

Review

Mulligan's mobilization-with-movement, positional faults and pain relief: Current concepts from a critical review of literature

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Abstract

There are an increasing number of reports espousing the clinically beneficial effects of Mulligan's mobilization-with-movement (MWM) treatment techniques. The most frequent reported effect is that of an immediate and substantial pain reduction accompanied by improved function. Prompted by these dramatic effects are questions regarding the mechanism(s) of action that underpins MWM. It appears timely that a review of the current literature is performed to synthesize and evaluate claims of the effectiveness of MWM and speculation about the proposed mechanisms of action.

This article provides an overview of the literature concerning the clinical efficacy, effects and putative mechanisms of action of the MWM approach in the treatment of musculoskeletal conditions. The literature regarding the mechanisms of action in both the biomechanical and pain science paradigms is covered herein by reviewing all available scientific evidence from laboratory-based studies. Limitations of reported studies and directions for further research are also considered.

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1. Introduction

Mulligan's mobilization-with-movement (MWM) treatment techniques are gaining a reputation for use in musculoskeletal conditions, many of which have a reputation of being difficult to treat and for which manual therapy is not traditionally used (e.g. lateral epicondylalgia, complicated De Quervain's).

MWM is a manual therapy treatment technique in which a manual force, usually in the form of a joint glide, is applied to a motion segment and sustained while a previously impaired action (e.g. painful reduced movement, painful muscle contraction) is performed. The technique is indicated if, during its application the

technique enables the impaired joint to move freely without pain or impediment (Mulligan, 1993). The direction of the applied force (translation or rotation) is typically perpendicular to the plane of movement or impaired action and in some instances it is parallel to the treatment plane (Mulligan, 1992, 1993, 1996).

Reports of clinical cases and case series have described the success of MWM in the management of various musculoskeletal conditions (Stephens, 1995; Vicenzino and Wright, 1995; Hetherington, 1996; O'Brien and Vicenzino, 1998; Miller, 2000; Exelby, 2001; Folk, 2001; Backstrom, 2002; Horton, 2002; Kochar and Dogra, 2002; Scaringe et al., 2002). This paper reviews the clinically based studies in order to develop an understanding of the current level of knowledge of the MWM approach and to provide a basis for future work in this area. Clinically based studies are defined for the purpose of this paper as studies that follow a treatment program through to completion as opposed to studying the effects of a treatment technique at only one treatment session.

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The mechanism(s) by which the MWM exerts its ameliorative effects in clinical practice remains somewhat of an enigma. It has been proposed that the MWM treatment technique produces its effects by correcting positional faults of joints that occur following injuries or strains (Mulligan, 1993). This putative mechanism of action is in need of further evaluation, especially when considering the controversy generated by similar proposals for spinal manipulation, such as in chiropractic subluxation (LeBoeuf-Yde, 1998; Haldeman, 2000).

The aim of this review was to critically evaluate the relevant current literature under two broad paradigms: the biomechanical and neurophysiological paradigms. Current concepts of the efficacy and mechanism of action of MWM will be presented and directions for future research provided.

2. Methods

The literature was accessed through computerized bibliographic medical and allied health databases (AMED, CINAHL, Cochrane library, EMBASE, MEDLINE and SPORT Discus). All available literature written in the English language was searched without restriction of the publication date (from databases' inception to current issue, 02/2006). Relevant articles were identified by using the keywords "mobilization*" or "mobilization*" and "movement"; "MWM"; "SNAG" and "Mulligan". This search was complemented by an on-line library search (i.e. ScienceDirect), article citation tracking, and through correspondence with researchers in the field. Due to the limited numbers of studies in this field, articles in refereed journals were selected for inclusion if their reported data was based on a study of symptomatic subject(s) (e.g. case studies, case series, controlled clinical trial, randomized-controlled trial, randomized-controlled design with blinding procedures). Reports in dissertations, personal or anecdotal experience were excluded as it is considered to be the lowest hierarchy of evidence (NHMRC, 2000; Harbour and Miller, 2001).

The results of search strategies revealed that publications in this topic area of MWM have appeared since 1992. A total of 45 non-overlapping journal articles were found. Of these, only 19 met the pre-specified criteria and were included in this qualitative review. Two main categories of the MWM studies were explored; clinical-based studies (9) and laboratory-based studies (10). Two investigators reviewed these articles. We used a qualitative approach as we could only find one randomized clinical trial. The majority of the studies to date are largely descriptive in nature. No systematic quantitative review was possible (NHMRC, 2000).

