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Mulligan's mobilisation with movement: a review of the tenets and prescription of MWMs

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ABSTRACT

Introduction: Mulligan's manual therapy technique at peripheral joints, namely mobilisation with movement (MWM), has been well documented in research for over a decade. The specific parameters of MWM prescription are relatively variable and generally ill defined. The purpose of this review was to critically evaluate the literature regarding MWM prescription at peripheral joints.

Methods: A search was conducted from 1990 to June 2007, to identify all studies pertaining to MWM's at peripheral joints, using the keywords mobilisation with movement* OR mobilization with movement* OR MWM*; manual therapy AND (mobilisation* OR mobilization); mulligan mobilisation* OR mulligan mobilization* from the following databases: Cinahl, Medline and Amed via Ovid, Pubmed and Medline via Ebsco Health Databases, Cochrane via Wiley and PEDro. Two researchers independently reviewed all papers and cross-examined reference lists for further potential studies. Tables were compiled to determine study content and the specifics regarding MWM prescription; including tenets, technical, and response parameters.

Results: Twenty-one studies, which have investigated MWM's at peripheral joints, were included for analysis. This review highlights that specific parameters identified for MWM prescription (tenets, technical and response parameters), are variable and in general inconsistently implemented and explained. The efficacy of MWM's at peripheral joints is well established for various joints and pathologies with 20 out of 21 studies (95%) demonstrating positive effects overall.

Conclusions: A proposed algorithm has been formulated for the integration into clinical practice to ensure necessary parameters are considered. It would be advisable that future research has more robust methodology and investigates and/or implements all necessary established parameters of MWM prescription. **Hing W, Bigelow R, Bremner T (2008): Mulligan's mobilisation with movement: a review of the tenets and prescription of MWMs. New Zealand Journal of Physiotherapy 36(3): 144-164.**

Keywords: mobilisation with movement, MWM, manual therapy, mulligan mobilisation, manipulative technique.

INTRODUCTION

The treatment of musculoskeletal joint dysfunction may require a physiotherapist to use manual therapy. One of these manual therapy techniques include mobilization with movement (MWM), a type of joint mobilisation developed by Brian Mulligan (Mulligan 2004, Mulligan 2007); also referred to as a Mulligan mobilisation (Collins et al 2004, Kochar and Dogra 2002, Teys et al 2006) or a manipulative technique (Paungmali et al 2003b, Vicenzino et al 2001). The MWM technique consists of many necessary parameters for prescription, which are outlined in Figure 1. An accessory glide is applied at a peripheral joint, while a normally pain-provoking physiological movement or action is actively or passively performed. A key component to MWM is that pain should always be reduced and/or eliminated during the application (Exelby 1995, Exelby 1996, Mulligan 2004, Wilson 2001).

Parameters

Note: * = Duplication of parameters as defined by different clinicians

Tenets (Hing 2007, Mulligan 2004)
- Accessory glide
- Physiological movement
- Pain-free or pain alteration *
- Immediate/instantaneous effect *
- Overpressure

Technical Parameters (Hing, 2007)
- Repetitions
- Sets
- Frequency
- Amount of force
- Rest periods

Response Parameters ('PILL' Acronym) (Hing, 2007)
- Pain-free or pain alteration *
- Immediate/instantaneous effect *
- Long-Lasting
- Client specific outcome measure (CSOM) or comparable sign

Figure 1: Key parameters of MWM prescription

Further gains in pain relief may be attained via the application of pain-free passive overpressure at the end of the available range during the MWM (Mulligan, 2004; Wilson, 2001). Adaptation, or 'tweakanology' as described by Mulligan, is essential to perform if the technique does not positively improve pain behaviour (Exelby 1996). Primarily this includes the direction or angle of the accessory glide, and/or the amount of force. The MWM technique also requires a comparable sign or client specific outcome measure (CSOM) as a baseline measure, to evaluate treatment effectiveness (Exelby 1995, Exelby 1996, Wilson 2001).

With respect to the research, the clinical efficacy of Mulligan's MWM techniques has been established for improving joint function, with a number of hypotheses for its cause and effect. Mulligan's original theory for the effectiveness of an MWM is based on the concept related to a 'positional fault' that occur secondary to injury and lead to mal-tracking of the joint; resulting in symptoms such as pain, stiffness or weakness (Mulligan, 2004). The cause of positional faults has been suggested to be due to changes in the shape of articular surfaces, thickness of cartilage, orientation of fibres of ligaments and capsules, or the direction and pull of muscles and tendons. MWM's correct this by repositioning the joint causing it to track normally (Mulligan, 2004; Wilson, 2001).

More recent studies have investigated further mechanisms that including the hypoalgesic and sympathetic nervous system (SNS) excitation effects (Abbott 2001, Paungmali et al 2003a, Paungmali et al 2004, Teys et al 2006). Further research has established the effectiveness of MWM's for increasing joint range of motion (ROM), enhancing muscle function, or more specifically treating particular pathologies (Collins et al 2004, DeSantis and Hasson 2006, Exelby 1996, Mulligan 2004, Paungmali et al 2003b, Teys et al 2006, Vicenzino et al 2006).

Despite the common use of MWM techniques in clinical practice for many musculoskeletal conditions, the prescription is not clearly defined, although there is common reference in the literature to Mulligan's recommendations as outlined in his text (Mulligan 2004). Prescription refers to many parameters within an MWM, including tenets, technical and response parameters, along with a comparable sign or CSOM (refer to Figure 1). Prescription can be defined as 'a written direction for the preparation, compounding, and administration of a medicine' (Lexico Publishing Group Ltd 2007). With respect to MWM prescription, this definition refers to having written guidelines that are clearly defined to draw on for the application of this treatment technique. Tenets represent the principles included in an MWM, which have been outlined by Mulligan (Hing 2007, Mulligan 2004). Both the technical and response parameters are contemporary concepts devised by Vicenzino & Hing (Hing, 2007). To date these aspects of prescription have not yet been reviewed or validated, which may impact on the clinical application of MWM treatment.

Therefore, the purpose was to undertake a review to critically evaluate the literature regarding MWM prescription at peripheral joints and to determine the specific parameters and rationale related to this prescription thus in attempt to formulate guidelines for clinical practice.

METHODS

Literature Search Strategy

The purpose of this review was to research relevant articles in relation to MWM of peripheral joints only. The electronic databases in the search from 1990 to June 2007, included: CINAHL via Ovid and Ebsco Health Databases, Cochrane via Wiley and Ovid, AMED, Medline via Ebsco and Pubmed, and PEDro. The refined key terms, included mobilisation with movement* OR mobilization with movement* OR MWM*; manual therapy AND (mobilisation* OR mobilization); mulligan mobilisation* OR mulligan mobilization*. These search phrases were adapted for particular databases (Medline via Pubmed and Ebsco, and Ebsco Health Databases), due to the excessive number of results (refer to Figure 2). While performing the search, two independent researchers evaluated all titles and abstracts and were obtained from the various databases or from other sources to determine appropriateness. If this was unclear the full-text article was obtained to confirm whether MWM at peripheral joints was employed. All articles to be included in this review were obtained in hard copy. For more detail on this search strategy see the flow chart below (Figure 2).

Exclusion criteria which was incorporated during the search included: studies prior to 1990, non-English written articles, studies not relevant to peripheral joint manual therapy/MWM/physiotherapy, spinal manual therapy, chiropractic studies, non-original research, cadaver or animal studies, and/or if there was no clear indication of the use of MWM. The aim of this review was to obtain every study, which has utilised MWM techniques; therefore no restrictions were placed on study design or methodological quality. All literature needed to be reviewed accurately to analyse the possible variations in its prescription. As papers were examined, reference lists were cross checked by both reviewers for citations of other potentially relevant studies, and in total three studies were subsequently retrieved from this process of cross-referencing (Hetherington 1996, Stephens 1995, Vicenzino et al 2001).

Review of Study Characteristics

Using a generic critical appraisal checklist, data was extracted from the included 21 articles and information was recorded. Four specific tables relating to MWM prescription were also formed, which included the tenets, pain behaviour analysis, technical parameters, and response parameters (CSOM and the PILL acronym). Each reviewer

Figure 2: Flow chart outlining research process

Objective: Two independent researchers to obtain relevant articles in relation to mobilisation with movement in peripheral joints only

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Global search followed by a refined search (*exclusion criteria* implemented)

Generic search terms for the refined search:
KEY:

- A) mobilization* with movement OR mobilisation* with movement OR MWM*
- B) manual therapy AND (mobilization* OR mobilisation*)
- C) mulligan mobilization* OR mulligan mobilisation*

Sources:

1) Amed

A) 22 results	Excluded:	A) 10
B) 56 results		B) 51
C) 1 results		C) 0

2) Cinahl via Ovid

A) 29 results	Excluded:	A) 16
B) 132 results		B) 126
C) 2 results		C) 1

3) Cochrane via Ovid

A) 11 results	Excluded:	A) 2
B) 53 results		B) 50
C) 1 results		C) 0

4) Cochrane via Wiley

A) 84 results	Excluded:	A) 84
B) 1 results		B) 1
C) 4 results		C) 0

5) Ebsco Health Databases

NB: Adapted search terms:
[A) mobilization* with movement OR mobilisation* with movement]

A) 24 results	Excluded:	A) 10
B) 89 results		B) 84
C) 1 results		C) 1

6) Medline via Ebsco

NB: Adapted search terms:
[A) mobilization* with movement OR mobilisation* with movement]

A) 19 results	Excluded:	A) 6
B) 68 results		B) 63
C) 0 results		C) 0

7) Medline via Pubmed

NB: *Adapted search terms*
mobilization* with movement OR mobilisation* with movement OR MWM* = 71398
mobilization* with movement OR mobilisation* with movement = 71173
i.e. [A) manual therapy AND (mobilization* with movement OR mobilisation* with movement OR MWM*]
manual therapy AND (mobilization* OR mobilisation*) = 2873
i.e. [B) manual physical therapy AND (mobilization* OR mobilisation*)]

A) 333 results	Excluded:	A) 319
B) 111 results		B) 110
C) 634 results		C) 632

8) PEDro

A) 3 results	Excluded:	A) 0
B) 22 results		B) 20
C) 3 results		C) 0

Figure 2 (continued)

TOTAL articles identified for analysis in relation to the exclusion criteria: 117 studies

Cross matching of search results for repeated articles resulted in: 18 studies

Cross-referencing of all articles resulted in: 3 studies

→

Selected Studies

Total: 21 studies to be reviewed

- 4 True randomised control trials (RCTs)
- 5 Randomised control trials, participants as own control
- 1 Quasi-experimental study (no control)
- 3 Non-experimental studies (2 pretest/posttest, 1 repeated measures)
- 3 Case studies
- 5 Case reports

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Critiquing method:

- Critiquing tool selected (Downs & Black, 1998)
- All articles critiqued by both researchers. Simultaneously compared findings

analysed all of this data. The content of these tables will be discussed further in the results.

