Mulligan's Mobilization with Movement: A Systematic Review

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The treatment of musculoskeletal joint dysfunction may require a physiotherapist to use a number of modalities. Developed manual therapy techniques include that of Brian Mulligan's widely used mobilization with movement (MWM) for peripheral joint pain[1,2], also referred to as a Mulligan mobilization[3-5] or a manipulative technique[6,7].

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 a mechanical model documented in his first teaching text[8]. This concept is related to minor positional faults that occur secondary to injury and that lead to maltracking of the joint, resulting in symptoms such as pain, stiffness, or weakness[1]. This theory in conjunction with the prescription of MWMs is still advocated in Mulligan's latest edition and remains unchanged[9]. The cause of positional faults has been suggested as changes in the shape of articular surfaces, thickness of cartilage, orientation of fibers of ligaments and capsules, or the direction and pull of muscles and tendons. MWMs correct this by repositioning the joint, causing it to track normally[1,10]. Subsequent research to date also suggests that the mechanisms behind the effectiveness of MWMs are based on mechanical dysfunction and therefore positional fault correction[1,3,11,12].

More recent studies have investigated further mechanisms and effects that may underpin MWM techniques, including hypoalgesic and sympathetic nervous system (SNS) excitation effects[5,13-15]. Further research has established the effectiveness of MWMs for increasing joint range of motion (ROM),

ABSTRACT: Mulligan's manual therapy technique at peripheral joints, namely mobilization with movement (MWM), has been well documented in research. The efficacy of MWM has been established in the treatment of joint dysfunction and various pathologies. The purpose of this systematic review was to critically evaluate the literature regarding MWM at peripheral joints and determine the overall efficacy related to MWM prescription. Electronic databases (Cinahl, Medline and Amed via Ovid, Pubmed and Medline via Ebsco Health Databases, Cochrane via Wiley and PEDro) were searched up to August 2008 with no date restriction to identify all studies pertaining to MWM at peripheral joints. The keywords used were mobilisation with movement* OR mobilization with movement* OR MWM*; manual therapy AND (mobilisation* OR mobilization); mulligan mobilisation* OR mulligan mobilization*. Two researchers independently reviewed all papers and cross-examined reference lists for further potential studies. Methodological quality was assessed using the Downs and Black checklist, and tables were compiled to determine study characteristics. Twenty-one studies, which have investigated MWM at peripheral joints, were included for analysis. This review highlights that there is an overall moderate level of methodological quality (mean = 15 (/28), SD ± 4.54, range = 4—23 /28). The efficacy of MWM at peripheral joints is well established for various joints and pathologies with 24 out of 25 studies (96%) demonstrating positive effects. It would be advisable that future research have more robust methodology and investigate and/or implement all necessary established parameters of MWM prescription.

KEYWORDS: Manipulative Technique, Manual Therapy, Mobilization with Movement (MWM), Mulligan Mobilization

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enhancing muscle function, or more specifically treating particular pathologies[1,3,5,6,16-18].

The purpose of this review initially originated from a global search that was undertaken to explore the literature regarding Mulligan's manual therapy techniques. From this search, it became evident that there has been no review or consensus regarding the prescription of MWMs in peripheral joints. Therefore, the purpose was to undertake a systematic review to critically evaluate the literature regarding the overall efficacy of MWM prescription and use at peripheral joints in an attempt to formulate guidelines for clinical practice.

Methods

Search Strategy

Electronic databases (Cinahl, Medline and Amed via Ovid, Pubmed and Medline via EBSCO Health Databases, Cochrane via Wiley and PEDro) were searched to August 2008 with no date restriction to identify all studies pertaining to MWM at peripheral joints. The refined key terms were 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 (Figure 1). While performing the search, two independent researchers evaluated all titles and abstracts that 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.

Exclusion criteria that were 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. Due to the aim of this systematic review, to obtain every study that had used MWM techniques, no restrictions were placed on study design or methodological quality, as all literature needed to be reviewed to accurately analyze the possible variations in its prescription. As papers were read, reference lists were cross-examined by both reviewers for citations of other potentially relevant studies, and in total three studies were subsequently retrieved from this process of cross-referencing[7,19,20].