3. Clinically based studies

The clinical efficacy of MWM techniques in the treatment of musculoskeletal conditions has attracted much interest recently. Kochar and Dogra (2002) conducted a quasi-randomized-clinical trial of MWM with ultrasound (US), US alone and a no treatment control on 66 subjects with lateral epicondylalgia (Table 1). Forty-six of the 66 cases were randomized into the two treatment groups (23 each group). The remaining 20 cases, who were unable to visit the hospital for therapy sessions, were included in the study as a non-randomized control group. Ten therapy sessions of the assigned treatment condition (i.e. MWM+US or US) were delivered within the first 3 weeks and then followed up by a progressive exercise regime for a further 9 weeks. Four outcome measures (10 cm pain visual analogue scale (PVAS), grip strength, a weight lifting test, and patient self-assessment) were evaluated at baseline and then after weeks 1, 2, 3 and 12. The results showed that the MWM+US group was superior to the US group and that both interventions (MWM+US, US) were superior to control, which remained unchanged. At the final outcome measurement session the MWM+US group demonstrated a 5.9 cm (97%) improvement in PVAS and an approximate 4.4 kg increase in weight lifted. The US group also showed improvements of 1.7 cm (29%) on PVAS and approximately 1.6 kg on weight lifted. The patient self-assessment scale improved significantly with the MWM+US group but not the US and control groups, whereas changes in maximum grip strength were not significantly different from the US group. Several methodological issues compromise the internal and external validity of the study of Kochar and Dogra (2002). The subjects were not randomly allocated to the control group, the demographics (e.g. attitude, socio-economic, health care) of the control group was therefore likely to be different from that of the treatment groups. Also, there were scant details about the baseline comparisons of the duration of the condition between the three groups prior to the commencement of the study.

Apart from Kochar and Dogra (2002) all other studies of clinical efficacy that we identified were case reports and case series (Table 1). Interestingly, the majority of these papers deal with upper limb injuries that are widely recognized as soft tissue disorders (e.g. De Quervain's, "trigger thumb", lateral epicondylalgia). There were also two case studies describing the effects of sustained natural apophyseal glides (SNAG); a form of MWM applied to the spine (Mulligan, 1999).

Folk (2001) described the use of MWM in a 39-year-old female who had injured her thumb during a fall on to her outstretched hand while rollerblading. The patient reported pain around the thumb with radiation across the hand dorsally to the medial side of the wrist

Table 1
Clinical-based studies on efficacy of mobilization-with-movement treatment techniques

First author (year)	Design (N)	Condition Treatment(s)	Outcome Measures	Results	Comments
Backstrom (2002)	Case study	De Quervain's MWM (radial glide) at radio-carpal joint	Pain level ROM Self-rated function level	<ul style="list-style-type: none"> ● 25% improvement in pain level initially after treatment. ● Wrist/thumb ROM √√ and –ve Finklestein test on discharge and full function 12 months later. 	<ul style="list-style-type: none"> ● Other physiotherapy was also used; making it difficult to delineate specific MWM effects.
Exelby (2001)	Case studies <i>N</i> = 5	Locked lumbar zygapophyseal joint <i>L</i> _{4/5} SNAG (postero-anterior with cephalad inclination)	Pain level Lumbar PAIVM ROM Number of treatments	<ul style="list-style-type: none"> ● Minor discomfort remained, PAIVM √√, and increase Lumbar ROM initially after treatment. ● ROM √√ or minor discomfort EOR and 3 or fewer treatments required by discharge. 	<ul style="list-style-type: none"> ● Long-term follow up was not described in detail.
Folk (2001)	Case study	Post-traumatic (recalcitrant) thumb Internal rotation MWM at first MCP joint	Pain level ROM	<ul style="list-style-type: none"> ● ROM √√ initially after treatment and symptom free at 1, 8 and 52 weeks later. 	<ul style="list-style-type: none"> ● Juxtaposed the clear-cut guidelines of MWM (i.e. treatment only proceeds if there is a substantial reduction in pain and impairment) against a prior 10-month history of treatment by an MD, orthopaedic surgeon and OT with 3 different diagnoses.
Hetherington (1996)	Case study	Ankle sprains Posterior glide distal fibular MWM	Pain level Ankle inversion Observed balance	<ul style="list-style-type: none"> ● Inversion √√ and observed balance improved initially after treatment. 	<ul style="list-style-type: none"> ● Number of cases in the study and long term follow up were not reported. ● Taping was added post-MWM
Horton (2002)	Case study	Locked thoracic zygapophyseal joint <i>T</i> _{8/9} SNAG	Pain level Thoracic spine ROM	<ul style="list-style-type: none"> ● 95% improvement with residual intermittent mild ache initially after treatment. ● ROM √√ except for pain at EOR left Lateral Flexion a day later. 	<ul style="list-style-type: none"> ● Clinically reasoned that SNAG was no longer required after 1 session as patient was better. No long-term follow-up. ● Taping was used after MWM
Kochar and Dochar (2002)	Quasi-RCT <i>N</i> = 66	Lateral epicondylalgia MWMLE (lateral glide) plus US or US alone for 3 weeks followed by 9 weeks of exercise were compared to control (no treatment)	Pain VAS Grip strength Weight lift Self-assessment score	<ul style="list-style-type: none"> ● MWMLE plus US was better than US and control on all outcomes, except grip strength, which was only better than control. 	<ul style="list-style-type: none"> ● Control group was not randomised. ● An immediate effect after treatment was not evaluated.
O'Brien and Vicenzino (1998)	Case studies <i>N</i> = 2	Lateral ankle sprains Posterior glide distal fibular MWM	Pain and function VAS Ankle ROM Kaikkonen functional	<ul style="list-style-type: none"> ● 1–4.5 cm reduction on pain VAS and 2–5° inversion gain during application. ● Over the course of 5 weeks the Kaikkonen 	<ul style="list-style-type: none"> ● Included a short control period in one patient at the outset in order to cater for the anticipated rapid resolution of acute pain and impairment