RESULTS

During the search, articles were excluded on the basis of the strict exclusion criteria previously mentioned. A total of 117 articles were identified from the stated databases (refer to Figure 2 for details). Once search results were matched for repeated articles between the databases, 18 were included for analysis. An additional three studies were found by means of further cross-referencing by both reviewers (Hetherington 1996, Stephens 1995, Vicenzino et al 2001), increasing the total to 21 studies for analysis - including four true randomised controlled trials (RCT's), five RCT's with participants as own control, one quasi-experimental, three non-experimental, three case studies, and five case reports. Further detail of each of the studies methodological data variation and study design are detailed in Appendix 1.

1) Specific Parameters and Rationale Related to MWM Prescription

Within the prescription of MWM's, there are different areas that need investigating. Firstly there are the five tenets, described by Mulligan, which should be considered with all MWM's. These are: the accessory glide generated by the therapist, the physiological movement or action, pain reduction or elimination, an immediate effect, and the use of overpressure, which are outlined in Table 1 (Hing, 2007). Pain behaviour is further elaborated in Table 2. The second consideration of MWM's is the technical parameters of prescription, which are: repetitions, sets, frequency, amount of force, and rest periods, which are outlined in Table 3. Vicenzino & Hing have devised a new concept of response parameters, which are the effects that the MWM should have on the patient to continue with treatment (Hing, 2007). These are 'pain-free' or pain altering application (reduction + / – elimination), instantaneous and long-lasting effects, namely the 'PILL' acronym (refer to Tables 2 and 4). Lastly Vicenzino & Hing have also discussed the use of a comparable sign to determine treatment effectiveness, which is also known as a CSOM, also found in Table 4 (Hing, 2007). There is a duplication of parameters, such as 'pain-free' or pain altering application and an immediate or instantaneous effect, which are both components of tenets and the PILL acronym. This duplication is secondary to two different clinicians defining these parameters of prescription.

(Abbott 2001, Abbott et al 2001, Altman and Burton 1999, Backstrom 2002, Bisset et al 2006, Collins et al 2004, DeSantis and Hasson 2006, Downs and Black 1998, Exelby 1995, Exelby 1996, Folk 2001, Hartling et al 2004, Hetherington 1996, Hignett 2003a, Hignett 2003b, Hing 2007, Hsieh et al 2002, Kavanagh 1999, Kochar and Dogra 2002, Lexico Publishing Group Ltd 2007, McLean et al 2002, Monteiro and Victora 2005, Mulligan 1989, Mulligan 1995, Mulligan 1999, Mulligan 2004, Mulligan 2006, Mulligan 2007, O'Brien and Vicenzino 1998, Paungmali et al 2003a, Paungmali et al 2004, Paungmali et al 2003b, Roddy et al 2005, Saunders et al 2003, Slater et al 2006, Stephens 1995, Teys et al 2006, Vicenzino 2003, Vicenzino et al 2006, Vicenzino et al 2001, Vicenzino et al 2007, Vicenzino and Wright 1995, Wilson 2001, Zhang et al 2005)

Tenets of MWM

Accessory glide

The accessory glide performed should either be at a right angle to the joint such as a lateral glide of the elbow, or follow Kaltenborn's concave-convex rule such as an anterior-posterior glide of the ankle (Exelby 1995). All studies, except Bisset et al. (2006) clearly defined the direction of glide, although referred to Vicenzino (2003) for the prescription of their MWM, which clearly outlines that the glide should be a lateral glide of the forearm for treatment of lateral epicondylalgia. All studies at the elbow applied a lateral glide to the ulna. The second most common form of glide was an anterior-posterior mobilisation either directly from mobilising the distal bone of the joint, or mobilising the proximal bone in the opposite direction, such as a posterior-anterior mobilisation (Collins et al., 2004; Vicenzino et al, 2006). The techniques for the wrist and thumb were highly variable (Backstrom, 2002; Folk, 2001; Hsieh et al., 2002).

Physiological movement

All studies involved a secondary movement or action to be performed by the patient during the MWM. Only two studies did not clearly state the movement performed during the MWM (Abbott, 2001; Bisset et al., 2006). Bisset et al. (2006) once again referred to Vicenzino (2003), which states that the patient should perform a pain-free gripping action. Abbott (2001) stated that the painful movement was performed, although this was not specified. For the treatment of lateral epicondylalgia the movement was either wrist extension or gripping of the hand (Abbott, Patla & Jensen, 2001; Kochar & Dogra, 2002; McLean et al., 2002; Paungmali et al., 2003a; Paungmali et al., 2003b; Paungmali et al., 2004; Slater et al., 2006; Stephens, 1995; Vicenzino & Wright, 1995; Vicenzino et al., 2001). MWM's for lateral ankle sprains included either dorsiflexion or inversion movements (Collins et al., 2004; Hetherington, 1996; O'Brien & Vicenzino, 1998; Vicenzino et al., 2006). The two studies investigating MWM for treatment of shoulder pain were similar utilising either pure abduction or abduction in the scapula plane (Teys et al., 2006; DeSantis & Hasson, 2006). The movement involved in the treatment of thumb sprains varied between the two studies, either including MCP flexion or extension (Folk, 2001; Hsieh et al., 2002). Only one study to date has investigated the use of MWM's in de Quervain's, which employed all wrist movements and thumb abduction (Backstrom, 2002). Overall the rationale for all studies of which physiological movement was performed during the MWM, was based upon utilising a normally pain provoking movement, with which the MWM was to eliminate this pain.

'Pain-free' or pain alteration (reduction +/ – elimination)

Mulligan (2004) states that the MWM technique must be pain-free during its application. This tenet of an MWM is questionable, as it is more of an alteration to pain with a reduction and/or elimination, and thus not always 'pain-free' as indicated by Mulligan. Majority of studies (86%), have reported pain-free application, conversely three studies in this review did not state whether their MWM technique reduced or eliminated pain (Bisset et al 2006, Slater et al 2006, Stephens 1995). However the study by Bisset et al (2006) referred to Vicenzino (2003), which states that the application should be 'pain-free'. It is pertinent to the application and effectiveness of an MWM that a reduction and/ or an elimination of pain is achieved throughout the technique, with appropriate adaptation of the technique in relation to pain response. Table 2 summarises the analysis of the concept of pain behaviour and alteration with the MWM technique, and furthermore how the adaptation of the MWM in response to pain behaviour changes have occurred in studies.

Immediate / instantaneous effect

For an MWM to be deemed effective and progressive, there must be a positive instantaneous or immediate effect during its application. This is determined by the CSOM, which will soon be discussed. All studies that included a CSOM found a positive instantaneous effect, except Slater et al. (2006), which found no significant effects of MWM treatment. Only two studies did not report any immediate/instantaneous effect (Bisset et al 2006, Kochar and Dogra 2002). All the CSOM's improved post treatment, except temperature pain threshold (TPT), which has not been found to be affected by MWM's in any studies to date (Abbott, 2001; Abbott et al., 2001; Collins et al., 2004; DeSantis & Hasson, 2006; Folk, 2001; Hetherington, 1996; McLean et al., 2002; O'Brien & Vicenzino, 1998; Paungmali et al., 2003a; Paungmali et al., 2003b; Paungmali et al., 2004; Slater et al., 2006; Stephens, 1995; Teys et al., 2006; Vicenzino et al., 2001; Vicenzino et al., 2006; Vicenzino & Wright, 1995).

Overpressure

Overpressure is stated by Mulligan (2004) as been an essential element of MWM prescription, however it was only utilised in five studies (24%) within this review (DeSantis and Hasson 2006, Folk 2001, Hetherington 1996, O'Brien and Vicenzino 1998, Vicenzino et al 2006). The particular joints and pathologies of which this was applied include the shoulder for supraspinatus tendinopathy (DeSantis and Hasson 2006), the thumb for de Quervain's (Folk 2001), and also for lateral ankle sprains (Hetherington 1996, O'Brien and Vicenzino 1998, Vicenzino et al 2006). As grip strength was applied, overpressure is indirectly incorporated into any of the studies assessing the effects of MWM at the elbow that focused on lateral epicondylalgia.