Review of Methodological Quality

The critical appraisal tool employed for this research was the Downs and Black checklist for the assessment of methodological quality[21]. This tool has been stated to be valid and reliable for critically evaluating experimental and non-experimental studies[22,23], and it has previously been used in many systematic reviews[24-29]. The Downs and Black tool consists of four categories: reporting (/11), external validity and power (/4), internal validity (bias) (/7), and internal validity (confounding or selection bias) (/6) totalling 28. The last item in this tool, regarding the power of a study, was modified due to its complexity and to ensure consistency with the scoring. The item was changed from a score out of five to a score out of one, and it was placed with the external validity category in the table. An example of a study in which this tool was previously modified is Monteiro and Victora[27].

Each article was assessed with this scoring system, independently by the two researchers, to decrease bias. The scores and content of each article were meticulously discussed throughout. If any disagreements arose, they were deliberated between the two researchers and resolved. After critiquing each study, it was categorized as being of a *strong*, *moderate*, *limited,* or *poor* quality depending on its score (Table 1). This method of score categorization was adapted from previous systematic reviews that have used the Downs and Black checklist and have further classified the resulting values[24,26]. No studies were excluded on the basis of limited quality, due to the purpose of the review and its aim to assess all studies that have incorporated MWMs in peripheral joints.

Review of Study Characteristics

Using a generic critical appraisal checklist, data was extracted from the included 25 articles and information was recorded into tables under the following headings: design, purpose, participants, interventions, MWM prescription or other treatment, outcome measures and timing of assessment, statistical analysis, results, and strengths and limitations.

Results

During the search, articles were excluded on the basis of the strict exclusion criteria previously mentioned. A total of 121 articles were identified from the stated databases (Figure 1). Once search results were matched for repeated articles between the databases, 22 were included for analysis. An additional 3 studies were found by means of further cross-referencing by both reviewers[7,19,20], increasing the total to 25 studies for critical analysis—including 4 true randomized controlled trials (RCTs), 6 RCTs with participants as own control, 3 quasi-experimental, 3 non-experimental, 4 case studies, and 5 case reports. Both researchers performed the statistical calculations independently, to ensure correct results.

Methodological Scoring and Categorization (critical evaluation of the literature regarding MWM prescription at peripheral joints)

The included 25 articles were analyzed using the Downs and Black tool resulting in a variation of data in relation to the particular study design (mean = 15/28; SD ± 4.54; range = 4—23/28). Table 2 reflects the reporting analyses of items 1 through 10. Table 3 reflects the reporting analyses of the external validity items of 11 through 14. Table 4 outlines the scoring for the internal validity items of 15 through 21. Table 5 also includes internal validity items but focuses on confounding or selection biases of