Table 1 (continued)

First author (year)	Design (N)	Condition Treatment(s)	Outcome Measures	Results	Comments
				score significantly improved (5.3–7.4 units/day), which was greater than the natural rate of progression (i.e. 1.5 units/day)	following ankle sprain.
				<ul style="list-style-type: none"> • Pain-free and full function • Progression rates were greater than natural recovery 	<ul style="list-style-type: none"> • Comparison with the actively treated patient, showed the MWM to exert superior effects to that of natural resolution. • Tape was applied post-treatment.
Scaringe et al. (2002)	Case study	Chronic shoulder, arm and neck pain Shoulder MWM: postero-lateral glide on humerus with scapular stabilization Spinal MWM with shoulder abduction (pressure on T4 spinous process) Cx spine manipulations	performance test Pain level Shoulder and Cx ROM Limited function	<ul style="list-style-type: none"> • Initially after treatment: MWM increased abduction from 105° to 145° and spinal MWM further increased abduction to full ROM. • After 2-weeks: abduction was $\sqrt{\sqrt{}}$, function 95%, and there was mild pain (3/10) after golfing. • At 29 weeks post-discharge: Cx spine ROM was $\sqrt{\sqrt{}}$, function 100%, and there was minor discomfort (1–2/10) with golf 	<ul style="list-style-type: none"> • Multiple techniques were applied making it difficult to delineate the specific effects of a certain treatment. • Gliding directions for Spinal MWM were not described
Vicenzino and Wright (1995)	Case study	Lateral epicondylalgia MWMLE (lateral glide) Self-treatments (self-MWM, stretching and strengthening exercises, elbow taping)	Pain and function VAS Pain-free function questionnaire PFG PPT	<ul style="list-style-type: none"> • Pain was reduced by 36%, and PFG increased by 200% initially after treatment. • No improvement in baseline after first 2 treatment sessions • Full resolution 10 weeks after discharge (i.e. full function, restored grip strength and 230% improvement in PPT) 	<ul style="list-style-type: none"> • Used A-B-C study design (modified A-B-A design) with within-subject baseline comparisons. • Tape, self MWM and exercises were used following MWMLE as a home programme of physical treatment

Abbreviation: $\sqrt{\sqrt{}}$ (double ticks), pain-free full range of motion; Cx, cervical; EOR, end of range; L, lumbar; MCP, metacarpophalangeal; MWM, mobilization-with-movement; MWMLE, mobilization-with-movement for lateral epicondylalgia; N, number of subjects; PAIVM, passive accessory intervertebral movements; PFG, pain-free grip force; PPT, pressure pain threshold; ROM, range of motion; SNAG, sustained natural apophyseal glide; US, ultrasound; VAS, visual analogue scale.

and forearm. No bony injury was seen on X-ray. Prior to presentation to physical therapy, the patient underwent numerous interventions, including rest, splinting, corticosteroid injections, and at approximately 6 months post-injury, surgery. The physical therapist was consulted 6 weeks after surgery. Physical examination of the thumb found that overpressure into extension of the

first metacarpophalangeal (MCP) joint produced pain. A sustained internal rotation of the first proximal phalanx about its longitudinal axis with manual fixation of the first metacarpal bone abolished the pain and allowed the patient to move into full pain-free extension. This manoeuvre was then applied as a MWM for 2 sets of 10 after which post-treatment assessment revealed full

pain-free range of extension at the MCP, which was maintained at the 1 year follow-up. Folk (2001) speculated that the MCP joint dysfunction following the injury might have manifested as a positional fault that lead to the patient's symptoms and that the MWM reduced the positional fault.