Repetitions/sets

Although Mulligan recommends ten repetitions and three sets for a typical MWM treatment, there are variations in the literature regarding repetitions and sets of its application. Mulligan (1995) states this prescription in the text, but the rationale is ill

Table 1. Tenets of MWM application

Author	Accessory glide	Physiological movement	Pain alteration (Reduction +/- elimination)	Immediate effect	Overpressure
Bisset et al., 2006	NS	NS	NS	NT	NS
Kochar & Dogra, 2002	Lateral glide	Wrist extension with weights	Yes	NT	NS
Slater et al., 2006	Lateral glide	Gripping	NS	No	NA
Teys et al., 2006	Posterolateral glide to humeral head. At right angle to shoulder elevation	Patient actively elevated arm in scapula plane	Yes	Yes	NS
Collins et al., 2004	PA glide of tibia	DF in WB	Yes	Yes	NS
Paungmali et al., 2003a	Lateral glide	Gripping a dynamometer for approx 6 seconds	Yes	Yes	NA
Paungmali et al., 2004	Lateral glide	Gripping	Yes	Yes	NA
Vicenzino et al., 2001	Lateral glide	Gripping	Yes	Yes	NA
Vicenzino et al., 2006	1) PA force applied at the tibia with a belt, therefore a posterior glide of the talus. 2) AP force applied to glide the talus	Patient actively moving into the onset of pain or end range DF	1) Yes 2) NS	Yes	Overpressure if no pain after active movement
McLean et al., 2002	Lateral glide	Gripping a dynamometer	Yes	Yes	NA
Abbott, 2001	Lateral glide	Specific combined movement NS. Only states that patient performed the normally pain provoking movement up to 10 times	Yes	Yes	NA
Abbott et al., 2001	Either direct lateral glide of the proximal forearm or 5° posterior, anterior or caudal of lateral	Gripping action, combine with wrist extension or 3rd finger extension	Yes	Yes	NS
Paungmali et al., 2003b	Lateral glide	Gripping for approx 6 seconds	Yes	Yes	NA
O'Brien & Vicenzino, 1998	Posterior glide of distal fibula	Active inversion	Yes	Yes	Passive overpressure
Stephens, 1995	Elbow: lateral glide. Wrist: dorsal glide. Thumb: palmar glide	Wrist extension, forearm supination, gripping, radial deviation, thumb opposition	NS	Yes	NS
Vicenzino & Wright, 1995	Lateral glide	Gripping a weight during the MWM	Yes	Yes	NA
Backstrom, 2002	Radial glide of proximal row of carpal bones. Ulna glide of trapezium and trapezoid for thumb radial abduction. Self MWM: Patient applied ulna glide on forearm with UL WB (i.e. radial glide of carpal bones), shifted BW	Wrist flexion, extension, ulna and radial deviation, and thumb radial or palmer abduction	Yes	Yes	NS
DeSantis & Hasson, 2006	Right angle to glenohumeral joint	Abduction movement (externally rotated; open can position)	Yes	Yes	Pain-free passive overpressure
Folk, 2001	Glides at the proximal end of the proximal phalanx: medial, lateral, axial IR and ER. IR proved to be effective in decreasing pain and improving ROM	MCP extension	Yes	Yes	Passive overpressure
Hetherington, 1996	Posterior glide of the distal fibula at the lateral malleolus	Patient performed active inversion with and without a belt and then released	Yes	Yes	Passive overpressure
Hsieh et al., 2002	Supination of the proximal phalanx of the thumb	Thumb flexion	Yes	Yes	NS

Note: NS = not stated; NA = Not applicable; NT = not tested; PA = posterior-anterior; DF = dorsiflexion; WB = weight bearing; AP = anterior-posterior; approx = approximately; MWM = mobilisation with movement; UL = upper limb; BW = body weight; IR = internal rotation; ER = external rotation; ROM = range of motion; MCP = metacarpophalangeal.

Table 2. Pain behaviour explanation for application and technique adaptation

Author	Pain alteration (reduction +/- elimination):		Adaptation of MWM in response to pain behaviour
	Stated (Yes / No)	Details regarding classification of pain behaviour	
Bisset et al., 2006	No – referred to Vicenzino (2003)	Vicenzino (2003) states the gripping action performed during the MWM should be to the onset of pain and no more	Vicenzino (2003) states to repeat the MWM several times, only if there is a substantial decrease in pain. If the pain relief has not occurred then glides at different angles should be attempted, up to a maximum of 4
Kochar & Dogra, 2002	Yes	States that MWM's are pain-free with a correct glide, although they noted that pain was only diminished during their MWM application	NS
Slater et al., 2006	No – referred to Mulligan (1999), Vicenzino & Wright (1995), Abbott et al. (2001), Vicenzino et al. (2001), & Paungmali et al. (2003a)	NS (Mulligan 1999)	NS
Teys et al., 2006	Yes	Pain-free arm elevation during the glide	The MWM was ceased immediately if any pain was experienced
Collins et al., 2004	Yes	MWM was applied to the end of the pain-free range	If pain was experienced during the MWM the treatment was ceased, and the participant was excluded from the study
Paungmali et al., 2003a	Yes	The glide was painlessly applied, and the patient performed a pain-free gripping action	NS. Although no patients reported pain with treatment
Paungmali et al., 2004	Yes	The glide was painlessly applied, and a pain-free gripping action was performed	NS
Vicenzino et al., 2001	Yes	The glide was performed whilst the patient performed a pain-free gripping action	NS. Although no patients reported pain with treatment
Vicenzino et al., 2006	Yes	It was stated in the text that the essential parameter of an MWM is that they do not inflict any pain but rather alleviate pain during normally painful actions	NS
McLean et al., 2002	Yes	Pain-free grip strength test performed while the glide was sustained	NS - The force was changed in relation to the study intervention, not the pain response
Abbott, 2001	Yes	It is stated that the normally pain provoking movement is performed during the MWM (it is unclear whether this was pain-free during the treatment)	If pain returned, no further repetitions were performed
Abbott et al., 2001	Yes	Stated that the aim for the MWM was an elimination of pain with the comparable sign (normally pain provoking action) that was particular to the patient	Four attempts of the direction of manual pressure were allowed to determine which eliminated the pain. If there pain was not eliminated or it returned during treatment, no further repetitions were performed
Paungmali et al., 2003b	Yes	The glide was painlessly applied, and a pain-free gripping action was performed	NS
O'Brien & Vicenzino, 1998	Yes	Stated that MWM success is based on an immediate relief of symptoms during its application. MWM, which consisted of inversion to the end of pain free range. It was stated that the MWM reduced pain overall (unclear whether this was during or after the MWM application)	NS
Stephens, 1995	No	The elimination of pain was stated, but was unclear whether this was during or after the MWM application	NS. Within the literature review of the case study they state that if the MWM application is painful, an alternative painless angle of mobilization is utilised
Vicenzino & Wright, 1995	Yes	Glide was performed whilst a pain-free gripping action was performed. Stated that the pain-free application was fundamental	After the first treatment session causing an exacerbation of pain, the patient was encouraged to perform the gripping action well below their pain threshold during the MWM
Backstrom, 2002	Yes	Pain-free glides were applied. Chosen MWM resulted in immediate elimination of painful action however was not clear if this was during or after the application	Continued directional modification of the imposed glide was applied throughout Rx to achieve a pain free
DeSantis & Hasson, 2006	Yes	The physiological movement performed during the MWM (shoulder abduction), must be pain-free	NS
Folk, 2001	Yes	The patient was instructed that the MWM with overpressure used must be pain-free	Constant repositioning of the joint with alteration of the glide, positioning, force, overpressure, and therapist to patient generated movement, abolished the pain
Hetherington, 1996	Yes	The MWM application was only continued with if the application of the glide and the active movement of ankle inversion was pain-free	NS
Hsieh et al., 2002	Yes	Patient performed self MWM's, and their was an emphasis on pain-free application. In the discussion it was stated that pain alleviation is important with MWM application	NS

Note: MWM = mobilization with movement; NS = not stated.
Technical Parameters of MWM

defined. Eighteen out of the 21 articles (86%) stated their repetitions and 11 stated their sets. Majority of studies have followed Mulligan's recommendations and prescribed three sets of ten repetitions. It is evident that this is the only rationale for MWM prescription, in combination with its use in previous studies. Variations of this prescription were utilised, ranging from two to ten repetitions, with one to four sets.

Frequency

The frequency of treatment varied from one to 19, with one session most commonly utilised (Abbott, 2001; Abbott et al., 2001; Folk, 2001; Hetherington, 1996; McLean et al., 2002; Paungmali et al., 2003a; Slater et al., 2006; Stephens, 1995; Vicenzino et al., 2001; Vicenzino et al., 2006). The other two most common frequencies were three or six sessions, which commonly implemented an interval between treatment sessions, varying from 24 to 48 hours (Collins et al., 2004; DeSantis & Hasson, 2006; Kochar & Dogra, 2002; O'Brien & Vicenzino, 1998; Paungmali et al., 2003b; Paungmali et al., 2004; Teys et al., 2006; Vicenzino & Wright, 1995). The most frequent treatment carried out two hourly during waking hours, for three weeks (Hsieh et al., 2002), and the less frequent was approximately one treatment every five days (Backstrom, 2002; Bisset et al., 2006).

Amount of force.

The amount of force recommended for an MWM is not stated in Mulligan's text (2004), nor was it stated in majority of studies. McLean et al. (2002) is the only study to state the amount of force used, as this was the aim of their study. Using a hand-held dynamometer, therapists applied a lateral glide to elbows with lateral epicondylalgia at 33%, 50%, 66% or 100% of maximal force. The outcome measure was pain-free grip strength (PFGS), and the results showed that 66% or 100% of force resulted in significant gains. The remainder of the studies either did not state the force used (13/21, 62%), or distinguished between using body weight or therapist arm force (7/21, 33%). Therefore the application of force is an important variable in MWM prescription, for determining treatment effectiveness, and this should be investigated further (Backstrom 2002, Collins et al 2004, DeSantis and Hasson 2006, Kochar and Dogra 2002, Paungmali et al 2003a, Slater et al 2006, Vicenzino et al 2006).

Rest periods

There is large variation in rest periods among the studies reviewed and it has only been stated in 11 studies (52%) ranging from 30 seconds to two hours between sets (Collins et al 2004, Hsieh et al 2002, McLean et al 2002, Slater et al 2006, Teys et al 2006, Vicenzino et al 2006), and 15 to 60 seconds between repetitions (Paungmali et al., 2003a; Paungmali et al. 2003b; Paungmali et al., 2004; Vicenzino et al., 2001; Vicenzino & Wright, 1995). Most commonly the rest period was 15 seconds between repetitions with these four studies investigating the hypoalgesic effects of a lateral glide performed at the elbow in patients with lateral epicondylalgia (Paungmali et al., 2003a; Paungmali et al. 2003b; Paungmali et al., 2004; Vicenzino et al., 2001). These studies found positive results with increases in PFGS and pressure pain threshold (PPT).

