)
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	MWM & Exercise hot packs (n=22)	Exercise/hot packs (n=22)		
VAS with maximal HBB	2.79 (0.60)	4.56 (0.72)	-1.77* (-2.17,-1.36)	2.73 (2.54:2.92)
IR ROM°	34.55 (3.76)	26.79(2.74)	7.75* (5.71, 9.80)	2.44 (1.46:3.36)
HBB ROM°	16.20 (3.99)	6.89 (2.16)	9.31* (7.38, 11.27)	2.97 (2.04:3.90)
SPADI score	23.86 (6.05)	46.04(5.33)	-22.17* (-25.64, -18.70)	3.98 (5.62:2.34)

VAS: visual analogue scale. IR: Internal rotation. ROM: Range of motion. HBB: Hand behind back. SPADI: Shoulder pain and disability index. CI: confidence interval

* Significant difference between groups, $p < 0.05/4$.

Cohen's d relation (between groups effect size, standardized mean difference)

Figure Captions

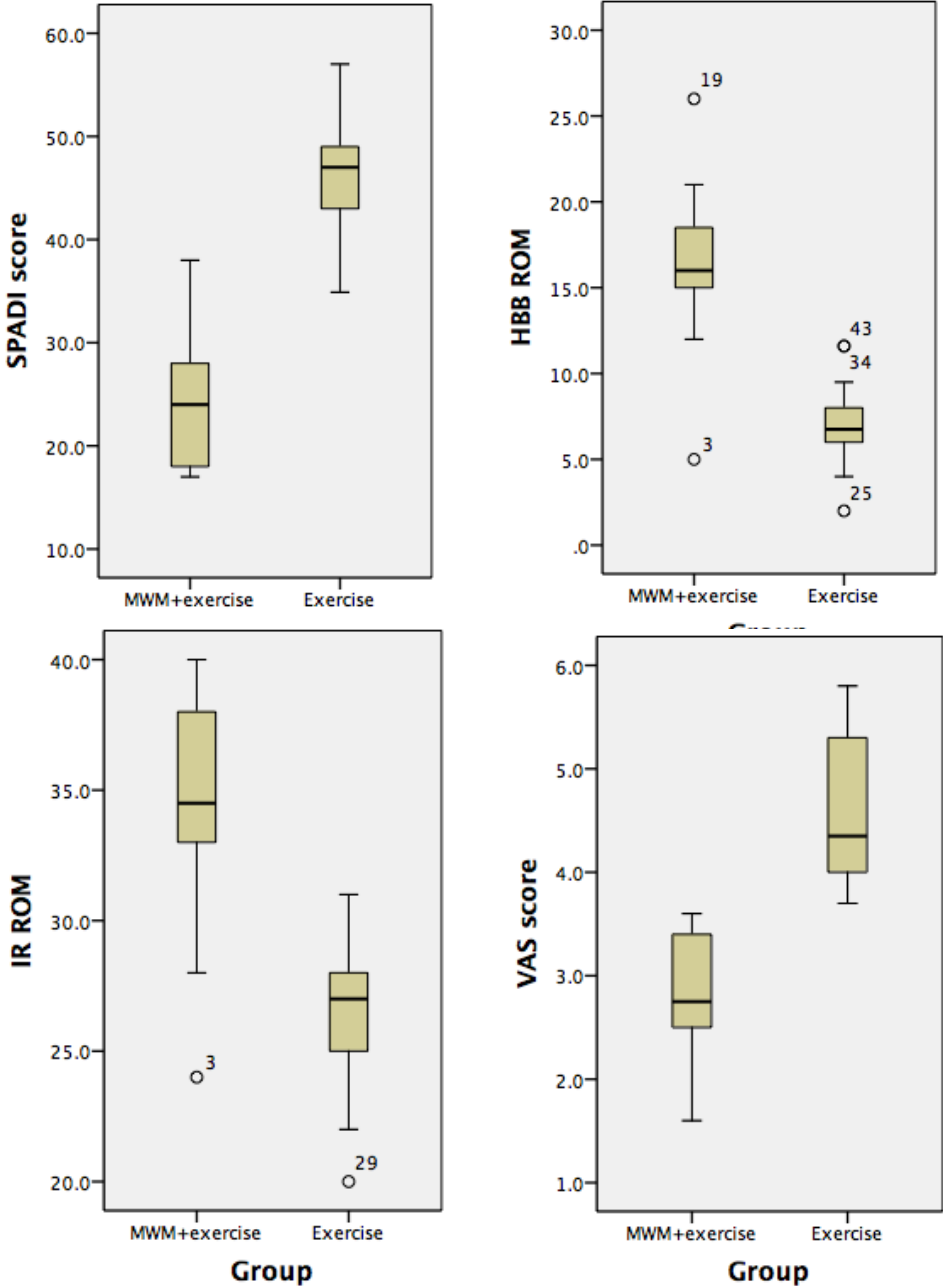
Figure 1: Flow chart of the participants through the study

Figure 2: Measurement of Internal rotation range of motion in side lying

Figure 3: Exercise protocol

Figure 4: Hand behind back mobilization with movement technique

Figure 5: Box plots showing comparison of dependent variables post intervention in both groups



IR: Internal rotation. ROM: Range of motion. VAS: Visual analogue scale pain score for maximal hand behind back. HBB: Hand behind back. SPADI: Shoulder pain and disability index