Backstrom (2002) reported a case study of a 61-year-old woman with a 2-month history of trauma-induced stiffness, pain and limited function of the thumb and hand during activities such as grooming, brushing, and washing. Radiographs at 6 weeks revealed no fractures. All motions of the right wrist, carpals and first carpometacarpal joints were limited and pain was elicited on contraction of the right extensor pollicis brevis and abductor pollicis longus. There was a positive Finklestein test. A MWM, which consisted of a sustained radial glide of the proximal row of carpal bones allowed full thumb and wrist motion to occur painlessly. Following the first treatment session, which included 3 sets of 10 repetitions, there was a 25% improvement in PVAS. A total of 12 treatment sessions over a 2-month period resulted in complete resolution of the condition, which was maintained throughout the following year. Although the author ascribed much of the success in outcomes to the MWM, the inclusion of many other treatments (e.g. elastic support, carpal mobilization, massage, iontophoresis and exercises) may have compromised this assertion.

Vicenzino and Wright (1995) reported a single case study of MWM treatment for lateral epicondylalgia (MWMLE) in a 39-year-old female with a 3-month history of lateral epicondylalgia. The patient had previously attended 6 sessions of therapy consisting of massage, ice, LASER, electrical stimulation, stretching and gripping exercise over a 5-week period, without any progress. The MWMLE was applied for 6 repetitions per treatment session during 4 sessions over a 2-week period. The patient's elbow was taped following treatment, and she performed self-MWMLE and exercises involving stretching and gripping within pain limits as a home programme. Sustained and significant changes in pain-free-grip force (PFG), PVAS and function occurred during the treatment phase of the trial when compared to baseline data (2 weeks of data collected pre-treatment). The improvement was maintained during the 6-week post-treatment phase. No symptoms of elbow discomfort were demonstrated following the treatment phase as evaluated by the pain-free function questionnaire. The reduction in pain during the course of the study occurred more rapidly than the increase in function prompting the authors to speculate that the mechanism of action of this MWM technique and associated home programme of taping, exercises and self-MWM may be primarily related to its direct effect on pain (Vicenzino and Wright, 1995).

O'Brien and Vicenzino (1998) investigated the effect of a MWM for lateral ankle pain in 2 male patients following acute ankle sprain (2–3 days post-injury) using a single subject design. Subject I underwent an ABAC protocol while subject II underwent a BABC protocol, where "A" = no intervention period, "B" = intervention period, and "C" = post-treatment return to sport period. The MWM treatment technique involved a sustained posterior glide with cephalad inclination to the distal fibula, while the patient actively inverted the ankle to the end of pain-free range with overpressure. Following treatment a strapping tape was applied to replicate the effects of the posterior glide of the fibula. The MWM produced immediate improvements in pain, range of motion and function within each treatment session, which accumulated over several (4) treatment sessions and was far greater than the natural resolution over time as observed in the "A" phase of subject 1. The authors speculated that the results may reflect the reduction of a positional fault at the inferior tibio-fibular joint.

SNAG techniques are also used in the treatment of spinal musculoskeletal conditions with as many as 41% of British therapists' who treat low back pain reporting their use (Konstantinou et al., 2002). Exelby (2001) reported success following a MWM treatment of a clinically diagnosed locked lumbar facet joint syndrome. A 46-year-old female presented to physiotherapy 3 days after experiencing a sharp pain in the lower lumbar region whilst returning from a flexed position after performing arm curls with a barbell in a flexed lumbar spine position. Physical examination revealed a flexed lower lumbar spine and lordotic (extended) upper lumbar spine with all active movements limited to a quarter range by pain. Treatment included a SNAG consisting of a central sustained glide of the L4 spinous process while the patient first performed repeated flexion followed by repeated extension in lying. A further four case studies were also reported. Long-term effects of the treatment were not reported.

Horton (2002) also reported success in treating an acute locked thoracic joint with a modified SNAG. The case involved a 20-year-old male university student who presented with acute left-sided thoracic pain adjacent to the T_{8/9} inter-vertebral joint following an incident the previous night when his friend had picked him up and shaken him in a bear hug manoeuvre. Initial examination revealed that he had a constant dull ache over the left thoracic spine and was locked in a position of forward and right side flexion such that he needed to support himself on his right hand. Any attempt to extend, flex to the left or rotate produced acute severe pain. Pain and resistance to displacement was elicited on palpation of the left T_{8/9} zygapophyseal joint. The initial treatment involved a central SNAG applied in a cephalad direction on the spinous process of T8 while

supporting the patient's trunk and assisting him to move into an upright posture. This procedure, performed pain-free, was repeated another three times until the patient was able to sit upright independently with only a mild ache. Tape was applied to provide further support. On the second visit the patient reported a 95% improvement and had maintained an upright posture. Examination of range of movement revealed only a slight restriction in lateral flexion to the left and slight tenderness over the left T_{8/9} area. The biomechanical explanation for the clinical presentation was that of a locked T_{8/9} zygapophyseal joint in which there was compromise of a meniscoid structure (Bogduk and Jull, 1984; Singer et al., 1990). Horton (2002) postulated that the SNAG could be likened to a longitudinal distraction, which may have been sufficient to release the trapped meniscoid, allowing it to re-enter the joint space.