Response Parameters

Long-lasting

Effective MWM's should have a long-lasting effect in order for permanent change to occur. This is a further response parameter, as proposed by Vicenzino & Hing (Hing, 2007). Unfortunately this was only investigated in nine of the studies (43%) via follow-up assessments to establish deterioration or improvement from treatment (Backstrom 2002, Bisset et al 2006, Folk 2001, Hsieh et al 2002, Kochar and Dogra 2002, O'Brien and Vicenzino 1998, Paungmali et al 2003b, Stephens 1995, Vicenzino and Wright 1995). Interestingly, five were case studies/reports, which highlights the fact that other research designs have not incorporated follow-up assessment (Backstrom, 2002; Folk, 2001; Hsieh et al., 2002; O'Brien & Vicenzino, 1998; Stephens, 1995). The follow-up period varied from one to 52 weeks. The results included reduction in pain levels, increase in participant assessment scores, increase in pain-free strength, function and ROM. No studies that investigated this parameter found any negative long-term effects of MWM treatment when compared to placebo or control.

Client specific outcome measure (CSOM) or comparable sign

The CSOM or comparable sign is the outcome measure utilised during and immediately after MWM treatment, to determine its effectiveness, and whether the treatment should be continued with. Vicenzino & Hing have established that this should be carried out after all MWM applications, and only continued with if the CSOM has improved (Hing, 2007). It determines whether adaptation in relation to pain response needs to be applied. All studies incorporated a CSOM in their MWM application, which varied in relation to the joint, main problem or deficit, and purpose of research. The number of specific CSOM's also varied between studies, but all included either pain levels, strength, ROM or PPT (Abbott, 2001; Abbott et al., 2001; Collins et al., 2004; DeSantis & Hasson, 2006; Folk, 2001; Hetherington, 1996; McLean et al., 2002; O'Brien & Vicenzino, 1998; Paungmali et al., 2003a; Paungmali et al., 2003b; Paungmali et al., 2004; Slater et al., 2006; Stephens, 1995; Teys et al., 2006; Vicenzino et al., 2001; Vicenzino et al., 2006; Vicenzino & Wright, 1995). Others that were included were TPT, upper limb tension tests (ULTT), sympathetic SNS, joint glides or balance (Collins et al., 2004; Hetherington, 1996; Paungmali et al.,

Table 3. Technical parameters of the MWM technique and rationale for treatment effectiveness

Author	Reps/Sets Y/N Reps	Sets	Number	Frequency	Force	Rest period	
Bisset et al., 2006	Referred to Vicenzino (2003) for MWM prescription. Not stated in the study itself			8 sessions. 6 weeks	NS	NS	NS
Kochar & Dogra, 2002	Y	Y	10 reps. 3 sets. 10 sessions	10 sessions. 3 weeks	NS. Used body weight (belt)	NS	Pain relief due to sensory gating and positional fault correction. Increased tensile strength of tissue
Slater et al., 2006	Y	Y	6 reps (30 secs). 3 sets. Total duration = 2.5 mins approx	1 session	NS. Used arm force	30 secs between sets	To exert rapid pain relieving effects associated with sympathoexcitation mechanisms that would be likely to occur in actual tennis elbow pain
Teys et al., 2006	Y	Y	10 reps. 3 sets	3 sessions. 24 hours apart	NS	30 secs between sets	Changes to joint or muscle structures and positional fault correction
Collins et al., 2004	Y	Y	10 reps. 3 sets	3 sessions. 24 hours apart	NS. Use of body weight	1 min between sets	MWM has a mechanical effect rather than a hypoalgesic. After ankle sprain anterior displacement of the talus may occur, and MWM may correct this positional fault
Paungmali et al., 2003a	Y	N	10 reps applied for approx 6 secs	1 session	NS. Used arm force	15 secs in between reps. Sets not stated	Positional fault correction has been researched, however physiological effects have not been. Hypoalgesic effects of MWM treatment
Paungmali et al., 2004	Y	N	6 reps	3 sessions. 48 hours apart	NS	15 secs between reps	Non-opioid and possible a noradrenergic endogenous pain modulation mechanisms
Vicenzino et al., 2001	Y	N	6 reps	1 session	NS	15 secs between reps	Hypoalgesic/physiological mechanisms of pain relief versus mechanical joint correction/positional fault mechanism
Vicenzino et al., 2006	Y	Y	1 &2) 4 reps of glides. Each glide maintained for 10 secs at end range or at the onset of pain. 4 sets per Rx.	1 session	NS. Used a belt and bodyweight to produce PA force	1) 20 secs. 2) NS	Use of MWM indicated as evidence shows that people with recurrent ankle sprains have common physical impairments being a lack of posterior talar glide and WB dorsiflexion. Based on the arthrokinematic principle of that the talus glides posteriorly during dorsiflexion. To improve the coupling joint motion at the talocrural joint, not just simple posterior talar glide
McLean et al., 2002	Y	Y	2 reps each force. 4 force levels (sets)	1 session	Mean % of max force: 100% =113.2N 66% = 74.5N 50% = 55.6N 33% = 36.8N	2 mins between each Rx	Specific force needs to be applied for sufficient pain relief
Abbott, 2001	N	N	Performed the provoking movement 10 times. Total time for both sides and measuring = approx 15 mins	1 session	NS	NS	People with lateral epicondylalgia have reduced shoulder rotation. A change in shoulder ROM with manual therapy at the elbow suggests that the pre intervention limitation was neurophysiologic in nature, not mechanical
Abbott et al., 2001	Y	N	Up to 10 times	1 session	NS	NS	Correcting the joint malalignment with MWM techniques has an effect on increasing muscle strength and relieving associated pain with normally provoking actions
Paungmali et al., 2003b	Y	N	10 reps	6 sessions. 48 hours apart	NS	15 secs in between reps. Approx 48 hours between each session	Pain relief due to descending pain inhibition, not due to endogenous opioid mediators
O'Brien & Vincenzino, 1998	Y	N	4 reps	Subject 1: 6 sessions over 2 weeks, and 3 sessions over 1 week (with 1 week between). Subject 2: 6 sessions over 2 weeks	NS	NS	Positional fault. Post ankle sprain there may be antero-inferior subluxation of the distal fibula and MWM may correct this resulting in increased ROM and decreased pain

Table 3 (continued). Technical parameters of the MWM technique and rationale for treatment effectiveness

Stephens, 1995	N	N	NS	23 sessions	NS	NS	Minor positional fault occurring from an injury or strain. Mobilization perpendicular to the dysfunctional plane of motion corrects joints positional fault
Vincenzino & Wright, 1995	Y	Y	6 reps. Glide sustained for approx 5-10 secs	4 sessions. 2 weeks	NS	No longer than 60 secs in between reps	MWM effect was to decrease pain and increase function during and immediately after its application. Positional fault correction
Backstrom, 2002	Y	Y	3 sets of 10 reps for each of the movements	12 sessions. 2 months	NS. Used arm force and WB through the right UL	NS	Positional fault of carpal bones. MWM realigns bones allowing pain-free movement with correct alignment
DeSantis & Hasson, 2006	Y	Y	Initially: 10 reps. 2 sets. 5 more sessions: 10x1 only	5 sessions. 2 weeks	NS Used arm force	NS	Use of MWM versus Maitland sustained glides without movement to not only decrease pain but increase ROM and function. To restore normal arthrokinematics by decreasing dysfunctional joint alignment and then in turn allow more uniform tensile stress applied at the tendon during activities
Folk, 2001	Y	Y	2 sets. 10 reps	1 session	NS	NS	MWM was used to reposition the 1st MCP with extension movement and therefore decrease pain and improve ROM. To normalise the arthrokinematics of the 1st MCP joint
Hetherington, 1996	Y	Y	10 reps. 3 sets	1 session	NS	NS	With a lateral ankle sprain the ligament remains intact and the forces are transmitted to the fibula gliding it anteriorly creating a positional fault. Balance deficits at ankle are commonly associated with mechanoreceptor damage in relation to the malposition of the fibula
Hsieh et al., 2002	Y	N	Self Rx: 6 reps	2 hourly during waking hours for 3 weeks	NS	2 hours between sets	MWM's used to correct positional fault and therefore decrease pain and improve ROM

Note: Rx = treatment; Y = yes; N = no; Reps = repetitions; MWM = mobilisation with movement; NS = not stated;; secs = seconds; mins = minutes; approx = approximately; PA = posterior/anterior; max = maximum; N = newtons; ROM = range of motion; WB = weight bearing; UL = upper limb; MCP = metacarpophalangeal.

2003a; Paungmali et al., 2004; Vicenzino et al., 2006). However specific studies did not use the CSOM immediately after the first set to test for an instantaneous/immediate effect (Bisset et al 2006, Kochar and Dogra 2002).

2) Overall Efficacy of MWM's

All studies included in this review found significant positive results with MWM applications, when compared to placebo or control groups. The only study in which no significant results were found with PPT or strength was by Slater et al. (2006), which is also the only study, which investigated the efficacy of MWM's on an induced condition. All other studies utilised patients with genuine pathologies, whereas this study induced lateral epicondylalgia pain via delayed onset of muscle soreness and hypertonic saline.

The most common significant results found were increase in strength, reduction in pain levels, increase in PPT, improved ULTT's, and overall function improvements when compared with placebo or control, mainly in lateral epicondylalgia (Abbott et al., 2001; Bisset et al., 2006; Kochar & Dogra, 2002; McLean et al., 2002; Paungmali et al., 2003a; Paungmali et al., 2003b; Paungmali et al., 2004; Stephens, 1995; Vicenzino et al., 2001;Vicenzino & Wright, 1995). No change in TPT has been found at the elbow (Paungmali et al., 2004). Other interesting findings were that repeated applications of MWM, or MWM with naloxone did not have an inhibitory effect on the pain relieving effects, therefore suggests that a non-opioid mechanism occurs for the analgesic response (Paungmali et al., 2003a; Paungmali et al., 2004). The only study investigating the required force for optimal effects, demonstrated that best results are gained when an MWM is applied at either 66% or 100% of maximal force (McLean et al., 2002). MWM treatment was also found to be superior in the long-term when compared to corticosteroid injection (Bisset et al., 2006). Alterations in SNS function following an MWM were demonstrated, showing an increase in heart rate, blood pressure, skin conductance, blood flux and skin temperature. These are similar to the effects of spinal manipulation (Paungmali et al., 2003b). MWM applied at the elbow has shown to have beneficial effects on shoulder rotation ROM (Abbott, 2001).