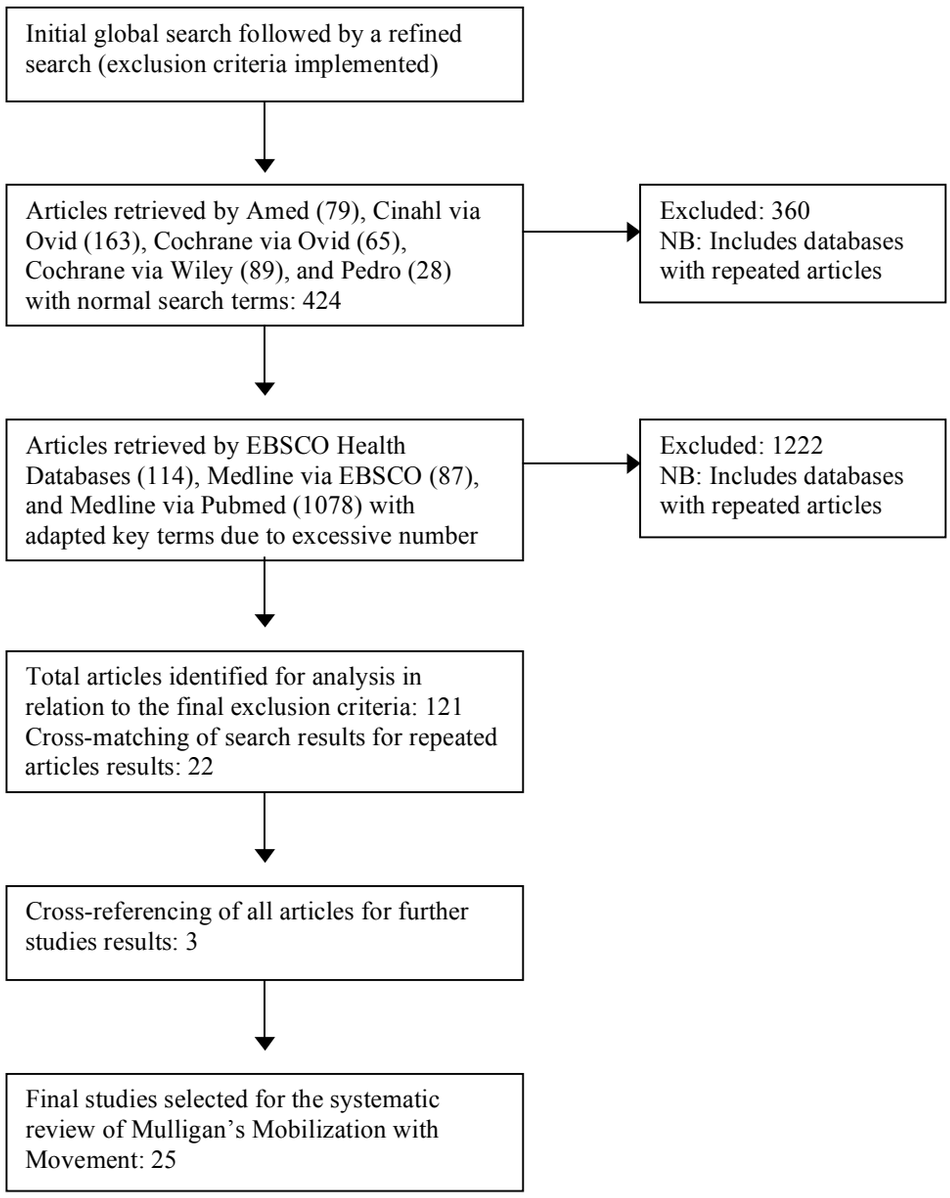

FIGURE 1. Flow chart outlining search results

TABLE 1. Categorization of total methodological scores

Quality Index:	Percentage:	Methodological Quality Score:
Strong	75% +	21 +
Moderate	50–74%	14–20
Limited	25–49%	7–13
Poor	< 25%	< 7

Adapted from Hartling et al[24] and Hignett[26]

items 22 through 27. In general, the studies were of a moderate level of methodological quality. Categorization of the methodological scores, as detailed in Table 1, was adapted from systematic reviews that had previously used the Downs and Black critiquing tool for assessing quality of studies[24,26].

As illustrated in Table 6, RCTs with participants as their own control achieved the highest mean score (mean = 18.5) with the least variability (±1.71), meaning overall they were of moderate methodological quality. This is closely followed by true RCTs (mean = 17.5) and then non-experimental studies (mean = 17.33), both ranking at a moderate level of quality. Interestingly, the non-experimental group of studies had less variability (±3.68) compared to the true RCTs (±5.12). This suggests that there is greater variability (range = 11–23) in the methodological quality of true RCTs in this area of research, even though it includes the highest scoring study to date[30]. Quality of studies was

TABLE 2. Reporting analysis via the Downs and Black checklist for methodological quality

Author	1	2	3	4	5	6	7	8	9	10
Bisset et al[30]	1	1	1	0	2	1	1	1	1	0
Kochar & Dogra[4]	1	1	1	1	1	1	1	0	0	0
Slater et al[42]	1	1	1	1	0	1	1	0	0	0
Teys et al[5]	1	1	1	1	1	1	1	1	1	1
Collins et al[3]	1	1	1	1	0	1	1	0	1	1
Paungmali et al[14]	1	1	1	1	1	1	1	1	1	0
Paungmali et al[15]	1	1	0	1	1	0	1	1	1	0
Teys et al[40]	1	1	1	1	0	1	1	1	1	1
Vicenzino et al[7]	1	1	1	1	1	1	0	1	1	1
Vicenzino et al[18]	1	1	1	1	0	1	1	1	1	1
McLean et al[31]	1	1	1	1	0	1	1	0	0	1
Reid et al[32]	1	1	1	1	2	1	1	0	1	1
Yang et al[33]	1	1	1	1	2	1	1	0	1	0
Abbot[13]	1	1	1	1	0	1	1	0	0	1
Abbottet al[41]	1	1	1	1	0	1	1	0	1	0
Paungmali et al[6]	1	1	1	1	2	1	1	1	1	1
O'Brien & Vincenzino[38]	1	1	1	1	0	0	0	0	1	1
Penso[39]	1	1	1	1	1	1	0	0	1	0
Stephens[20]	0	0	1	0	0	0	0	0	1	0
Vincenzino & Wright[34]	1	1	1	1	0	1	0	1	1	0
Backstrom[35]	1	1	1	1	0	0	0	0	1	0
DeSantis & Hasson[16]	1	1	1	1	0	1	0	0	1	0
Folk[36]	1	0	1	1	0	1	0	0	1	0
Hetherington[19]	0	1	0	1	0	0	0	0	0	0
Hsieh et al[37]	1	0	1	1	0	1	0	0	1	0