Scaringe et al. (2002) reported a case in which manual therapy was employed in a 50-year-old male golfer who presented with a 3 year history of intermittent pain (4/10–8/10) over the left shoulder, upper trapezius, medial border of scapula, postero-lateral aspect of the arm and forearm. The pain increased in severity with arm movements. Shoulder range of motion (abduction) and function was restricted by 20–30%. Two MWM treatment techniques were used: one a postero-lateral glide of the humeral head while the scapula was stabilized, and two a spinal mobilization with arm movement for the T4 spinal segment. Additionally, chiropractic manipulation to the cervical spine was also used. There were a total of 3 treatment sessions over a 6-week period (Table 1). The authors reported that a significant improvement was observed immediately after the first treatment and that telephone and fax follow-up at 29 weeks revealed full function with only occasional minor shoulder pain (1/10–2/10). Although only a manual therapy approach was used in treating this patient, the combination of various forms of different manual treatment applications make it difficult to differentiate the specific therapeutic effect of any one individual treatment.

In summary, the level of evidence for the clinical efficacy of MWM treatments is presently low, consisting in the main of case reports. Further studies, such as randomized clinical trials, are required to substantiate or refute the positive claims from these preliminary reports. Many authors speculate about the underlying mechanism of action of MWM techniques with a tendency to conceptualize this as one of reducing positional faults at joints (subluxations). While randomized clinical trials will provide evidence of clinical efficaciousness, they will not address the issue of the underlying mechanism of action of MWM techniques. Questions regarding mechanism(s) of action are best answered in laboratory studies (Vicenzino and Wright, 2002).

4. Laboratory-based studies: biomechanics

It has been hypothesized that MWM reduces minor positional faults at joints (Mulligan, 1993; Exelby, 1995; Exelby, 1996; Hetherington, 1996; O'Brien and Vicenzino, 1998; Kavanagh, 1999; Mulligan, 1999; Exelby, 2001; Folk, 2001; Backstrom, 2002). This hypothesized mechanism of action is based on a premise that a minor positional fault results following joint injury (Hubbard et al., 2006) and that these faults are largely responsible for the pain and observed limitation of movement (Mulligan, 1999; Folk, 2001; Backstrom, 2002). Although many authors, putatively ascribe their observations of beneficial clinical effects to the correction of bony positional faults (O'Brien and Vicenzino, 1998; Exelby, 2001; Folk, 2001; Backstrom, 2002; Collins et al., 2004), few studies have directly evaluated this proposal (Kavanagh, 1999; Hsieh et al., 2002) (Table 2).

The positional fault hypothesis for MWM has been described by reference to plantarflexion-inversion sprain injury of the ankle (Hetherington, 1996; Mulligan, 1999). Mulligan (1999) hypothesized that the distal fibula subluxes anteriorly and caudally during plantarflexion-inversion injury of the ankle and Hetherington (1996) has proposed that the subsequent effusion and adhesions maintain this positional fault at the inferior tibio-fibular joint. There is preliminary evidence of radiographic positional faults in chronic ankle sprains that supports this hypothesis (Hubbard et al., 2006). Protagonists of this positional fault hypothesis argue that it is validated by the dramatic improvement in pain-free range of inversion that is brought about by the antero-posterior glide MWM technique on the distal fibula (Hetherington, 1996; O'Brien and Vicenzino, 1998). However, this evidence is based on measures of pain, range of motion and function, not of bone position. There is one exception to this trend. It is a study by Kavanagh (1999) who attempted to measure change in bone position with application of the antero-posterior glide MWM of the inferior tibio-fibular joint in 25 subjects (17 normals, 2 chronic ankle sprains, and 6 acute ankle sprains). In brief, the set up was such that the foot to be tested was placed in standardized position with the posterior heel supported on a wooden block and the posterior surface of each of the malleoli resting on potentiometers. The posterior displacement that occurred at the distal fibula during the MWM was recorded and plotted against the applied force, thus describing the force–displacement relationship for this technique. The author claimed that the data supported the proposal of anterior-caudal positional fault of the inferior tibio-fibular joint in ankle sprain patients, despite a *P*-level of 0.15 when comparing the treatment effect in the acute ankle sprain group to the normal and chronic sprained ankle groups. The author argued that the data from 2 of the 6 acute ankle sprains that

Table 2

Laboratory-based studies of MWM in which the biomechanical and pain effects were measured immediately after the treatment was applied, unless otherwise stated in the results and comments