At the shoulder, wrist, thumb and ankle, similar results were found. These were decrease in pain, increase in ROM, PPT, strength and joint glides, and improved function (Backstrom, 2002; Collins et al., 2004; DeSantis & Hasson, 2006; Folk, 2001; Hetherington, 1996; Hsieh et al., 2002; O'Brien & Vicenzino, 1998; Teys et al., 2006; Vicenzino et al., 2006). Again no change in TPT was found at the ankle (Collins et al., 2004). One study investigated MWM under magnetic resonance imaging and found MWM to correct a position fault at the thumb, although this was not maintained post MWM, although the positive effects were long-lasting (Hsieh et al., 2002).

Table 4. Client specific outcome measure (CSOM) or comparable sign, and PILL acronym

Author	Client specific outcome measure (CSOM) or comparable sign	Pain alteration (Reduction +/- Elimination)	Instantaneous effect	Assessment of 'Long-Lasting'	Long-lasting affects stated at follow-up assessment
Bisset et al., 2006	Grip force. Pain VAS scale	NS	NT	Yes – Assessed at week 6 and 52 post Rx	Physiotherapy Rx was superior to wait and see and corticosteroid injections at 6 weeks, however at 52 weeks there was no difference between physio and wait and see
Kochar & Dogra, 2002	PFGS. Pain VAS scale. Ability to lift 0-3 kgs	Yes	NT	Yes – Assessed at 1, 2, 3 & 12 weeks post Rx	Significant reductions in pain, improvements in grip strength and lifting strength in the intervention group
Slater et al., 2006	PPT. Maximal grip and wrist extension force	NS	Yes – No significant effects	NT	NT
Teys et al., 2006	Pain-free ROM in the scapula plane. PPT	Yes	Yes – significant increases in ROM and pressure pain threshold	NT	NT
Collins et al., 2004	WB DF ROM. PPT. TPT	Yes	Yes – increase in ROM and pressure pain threshold	NT	NT
Paungmali et al., 2003a	PFGS. PPT. TPT. SNS parameters	Yes	Yes – increase in pain-free grip strength and pressure pain threshold. SNS activation	NT	NT
Paungmali et al., 2004	PFGS. PPT. TPT. ULTT	Yes	Yes – increase in pain-free grip strength, pressure pain threshold and ULTT	NT	NT
Vicenzino et al., 2001	PFGS. PPT	Yes	Yes – increase in PFGS and PPT	NT	NT
Vicenzino et al., 2006	Posterior talar glide. WB ankle DF ROM	1) Yes 2) NS	Yes – increase in posterior talar glide and ROM	NT	NT
McLean et al., 2002	PFGS	Yes	Yes – increase in PFGS (only with 66% or 100% force)	NT	NT
Abbott, 2001	Passive shoulder internal and external ROM	Yes	Yes – increase in ROM	NT	NT
Abbott et al., 2001	PFGS. Maximal grip strength	Yes	Yes – increase in pain-free and maximal grip strength	NT	NT
Paungmali et al., 2003b	PFGS. PPT	Yes	Yes – increase in PFGS and PPT	Yes – Assessed at final (6th) session (48 hours in between sessions)	Hypoalgesic effect of MWM did not reduce with repeated applications. All treatments resulted in increased PFGS (significant) and PPT
O'Brien & Vicenzino, 1998	VAS. Inversion and WB DF ROM	Yes	Yes – decrease in pain and increase in ROM (inversion and DF)	Yes – Assessed 3 times. 1 week post Rx phase = phase C	Reduction in pain, improved inversion and DF ROM, improved functional performance at the ankle. No deterioration.
Stephens, 1995	Pain scale (VAS) during active and resisted wrist extension, forearm supination, and hand grip	NS	Yes – decrease in pain with all hand and arm motions	Yes – Assessed at each session and at the end of 23 treatments	Elimination of pain would continue for 1-2 days however pain would eventually re-occur. Self-MWM would eliminate the pain again. At discharge, MWMs were still effective at decreasing pain if needed
Vicenzino & Wright, 1995	PFGS	Yes	Yes – increase in PFGS during and after application	Yes – Assessed at 6 weeks post Rx	Patient had no pain and had returned to full function. Strong correlation between pain reduction and increased function

Table 4 (continued). Client specific outcome measure (CSOM) or comparable sign, and PILL acronym

Backstrom, 2002	Pain VAS scale. Strength and ROM at wrist and thumb	Yes	Yes – decrease in pain and increase in ROM	Yes – Assessed at 4 months, and 1 year post Rx	MWM application reduced pain to 0-1/10 (VAS). All impairments had resolved at 1 year (no evidence of wrist/thumb pain or functional deficits whatsoever)
DeSantis & Hasson, 2006	NPRS during active abduction. Abduction active ROM	Yes	Yes – decrease in pain and increase in ROM	NT	NT
Folk, 2001	Pain scale (VAS). End range MCP extension with overpressure	Yes	Yes – pain-free end range extension with overpressure	Yes – Assessed at 1 month and 52 weeks post Rx	At 1year follow-up assessment, the patient confirmed she had remained symptom free post the MWM Rx
Hetherington, 1996	Pain on inversion ROM. Balance – single leg standing with eyes closed	Yes	Yes – increase in ROM and balance	NT	NT
Hsieh et al., 2002	Pain scale (VAS). ROM	Yes	Yes – immediate decrease of pain following MWM application	Yes – Assessed 1 week post Rx	MRI examination showed no reduction in the initial positional fault, but she had no pain when flexing her right thumb

Note: VAS = visual analogue scale; NS = not stated; NT = not tested; Rx = treatment; PFGS = pain free grip strength; kgs = kilograms; PPT = pressure pain threshold; ROM = range of motion; WB = weight bearing; DF = dorsiflexion; TPT = temperature pain threshold; SNS = sympathetic nervous system; ULTT = upper limb tension test; MWM = mobilisation with movement; NPRS = numeric pain rating scale; MCP = metacarpophalangeal; MRI = magnetic resonance imaging.

The overall efficacy of MWM's has largely proven to be effective in both reducing pain and improving function in conditions such as lateral epicondylalgia, shoulder pain, de Quervain's, thumb and ankle sprains. The long-term results are discussed above, within 'long-lasting' effects.

DISCUSSION

Specific Parameters and Rationale Related to MWM Prescription

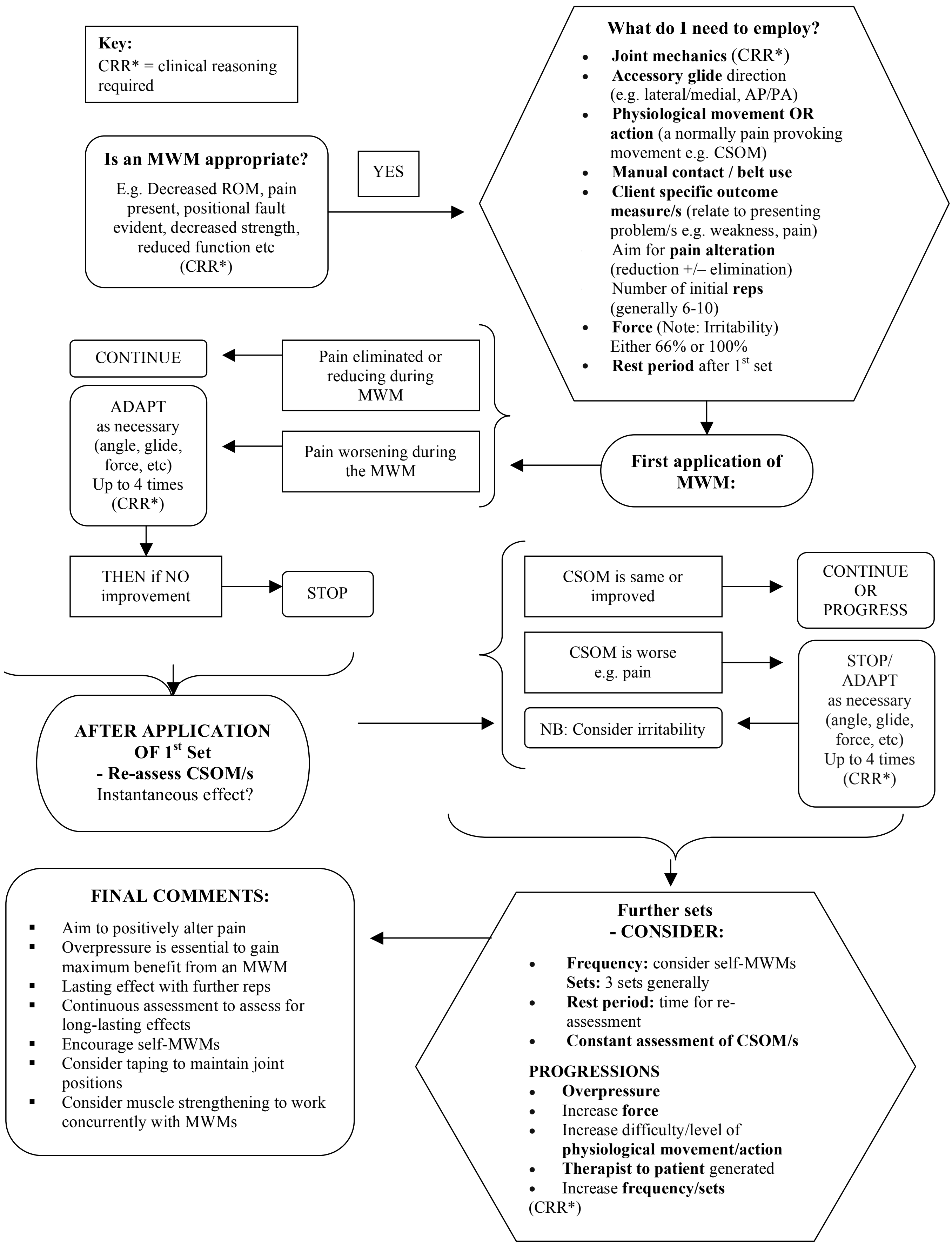
As previously described, tenets, technical and response parameters, all contribute to the effectiveness of Mulligan's manual therapy technique. However, a key finding from this review is that prescription of MWM has been poorly explained or not adequately applied in the literature. This is interesting considering that specific aspects of MWM application have been stated as being necessary components - such as 'pain-free', specific reps and sets, and overpressure. Variations exist in the prescription of MWM not only between studies, but also within individual studies.