Authors (year)	Design and <i>N</i>	Condition and treatment	Outcome measures	Results	Comments
<i>Biomechanics</i>					
Collins et al. (2004)	Double blind, cross-over, RCT with placebo <i>N</i> = 14	Subacute, grade II lateral ankle ligament sprain. Weight-bearing MWM of talocrural joint (tibial PA glide)	Ankle dorsiflexion PPT TPT	<ul style="list-style-type: none"> ● MWM significantly improved ankle dorsiflexion greater than placebo and control. ● No significant changes in PPT and TPT following the MWM, but a small change in PPT with placebo. 	<ul style="list-style-type: none"> ● Although a correction of positional fault was hypothesized as being responsible for the observed change in dorsiflexion; bony position was not measured.
Hsieh et al. (2002)	Case study	Post-traumatic thumb injury. MWM (external rotation) at MCP joint of the thumb.	MRI Pain VAS Thumb ROM Grip strength	<ul style="list-style-type: none"> ● MRI revealed 4° pronated positional fault of MCP joint before treatment, which was not present with MWM in situ. ● Full pain-free ROM initially with MWM in place, after 4 weeks treatment and on-discharge. ● Repeat MRI after discharge revealed no change from pre-treatment. 	<ul style="list-style-type: none"> ● Identified a positional fault on MRI, which was reversed during the application of the MWM, but not after discharge; despite full resolution of the thumb pain and impairment.
Kavanagh (1999)	quasi-experimental design <i>N</i> = 25	Acute (<i>N</i> = 6) and chronic (<i>N</i> = 12) ankle sprain Normal (<i>N</i> = 17) MWM (posterior glide) at distal fibular	Force–displacement relationship of distal fibular	<ul style="list-style-type: none"> ● 2 out of 6 of the acutely sprained ankles showed a greater amount of movement per unit force than normal. 	<ul style="list-style-type: none"> ● Conclusion relied on the data of 2 cases. ● MWM-effect on pain and ROM was not reported.
<i>Pain Science</i>					
Abbott (2001)	Case series <i>N</i> = 23	Lateral epicondylalgia MWMLE (lateral glide)	Shoulder ROM (IR and ER)	<ul style="list-style-type: none"> ● Deficit in Shoulder ROM pre-treatment was reduced after treatment of the elbow. 	<ul style="list-style-type: none"> ● Elbow treatment resulted in a change in shoulder ROM; suggesting that MWMLE evokes more than local mechanisms at the elbow.
Abbott et al. (2001)	Case series <i>N</i> = 23	Lateral epicondylalgia MWMLE (lateral glide)	PFG Maximum grip strength	<ul style="list-style-type: none"> ● PFG and maximum grip strength increased significantly (17% and 5%, respectively). 	<ul style="list-style-type: none"> ● Only cases that responded to the MWMLE were included in the study. ● Showed that the hypo-algesic effect was related to the inclination of the MWMLE in the transverse plane.
McLean et al. (2002)	Randomized, cross-over design <i>N</i> = 6	Lateral epicondylalgia MWMLE (lateral glide)	Level of force applied by a MWMLE PFG	<ul style="list-style-type: none"> ● Force level of 2.5 N/cm (66% of therapist rated maximum force) increased PFG significantly when compared to lower force levels. ● Higher levels of applied force did not improve the PFG any further. 	<ul style="list-style-type: none"> ● Preliminary evidence that the hypo-algesic effect of MWMLE depends on the amount of applied manual force.

Table 2 (continued)

Authors (year)	Design and N	Condition and treatment	Outcome measures	Results	Comments
Paungmali et al. (2003a)	Double blind, cross-over, RCT with placebo N = 24	Lateral epicondylalgia MWMLE (lateral glide)	PFG PPT TPT HR and BP Sudomotor and vasomotor function	<ul style="list-style-type: none"> ● Increase PFG (48%) and PPT (15%), which were greater than placebo and control. ● Sympatho-excitation also occurred concurrently. 	<ul style="list-style-type: none"> ● This study investigated a possible physiological effect of MWMLE, which was previously proposed for spinal manipulation. ● Only short-term (immediate) effects were evaluated.
Paungmali et al. (2004)	Double blind, cross-over, RCT with placebo N = 18	Lateral epicondylalgia Naloxone, Saline and Control delivered prior to the MWMLE (lateral glide)	PFG PPT TPT ULTT2b	<ul style="list-style-type: none"> ● Pain relieving effects produced by the MWMLE were not antagonized by Naloxone. ● Changes in outcome measures were not different from placebo and control conditions. 	<ul style="list-style-type: none"> ● This is consistent with an endogenous non-opioid analgesia. ● Later effects were not studied and so cannot discount a possible latent effect of endogenous opioid peptides
Paungmali et al. (2003b)	Repeated measure design N = 24	Lateral epicondylalgia MWMLE (lateral glide)	PFG PPT	<ul style="list-style-type: none"> ● Magnitude of improvement in PFG and PPT was not reduced with repeated applications of MWMLE over 6 successive sessions. 	<ul style="list-style-type: none"> ● Interpreted as supporting an endogenous non-opioid mechanisms of MWMLE-induced hypoalgesia.
Vicenzino et al. (2001)	Double blind, cross-over, RCT with placebo N = 24	Lateral epicondylalgia MWMLE (lateral glide)	PFG PPT	<ul style="list-style-type: none"> ● Increase PFG (46%) and PPT (10%), which were greater than placebo and control conditions. ● No such changes occurred when the asymptomatic elbow was treated. 	<ul style="list-style-type: none"> ● The MWMLE effect appears to be specific to the symptomatic elbow and to the sensory modality by which it is measured.