Tenets

The tenets of MWM prescription, as described by Mulligan, were generally well incorporated, with the exception of overpressure. All studies clearly defined the accessory glide together with the direction, with the exception of Bisset et al. (2006) who did not state it within the study treatment method, however did refer to Vicenzino (2003). The secondary physiological movement or action performed by the patient is important to ensure a normally pain provoking movement can be altered with the MWM technique. All studies involved this tenet, with only two not clearly stating the movement or action performed (Abbott 2001, Bisset et al 2006), however Bisset et al. (2006) referred to Vicenzino (2003) for its prescription.

The secondary physiological movement closely relates to pain behaviour and how the pain associated with this movement or action should be reduced or eliminated with an MWM. However the concept of terminology surrounding the term 'pain-free' as initially stated by Mulligan is controversial. As explained in the results and outlined in Table 2 the alteration of pain that occurs during and after MWM is not always an elimination of pain or otherwise known as 'pain-free'. Majority of studies (86%) documented pain-free application was utilised, with a minimal number discussing a reduction of pain as also being accepted. This raises the question of why is there is a chosen belief that MWM must be pain-free to continue with treatment? Thus should the term 'pain-free' be changed to pain alteration (reduction + / – elimination)? Several studies referred to the fundamental concept of pain-free application, yet it was not employed in the methods, or if stated it was not clear if pain was altered during or after the MWM (Abbott 2001, Backstrom 2002, Hsieh et al 2002, O'Brien and Vicenzino 1998, Stephens 1995).

Figure 3: Algorithm for the prescription



This also raises the importance of adaptation in response to pain behaviour during the MWM. Only eight studies explained their particular method of adapting the MWM application to alter pain (Abbott 2001, Abbott et al 2001, Backstrom 2002, Bisset et al 2006, Collins et al 2004, Folk 2001, Teys et al 2006, Vicenzino and Wright 1995). For example Bisset et al (2006) referred to Vicenzino (2003) for MWM prescription, who recommends that an MWM is repeated several times, only if there is a substantial decrease in pain, and if the pain relief has not occurred then glides at different angles should be attempted; up to a maximum of four times. Abbott et al. (2001) also states that four attempts of the glide direction are permitted, in order to determine which best eliminates the pain. If the pain was not eliminated or it returned during treatment, no further repetitions were performed.

Another tenet or response parameter associated with an MWM is the immediate or instantaneous effect, which occurs during and/or after the application and is determined by the related CSOM/s. Only two studies did not report any immediate or instantaneous effect (Bisset et al 2006, Kochar and Dogra 2002). This aspect of prescription is a necessity in relation to the effectiveness of the MWM, and also adaptation with regards to pain behaviour.

Overpressure is considered to be a key component in MWM techniques to produce effective pain relief, either as a progression and/or an adaptation if the patient remains symptomatic after initial application (Mulligan 2004, Wilson 2001). The literature however does not significantly reflect this, with only five studies (24%) incorporating this parameter (DeSantis and Hasson 2006, Folk 2001, Hetherington 1996, O'Brien and Vicenzino 1998, Vicenzino et al 2006). Several reviews have discussed the use of overpressure, to further alter pain behaviour and acquire pain-free end range (Exelby, 1996; Wilson, 2001).

Technical Parameters

The documentation of technical parameters was variable throughout the studies. Within this review 18 out of 21 studies (86%) stated the number of repetitions and sets employed. Majority of these studies referred to Mulligan's recommendations of three sets of ten repetitions, although no specific research has been undertaken to investigate the efficacy of these parameters (Mulligan 1995). While the rationale for prescription of repetitions and sets is generally ill defined and based on experimentation in clinical practice, Mulligan (2004) does state the importance of performing an adequate number of repetitions to result in a more lasting effect.

In regards to frequency of MWM treatment one session was most commonly utilised, which is unlikely in a clinical setting but is often carried out in research, especially with MWM's displaying immediate benefits (Abbott, 2001; Abbott et al., 2001; Folk, 2001; Hetherington, 1996; McLean et al., 2002; Paungmali et al., 2003a; Slater et al., 2006; Vicenzino et al., 2001; Vicenzino et al., 2006). A case study by Stephens (1995) utilised the most frequent treatment sessions (n = 19), which may reflect the chronicity of lateral epicondylalgia, and may represent the need for intense and regular physiotherapy intervention for effective treatment outcomes. This is a clear example of how case studies can be more clinically relevant with greater generalisability of results.

The amount of force applied during an MWM is a parameter of limited research and documentation within studies. McLean et al. (2002) is the only study to date, which has investigated the effects of MWM in relation to varied amounts of force applied for the accessory glide. The results illustrated that 66% or 100% of maximal force is superior over less amounts, indicating the amount of force is pertinent to consider with MWM effectiveness. It is therefore interesting that no other studies to date have detailed this parameter, apart from seven out of 21 (33%) distinguishing between the use of body weight or therapist arm force (Backstrom 2002, Collins et al 2004, DeSantis and Hasson 2006, Kochar and Dogra 2002, Paungmali et al 2003a, Slater et al 2006, Vicenzino et al 2006).

The rest period between sets of MWM's, has not been stated by Mulligan (1995), nor is it clearly outlined in any review articles (Exelby, 1995; Exelby, 1996; Vicenzino, 2003; Wilson, 2001), although re-testing between each set for treatment effectiveness is advocated (Exelby, 1996; Wilson, 2001). This area was poorly defined with approximately half of studies (52%) stating the rest periods, with large variations evident. Most commonly employed was a 15 second rest period between repetitions, which was unique to a research purpose of investigating hypoalgesic effects of a lateral glide performed at the elbow in patients with lateral epicondylalgia (Paungmali et al., 2003a; Paungmali et al. 2003b; Paungmali et al., 2004; Vicenzino et al., 2001). To date there are no consistencies within the literature to guide the rest periods between sets (Collins et al 2004, Hsieh et al 2002, McLean et al 2002, Slater et al 2006, Teys et al 2006, Vicenzino et al 2006). In the clinical setting it is probably most appropriate to have a rest period between sets, of a time that allows re-testing of the CSOM to determine treatment effectiveness, and therefore determine whether the MWM application is to be continued with.

Response Parameters

The response parameters as recently defined by Vicenzino & Hing includes the PILL acronym and the CSOM (Hing, 2007). As previously stated the PILL acronym consists of pain alteration, an instantaneous/immediate effect which have both been discussed earlier in tenets, along with long-lasting and the CSOM. Long-lasting effects have been investigated via follow-up assessments in nine studies (43%), all concluding with significant positive results. Paungmali et al. (2003b) established that hypoalgesic effects did not reduce with repeated treatments, therefore is probable that a non-opioid form of analgesia is the cause of pain relief. Also, the case report by Hsieh et al. (2002), determined at follow-up that pain was eliminated via the intervention, however the final magnetic resonance imaging (MRI) illustrated no change in the initial positional fault of the thumb.

The authors therefore suggested that the correction of positional faults during the MWM, as shown by MRI, resulted in immediate effects. The long-term effects, including, pain relief, was hypothesised to be due to changes in nociceptive and motor system dysfunction, possibly implying the role of hypoalgesia. Mulligan (2004) also states that the effects of MWM's can be maintained further via taping and self-MWM's, which may further enhance the possible long-lasting effects. This was included in several studies within this review (Backstrom 2002, Hetherington 1996, Hsieh et al 2002, O'Brien and Vicenzino 1998, Stephens 1995, Vicenzino and Wright 1995).

All studies in this review have incorporated the use of CSOM or a comparable sign to be utilised during and/or immediately after an MWM as a response parameter. The development of the CSOM by Vicenzino & Hing is a new concept, which is related to the requirements of what must occur in order to continue with MWM treatment (Hing, 2007). In general, the choice of the CSOM within the literature was variable but very consistent in relation to employing a normally provoking movement or action, with which the MWM is aimed to improve.

Proposed Guidelines for Clinical Practice

Overall, it is apparent that certain parameters of MWM prescription are ill defined, although the efficacy for particular joints is well established. It may be that experimentation or adaptation of the technique is necessary and common in daily practice, however, a review of its necessary components of prescription was timely. The key components of prescribing an MWM technique need to be defined. Thus it is proposed that the following algorithm is utilised for the prescription of MWM's at peripheral joints in clinical practice (refer to Figure 3). This algorithm is based on the findings of this systematic review and incorporates all necessary components of MWM prescription.

The algorithm encompasses all parameters that have been reviewed in this research and is based upon integration of results. This includes tenets (accessory glide, physiological movement or action, pain alteration (reduction + / – elimination), immediate/instantaneous effect, overpressure), technical parameters (repetitions, sets, frequency, amount of force, rest periods) and response parameters (long-lasting, CSOM). The content of the algorithm aims to allow the practitioner to easily follow it through in order to apply appropriate MWM prescription. Aspects of the algorithm require clinical reasoning in regards to prescription specifics and consideration of irritability.

Future Research

Subsequent to the extensive research and analysis undertaken for this review, there are particular areas within MWM prescription that require further investigation. This could include research into the efficacy and prescription of MWM's at joints that have not yet been examined such as the hip and knee. This could also incorporate the consideration of various pathologies as in the clinical setting, MWM's are utilised for many conditions and in all peripheral joints. It is clear that the specific prescription parameters of the MWM technique have not been consistently employed, nor evaluated. For example the use of overpressure was rarely implemented although it is considered a key component of MWM application, therefore investigation into its additional benefits may be necessary. Further parameters of MWM prescription, which were analysed in this review such as the accessory glide, repetitions, sets, frequency, rest periods, also warrant specific comparative research regarding the effects. Once the efficacies of the discussed parameters are further defined, they need to be prescribed appropriately and more clearly explained in future research. An example is with the amount of force used, which has been validated by McLean et al. (2002) although not implemented appropriately in subsequent research to date.

The efficacy of the proposed algorithm could be investigated via the comparison of its implementation versus the common clinician's MWM application. Perhaps common MWM application could be initially identified through a survey with case examples, which will determine a representative norm for everyday clinical practice and MWM prescription. This will overall establish the efficacy of the algorithm and the incorporation of all necessary MWM prescription components, with regards to treatment outcomes.

CONCLUSION

Mulligan's peripheral MWM techniques are commonly utilised within musculoskeletal physiotherapy. This review of the MWM prescription at peripheral joints highlighted that this area of research has strengths, limitations and inconsistencies.

The specific parameters identified for MWM prescription in the literature, is variable and in general inconsistently implemented and explained. The efficacy of MWM's appears to be well established for various joints and pathologies, as shown by previous reviews, however due to the methodological quality of studies, and gaps in particular areas of both prescription and application, it is apparent that further research is warranted into the specific parameters of MWM's. The proposed algorithm may be integrated into clinical practice, to aid in the inclusion of all necessary components established from this review.

To conclude, this manual therapy technique is widely used and advocated for many aspects of peripheral joint dysfunction. This review has presented an evaluation of MWM prescription, in attempt to guide the clinician appropriately, and provide a basis for future research into this area.

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Appendix 1. Characteristics of the included studies

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
Bisset et al., 2006	True RCT	To investigate the efficacy of PT intervention compared with corticosteroid injection and wait and see for lateral epicondylalgia	198 participants. 128 males, 70 females. Mean age: 48	Group 1: 8 sessions of PT. Group 2: corticosteroid injection. Group 3: wait and see	PT: 8 sessions for 30 mins over 6 weeks. Included MWM, theraband exercises and stretching. Corticosteriod injection: 1 injection, and a 2nd one if necessary after 2 weeks. Wait and see: advice, education on modifications to ADL's, encourage activity, using analgesic drugs, heat, cold and braces	6 weeks and 52 weeks	Global improvement. Grip force. Assessors rating of severity. Pain (VAS). Elbow disability (pain-free function questionnaire)
Kochar & Dogra, 2002	True RCT	To compare the effects of a combination of MWM and US versus US alone, followed by an exercise programme, for lateral epicondylalgia	66 participants. 36 males, 30 females. Mean age: 41	Group 1: combination of US and MWM on 10 sessions (different Rx on alternate days) completed in 3 weeks and an exercise programme (9 weeks). Group 2: US only on 10 sessions completed in 3 weeks and an exercise programme (9 weeks). Group 3 (control): no treatment	US: 3 MHz, 1.5 W/cm2, pulsed 1:5, 5 mins. MWM: elbow extended, forearm pronated, 10 reps, no pain, glide sustained while participant lifted weight that previously produced pain, for 3 sets, 10 sessions. Progressed MWM by increasing weights by 0.5kg. Exercise: stretching, PRT, concentric/ eccentric exercises	Week 1, 2 and 3. Follow-up at 4 months	Pain – VAS scale. Ability to lift 0-3kg weights with no pain, 24hrs after Rx. Grip Strength. Weight test
Slater et al., 2006	True RCT	To examine the effects of a lateral glide MWM in healthy subjects with induced lateral epicondylalgia pain	24 participants. 11 males, 13 females. Mean age: 23	Day 0 – induced DOMS (eccentric exercises on non-dominant arm). Day 1 – injected hypertonic saline (24hrs post exercise) to mimic tennis elbow symptoms (pain duration 10 mins), then applied MWM or placebo Rx	Exercises to induce DOMS: repeated eccentric wrist extension contractions – 5 sets of 60 reps, with 1 min rest interval between sets. MWM: sustained lateral glide, with PT's hand against participants ulna. Participant supine, shoulder abducted 20°, elbow extended and forearm pronated. Placebo: application of a firm constant manual contact around the medial and lateral aspects of the elbow	Before exercise, injection and MWM. After Rx. Follow-up at day 7	PPT. McGill pain questionnaire. Muscle force. Maximal grip force (dynamometer). Maximal wrist extension force (force transducer)
Teys et al., 2006	True RCT	Examine the effect of MWM of the shoulder in relation to ROM and PPT	24 participants. 11 males, 13 females Mean age: 46	Group 1: MWM Rx. Group 2: placebo. Group 3: control	MWM: posterolateral glide with patient seated. PT placed hands over posterior scapula and thenar eminence of other hand over anterior aspect of head of humerus. Posterior glide applied to humeral head. Participant actively abducted arm. Placebo: a/a, but hands of PT were anteriorly on the clavicle and sternum, and an anterior glide with minimal force was applied Control: no manual contact of PT	Before and after Rx, on 3 sessions	AROM (active pain-free shoulder elevation). PPT
Collins et al., 2004	RCT with participants as own control (repeated measures, crossover)	Evaluate the effect of MWM for lateral ankle sprains on ROM and hypoalgesia	16 participants. 8 males, 8 females. Mean age: 28	Group 1: MWM. Group 2: placebo. Group 3: control	MWM: at talocrural joint. Participant WB in stance position with affected leg forward. Belt around PT pelvis and distal tibia and fibula. Pt leaned back to create PA glide, with talus and forefoot stabilised by PT's hand and other hand over proximal tibia and fibula to maintain leg alignment. Placebo: a/a with belt over calcaneum and minimal force, with stabilising hand over metatarsals. Control: pt in stance position for 5 mins with no manual contact of PT	Before and after Rx	Weight-bearing DF ROM. PPT. TPT

Appendix 1 (continued). Characteristics of the included studies

Paungmali et al., 2003a	RCT with participants as own control (repeated measures)	To determine whether an MWM technique at the elbow produces physiological effects such as hypoalgesia and SNS function in patients with lateral epicondylalgia	24 participants. 17 males, 7 females. Mean age: 49	Each participant completed the 3 randomised Rx groups (Rx, placebo, control), at same time of day. 48 hrs in between each session	Rx group: lateral glide MWM with pain-free dynamometer gripping. Participant supine, with shoulder internally rotated, elbow extended, forearm pronation. 10 reps, for 6 secs, 15 sec rest period. Placebo: PT applied a firm manual contact with both hands over the elbow joint whilst the participant gripped the dynamometer pain-free. Control: involved the pain gripping action only (no manual force applied)	Before, during and after Rx	PFGS. PPT. TPT. Cuteneous blood flux. Skin conductance. Skin temperature. BP. HR
Paungmali et al., 2004	RCT with participants as own control (repeated measures crossover)	Evaluate the effect of naloxone on pain relief from an MWM applied to lateral epicondylalgia	18 participants. 14 male, 4 female. Mean age: 49	All participants received intravenously naloxone, saline or no-substance control on 3 different occasions, then a MWM was applied to the elbow	MWM: participant in supine position. Rx applied immediately after the injection. One hand stabilised the distal humerus on the lateral aspect, and the other hand applied a lateral glide to the proximal radius and ulna	Before infection and Rx, and after Rx	PFGS. PPT. TPT. Upper limb neural test provocation (radial nerve)
Vicenzino et al., 2001	RCT with participants as own control (repeated measures)	Determine whether MWM for lateral epicondylalgia produced hypoalgesia and to compare effects on the affected and non-affected arms	24 participants. 14 male, 10 female. Mean age: 46	Participants received either MWM Rx, placebo or control on affected and un-affected arm. They received all 3 intervention levels on different days	MWM: lateral glide of the elbow. One hand gliding the proximal forearm, and other stabilising the distal humerus, while participant performed pain-free gripping. Placebo: firm manual contact over elbow joint. Control: no manual contact of PT	Before and after each Rx session. PFGS also measured during Rx	PFGS. PPT
Vicenzino et al., 2006	RCT with participants as own control (repeated measures, crossover)	To explore the deficits in ankle ROM in patients with recurrent ankle sprains, and investigate the effect of a posterior glide MWM applied in NWB and WB on talocrural DF	16 participants. 8 males, 8 females. Mean age: 20	Group 1: WB MWM. Group 2: NWB MWM. Group 3: control. All participants experienced 1 of the 3 conditions in a randomised sequence on 3 separate days (at least 48 hours apart)	WB MWM: in standing with therapist manually stabilising the foot on the plinth, using belt to apply force and participant moving into DF. NWB MWM: applied with the participant in supine lying, tibia resting on plinth and ankle on the edge. Control group: no manual contact or movement. The participant stood for a similar period of time similar to the treatment time for the other two groups	Before and after Rx, on 3 sessions	Posterior talar glide. WB ankle DF (a WB lunge measured with a tape measure)
McLean et al., 2002	Quasi-experimental – repeated measures (randomisa-tion, no control)	To assess different manual forces used in a MWM technique for lateral elbow epicondylalgia and its effects on hypoalgesia	6 participants. 2 males, 4 females. Mean age: 49	MWM force levels were determined for 33%, 50%, 66% and maximum. All participants received applications of the MWM technique comprising of the 4 force levels in a random order	MWM: directed towards the medial aspect of the ulna. Duration of each Rx technique was no more than 10 secs. 3 applications with contraction for baseline measure. 2 applications of the 4 force levels, with 2 min rest intervals	Before and after Rx	PFGS. Muscle force: measured with a flexible pressure sensing mat between hand and elbow
Abbott, 2001	Non-experimental – pre/post test (randomisa-tion)	To investigate the effects of a single intervention of MWM at the elbow on shoulder ROM for patients with lateral epicondylalgia	23 patients. 18 male, 5 female. Mean age: NS	Random assignment of left or right arm to be Ax and Rx (MWM) first	MWM: participant in supine, and performed the normally provoking movement on the left and right side	Before and after Rx	Passive ROM (goniometer): in particular internal and external rotation