Abbreviation: PA, postero-anterior; BP, blood pressure; ER, external rotation; HR, heart rate; IR, internal rotation; MCP, metacarpo-phalangeal; MRI, magnetic resonance imaging; MWM, mobilization-with-movement; MWMLE, mobilization-with-movement for lateral epicondylalgia; N, number of subjects; PFG, pain-free grip force; PPT, pressure pain threshold; RCT, randomized clinical/control trial; ROM, range of motion; TPT, thermal pain threshold; ULTT2b, upper limb neural tissue provocation test 2b; VAS, visual analogue scale.

demonstrated greater posterior movement (displacement) per unit force was sufficient to support the positional fault hypothesis. This study did not report the effects of the MWM on pain, a critical omission for a technique that is strongly focused on pain alleviation.

A recent case study utilized magnetic resonance imaging (MRI) to evaluate the positional fault hypothesis in a 79-year-old female who injured her right thumb (hyperabduction of the MCP joint) during a fall with an umbrella in her right hand (Hsieh et al., 2002). One month after the injury the intensity of pain during function was 6 on a 10-point VAS. MRI examination showed the proximal phalanx of the right thumb to be 4° pronated compared to the left thumb (i.e. position fault) and that this was corrected with a supination MWM of the proximal phalanx while the patient flexed the MCP

joint to full range without pain. A course of such MWM treatment (including self-MWM) was then commenced. After 3 weeks of treatment, the patient reported that her right thumb was much improved. A further MRI evaluation was then performed. It showed that there was no change to the initial positional fault even though the patient was now symptom free. This finding implies that although MWM techniques may alter positional faults during their application, the long-term pain relieving effects are independent of permanent changes in the positional fault. On the basis of this case it would appear that the longer-term effect of MWM may occur via other mechanisms.

Collins et al. (2004) cited findings from their randomized placebo-controlled trial of 14 subacute ankle sprains as evidence of a predominantly mechanical

basis that underpins the initial clinical efficacy of MWM (Table 2). Ankle dorsiflexion but not pain threshold (pressure and thermal) was significantly greater immediately after the application of a MWM that consisted of a postero-anterior gliding technique of the tibia (i.e. a relative antero-posterior glide of talus) performed in a functional weight bearing position (Collins et al., 2004).

In summary, currently there is no substantive evidence that supports or refutes the hypothesis that a reversal of a positional fault is the predominant mechanism of action for MWM, although improvements in range of motion have been shown. Further work is urgently required in addressing this issue.

5. Laboratory-based studies: pain science

The initial pain relieving effects of the MWMLE has been demonstrated in several studies (Abbott, 2001; Abbott et al., 2001; Vicenzino et al., 2001; McLean et al., 2002; Paungmali et al., 2003; Hubbard et al., 2006) (Table 2). Abbott et al., (2001) evaluated the effect of a MWMLE in 23 patients by measuring PFG and maximum grip strength before and after a single session of 10 repetitions of the technique. PFG improved by 17% following the MWMLE compared to a 5% increase in maximum grip strength, thereby, confirming findings by Stratford et al. (Stratford et al., 1993) that PFG is more sensitive in detecting clinical change. This study supports the pain ameliorative properties of MWMLE reported in other studies using similar outcome measures (Vicenzino and Wright, 1995; Vicenzino et al., 2001; Kochar and Dogra, 2002; McLean et al., 2002; Paungmali et al., 2003a). However, no control or placebo groups were included in this study, limiting its internal validity. Abbott (2001) has also measured shoulder range of motion after the application of a MWMLE. At entry into the study subjects had significant reduction in shoulder external rotation range of motion on the affected side when compared to the unaffected side. This deficit was ameliorated after completion of the MWMLE treatment session, prompting Abbott (2001) to postulate that the technique may act neurophysiologically to decrease the level of contractile activity of the shoulder rotator muscles. This interpretation of the data should be construed with caution because it did not account for factors such as shoulder positioning during treatment and testing (Boon and Smith, 2000), as well as potential effects of muscular effort overflow to the shoulder during maximum grip strength testing (especially on the unaffected side) (Nelson and Cornelius, 1991). The inclusion of a no treatment control condition may have accounted for these factors (Bordens and Abbott, 1996).