Appendix 1 (continued). Characteristics of the included studies

Abbott et al., 2001	Non-experimental – pre/post test (randomisa-tion)	Determine what proportion of pts respond to MWM for lateral epicondylalgia, whether PGFS and maximum GS increases after 1 Rx of MWM, and determinants of responsiveness	25 participants. 17 males, 8 females. Mean age: 46	All participants received MWM to unaffected and affected arm (randomised order), in 1 Rx session. If participants pain could not be eliminated Rx was stopped	MWM: lateral glide of proximal medial forearm with the distal humerus stabilised, whilst participant performed previously painful movement (fist, gripping, wrist extension, 3rd finger extension). Either of the following glides were performed depending on participants pain response: directly lateral or approx 5° posterior, anterior or caudal of lateral	Before and after Rx, on each arm	PFGS. Maximal grip strength
Paungmali et al., 2003b	Non experimental – repeated measures	Examine whether initial hypoalgesia effects from MWM applied to lateral epicondylalgia were maintained after repeated applications	24 participants. 19 males, 5 females. Mean age: 50	All participants received lateral glide MWM. Applied on 6 occasions, approx 48 hours apart	MWM: patient supine with shoulder in internal rotation, elbow extended and supinated. Therapist stabilised the humerus and applied lateral glide at forearm. Technique performed was pain-free with participants maintaining a grip for approx 6 secs and repeated 10 times with 15 secs rest intervals	Before and after every Rx	PFGS. PPT
O'Brien & Vincenzino, 1998	Case study	To determine the effectiveness of MWM applied at the ankle for acute lateral ankle pain	2 male participants with recent (2-3 days) lateral ankle sprains. Aged 17 and 18	To determine the effectiveness of MWM applied at the ankle for acute lateral ankle pain	MWM Rx: posterior glide of distal fibula while participant inverted the ankle. Passive overpressure was applied. Repeated 4 times. Rx1: 6 sessions over 2 weeks. Rx2: 3 sessions over 1 week. No Rx1: 3 sessions over 1 week. No Rx2: 5 measurement sessions over 1 week. Strapping tape was applied to maintain the posterior glide after every Rx session	Before, during (pain, inversion ROM) and after each Rx	Pain: VAS. ROM: inversion and DF (WB). Functional performance (Kaikkonen scale). Function: VAS
Stephens, 1995	Case study	NS	43 year old female with left sided chronic lateral epicondylitis	Rx: 3 times a week for 1st 4 weeks, then once a week for the following 4 weeks, then once every 2 weeks for the last 6 weeks. Rx: MWM's, ice, US, transverse frictions, exercises began after MWM Rx, massage, stretching, HEP	MWM: lateral mobilisation of the forearm at the elbow during active wrist extension, forearm supination and gripping. Dorsal glide of the hand applied at the wrist during radial deviation and the metacarpal of the thumb was mobilised palmerly at the CMC during thumb opposition. Elbow was taped into a lateral glide. Self mobilizations were performed against a doorway to provide pain relief	NS	Pain: VAS. AROM: shoulder, elbow and thumb. Strength: shoulder, elbow, wrist and grip. Sensation: dermatomes. Special test: resisted wrist ext with elbow at 45°. Palpation
Vincenzino & Wright, 1995	Case study	To investigate effects of a manipulative PT technique on pain and dysfunction of a patient with tennis elbow	39 year old female with right tennis elbow	PT for 6 sessions over 5 weeks. Included 2 weeks Ax, 2 weeks Rx (4 sessions), and 6 weeks HEP	Initial physio Rx: deep and painful massage, ice, laser, some form of sensory stimulation. Exercises – stretching and gripping exercises. Experimental Rx: MWM – lateral glide applied at the proximal part of the forearm whilst stabilising the lateral aspect of the distal humerus (participant in supine, shoulder internal rotation, elbow extended, forearm pronated). Participant was taught self mobilisation and taping (taping was used to replicate the lateral force applied at the elbow by the MWM)	Before Rx, during 2 week Ax phase, and at 6 weeks following Rx	VAS. PPT. Grip strength. Function VAS. Pain-free function questionnaire

Appendix 1 (continued). Characteristics of the included studies

Backstrom, 2002	Case report	Introduce MWM in the treatment of de Quervain's tenosynovitis	61 year old female with de Quervain's tenosyno-vitis of the right wrist	Rx: Manipulation of capitate on first session only, MWM, elastic splint with horseshoe type insert (introduced on session 6), eccentric and concentric strengthening, AROM, tendon gliding, transverse friction, anti-inflammatories and HEP (AROM, strengthening, tendon gliding, frictions, self MWM)	MWM: radial glide of proximal row of carpal bones. 3 sets of 10 reps of each of the movements (wrist flexion, extension, ulna and radial deviation, and thumb radial or palmer abduction) (pain-free). Done at all Rx sessions. WB technique – participant WB through the hand and the same radial glide was performed as participant progressively WB through the right upper limb. Ulna glide of trapezium and trapezoid for thumb radial abduction. Self-MWM – WB of upper limb. Participant applied ulna glide on forearm (therefore radial glide of carpal bones), shifted BW (wrist flexion/extension) with thumb abducted	At each session. Follow-up at 4 months and 12 months post Rx	Pain (VAS). Observation. ROM (goniometer). Wrist flexion, extension, radial and ulna deviation. Thumb palmer and radial abduction. Strength – isometric and MMT. Accessory motion testing. Palpation. Finklestein test
DeSantis & Hasson, 2006	Case report	To describe the effects of an MWM treatment regime for shoulder impingement	27 year old male with left shoulder supra-spinatus tendinopathy	Physiotherapy 3 times a week for 30 mins with a total of 12 sessions	Warm-up: 5 min warm up on cycle ergometer prior to each session. Phase 1: focused on decreasing pain (education on rest, cryotherapy, restoring ROM with MWM) MWM: AP glide with abduction movement (guiding movement of the scapular and humerus with both hands). Phase 2: focused on strengthening rotator cuff, scapular stabilising muscles, improving function, education regarding posture. Each session ended with 10 mins of cryotherapy	Measure-ments of pain and AROM at every PT session	AROM (goniometer) – abduction mainly. MMT. Impingement tests (Neer, Hawkins Kennedy, empty can, apprehension). Functional status: shoulder pain and disability index. SF-36 (global self-report questionnaire). Pain (VAS)
Folk, 2001	Case report	To describe the differential diagnosis and treatment techniques for strained 1st MCP joint	39 years old female, 4.5 weeks after strain to 1st MCP, with diagnosis of de Quervain's of the left hand	Received OT (7 sessions in 6 weeks), then referred for trigger thumb release surgery, then back to OT, which then referred to PT. OT evaluation/Rx performed 3 weeks later	2 cortisone injections for de Quervain's. OT Rx: splint and gutter use, active ROM exercises. Operation: trigger thumb release. PT Rx: MWM at 1st MCP with sustained pain-free internal axial rotation, with overpressure at the end	Measure-ment taken throughout Rx. Follow-up at 2 months and 1 year post Rx	Pain (MCP ext). Swelling. ROM (MCP ext). MMT. Grip strength. Upper limb tension tests. Cervical spine Ax. De Quervain's tests (finkelsteins, pincer strength, palpation)
Hetherington, 1996	Case report	NS. People with ankle injuries were examined to detect a positional fault and managed using MWM and taping methods	NS. Patients post ankle sprain with limited and painful ROM	Majority of patients were treated only with MWM's and taping. No electro-physical therapies were used	MWM: lateral malleous of fibula glided posteriorly with active inversion (with and without a belt). Taping: two strips of 25mm tape approx 15cm in length. Posterior glide applied and then tape applied over the lateral malleolus and travelled around the lower leg (taping changed after 24 hrs)	Before, during and after Rx	Pain on inversion. ROM. One leg standing test (balance – eyes closed). Swelling. Gait Patterns

Appendix 1 (continued). Characteristics of the included studies

Hsieh et al., 2002	Case report	Investigate the use of MRI for positional fault and MWM effects in the thumb	79 year old female with right thumb pain	MWM was applied to the proximal phalanx. MRI was taken before, during MWM, then after a course of MWM Rx. Participant performed self MWM's	Self MWM: supinating the proximal phalanx of the thumb using other hands index and thumb, while performing flexion of the thumb undergoing MWM	MRI: pre Rx, during 1st Rx, after Rx. Week 1: pain, ROM, distraction/ compression, PROM. Week 2 - a/a. Week 3 - a/a, grip strength	MRI. Pain: VAS. AROM: goniometer (flexion of IPJ and MPJ) PROM: thumb radial abduction. Grip strength: hand dynamometer. Compression/ distraction of the MPJ

Note: MWM = mobilization with movement; Rx = treatment; Ax = assessment; O/C = outcome; RCT = randomised controlled trial; PT = physiotherapy; ADL's = activities of daily living; VAS = visual analogue scale; US = ultrasound; MHz = mega hertz; W/cm² = watts per centimetre squared; mins = minutes; PRT = progressive resistant training; reps = repetitions; kg = kilogram; hrs = hours; DOMS = delayed onset muscle soreness; PPT = pressure pain threshold; AROM = active range of motion; a/a = as above; WB = weight-bearing; pt = patient; PA = posterior-anterior; DF = dorsiflexion, ROM = range of motion; SNS = sympathetic nervous system; TPT = temperature pain threshold; secs = seconds; PFGS = pain-free grip strength; BP = blood pressure; HR = heart rate; NWB = non weight-bearing; NS = not stated; GS = grip strength; approx = approximately; HEP = home exercise programme; CMC = carpometacarpal, BW = body weight; MMT = manual muscle testing; AP = anterior-posterior; SF-36 = short form 36; MCP = metacarpophalangeal; OT = occupational therapy; ext = extension; mm = millimetres; cm = centimetres; MRI = magnetic resonance imaging; IPJ = interphalangeal joint; MPJ = metacarpal phalangeal joint.