A fundamental tenet of manual therapy (including MWM) is that the application of treatment requires

precise and specific application of manual forces to the target motion segments (Maitland, 1991). Abbott et al. (2001) demonstrated that the majority of the 23 subjects with lateral epicondylalgia responded to the lateral glide component of the MWMLE when it was inclined 5° posterior to the frontal plane or when directed purely laterally, but not when directed 5° anterior to the frontal plane. McLean et al. (2002) in a study of the manual force levels applied during the MWMLE in 6 subjects (4 female, 2 male) showed that manual force levels of approximately 75N (95% confidence interval (95 CI): 62–87N) improved PFG significantly when compared to lower mean force levels (e.g. 37–56N) and that a maximum force level of 113N did not provide any better effect. The 75N force level equated to approximately 66% of the maximum force that the therapist was prepared to apply to the unaffected side. It would appear that there is an optimal force (McLean et al., 2002) and direction of force (Abbott et al., 2001) that is necessary in bringing about the initial effect.

Several studies further evaluated the initial pain relieving effect of the MWMLE technique for lateral epicondylalgia using a randomized, controlled, repeated measures study design (Vicenzino et al., 2001; Paungmali et al., 2003a). The results demonstrated an immediate and substantial increase in PFG in the order of 46–48% following treatment, which was significantly greater than placebo and control (no treatment). Pressure pain threshold (PPT) improved approximately 10% under the treatment condition, which was significantly greater than placebo and control. A drawback of these studies is the lack of long-term follow-up. Nonetheless, there are two interesting characteristics of the initial effect of the MWMLE that have become apparent from this research. The first is that the MWMLE favours improvements in PFG over changes in PPT deficits, indicating it is specific in its effects (Vicenzino et al., 2001; Paungmali et al., 2003a). The second characteristic is that the treatment technique when applied to asymptomatic elbows does not produce changes in PFG or PPT, implying that the presence of symptoms and dysfunction is an important precondition of MWMLE (Vicenzino et al., 2001).

Recent work in our laboratory has further evaluated characteristics of the hypoalgesic effect of MWMLE (Paungmali et al., 2003; Paungmali et al., 2003a; Paungmali et al., 2004). The data indicate that the MWMLE produces a hypoalgesia and concurrent sympathoexcitation (indicated by changes in heart rate, blood pressure, and cutaneous sudomotor and vasomotor function) (Paungmali et al., 2003a). This finding of initial sympathoexcitation was similar to that reported previously with oscillatory manipulative therapy of the cervical spine (Vicenzino et al., 1998; Sterling et al., 2001). Further work by Paungmali and his colleagues evaluated the role of endogenous opioid peptides in

MWM-induced hypoalgesia by studying the effect of naloxone blockade on MWMLE-induced hypoalgesia (Paungmali et al., 2004) and the development of tolerance with repeated application of the treatment technique (Paungmali et al., 2003). The results of both these studies demonstrated that the initial hypoalgesic effect of the MWM does not appear to involve endogenous opioid systems, as the hypoalgesia did not demonstrate tolerance to repeated applications of the MWMLE treatment technique (Paungmali et al., 2003) and also it was not antagonized by naloxone (Paungmali et al., 2004). It has been previously proposed that the combination of sympathoexcitation, non-opioid hypoalgesia and improvements in motor function are indirect signs of a possible involvement of endogenous pain inhibition systems in manual therapy treatment effects (Wright, 1995; Vicenzino et al., 1998; Sterling et al., 2001).

In summary, there is much speculation about the probable role of neurophysiologic mechanisms in the pain relieving effect of MWM and some emerging evidence that indicates that the effect, although specific, appears to be intricately complex. Further research in this area is required to better understand the underlying mechanism(s) of MWM techniques.

6. Conclusion

The literature concerning MWM may be categorized according to study type, such as studies of clinical efficacy, biomechanics and the pain sciences. Much of the evidence contained in the literature is considered to be of low level. Despite this, there are trends in the data that support the clinical claim of the rapid ameliorative effects on pain and function during and initially after a single treatment application and also after a course of treatment. Further randomized-controlled trials are needed to evaluate the efficacy of the treatment intervention. The predominant explanation provided for this rapid pain relieving effect is mechanical in nature and based on the proposed existence of bony positional faults and the ability of MWM to correct these faults. The evidence from the pain science studies that have attempted to characterize the hypoalgesic effect has indicated that it may be non-opioid in nature as well as exhibiting features that are complex and widely distributed to other systems, such as the motor and sympathetic nervous systems. At this stage the literature does not support or refute this contention. Instead, it provides valuable insights into possible future directions for better-designed studies (i.e. randomized-controlled designs with adequate sample size) in both the biomechanical and pain sciences paradigms. The biomechanical hypothesis that MWM reverses positional faults requires further investigation.

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