1. Is the hypothesis/aim/objective of the study clearly described?
2. Are the main outcomes to be measured clearly described in the introduction or methods section?
3. Are the characteristics of the patients included in the study clearly described?
4. Are the interventions of interest clearly described?
5. Are the distributions of principle confounders in each group of subjects to be compared clearly described?
6. Are the main findings of the study clearly described?
7. Does the study provide estimates of the random variability in the data for the main outcomes?
8. Have all important adverse events that may be a consequence of the intervention been reported?
9. Have the characteristics of patients lost to follow-up been described?
10. Have the actual probability values been reported?

1 = yes, 0 = no

more consistent in the group of RCTs with participants as their own control. The quasi-experimental studies[31-33] had a mean score of 17.33 (±3.68), ranking them as moderate quality. Case studies and case reports had the lowest mean scores, 12.75 (±2.95) and 10.4 (±3.38) respectively, categorizing them as being of limited methodological quality. The range of case studies (range = 8–16) and reports (range = 4–14), however, was large, and two studies had a moderate level of quality[16,34], which is in general equivalent to the quality of several true RCTs, RCTs with participants as own control, quasi-experimental, and non-experimental studies.

When comparing the 4 categories from the Downs and Black tool, in regards to the mean, standard deviation, and range, it is evident that the different categories display either a low or moderate level of quality (Table 6). The categories of external validity/power (/4) and internal validity (confounding and selection bias) (/6) generally scored low, which is indicated by their means, standard deviations, and ranges, calculated across all studies: 0.84 (±0.78) (range = 0–4/4) and 2.84 (±1.22) (range = 1–6/6), respectively. Reporting (/11) and internal validity (bias) (/7) generally scored with a moderate level of quality, with scores of 7.16 (±2.22) (range = 2–11/11) and 4.64 (±1.87) (range = 0–7/7), respectively. Two studies in particular[19,20] had the lowest total scores, resulting in an overall reduction of the mean values and increasing the variability of the data. The study that displayed the highest overall score (by Bisset et al[30]) of 23 out of 27 also illustrated consistency in all 4

TABLE 3. External validity and power analysis via the Downs and Black checklist for methodological quality

Author	11	12	13	14
Bisset et al[30]	1	1	1	1
Kochar & Dogra[4]	0	0	1	0
Slater et al[42]	0	0	0	1
Teys et al[5]	0	0	0	1
Collins et al[3]	0	0	0	0
Paungmali et al[14]	0	0	0	1
Paungmali et al[15]	0	0	0	0
Teys et al[40]	0	0	0	0
Vicenzino et al[7]	0	0	0	0
Vicenzino et al[18]	0	0	0	0
McLean et al[31]	0	0	0	1
Reid et al[32]	0	0	0	0
Yang et al[33]	1	0	0	0
Abbot[13]	0	0	0	0
Abbottet al[41]	0	0	0	1
Paungmali et al[6]	0	0	0	1
O'Brien & Vincenzino[38]	0	0	1	0
Penso[39]	0	0	1	0
Stephens[20]	0	0	1	0
Vincenzino & Wright[34]	0	0	1	0
Backstrom[35]	0	0	1	0
DeSantis & Hasson[16]	0	0	1	0
Folk[36]	0	0	1	0
Hetherington[19]	0	0	1	0
Hsieh et al[37]	0	0	1	0

11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited?
12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited?
13. Were the staff, places, and facilities where the patients were treated representative of the treatment the majority of patients received?
14. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance was less than 5%?

1 = yes, 0 = no

categories, which differs from the other studies, which only excelled in particular categories.

Characteristics of Studies

Data extracted from the 25 studies for the generic critical appraisal checklist illustrate trends and variations in the overall characteristics of each study. Designs of studies have been previously mentioned and are outlined in Table 6. The characteristics of the studies can be found in Table 7, and the results, along with summaries of strengths and limitations of the studies, are found in Table 8. Nearly half of the studies (12/25; 48%) investigated MWM effects on lateral epicondylalgia. The next most common condition investigated was lateral ankle sprains (6/25; 24%). Following this, an equal number of studies have assessed the effects at the shoulder (4/25; 16%) and thumb (2/25; 8%), with pathologies including anterior shoulder pain and subacromial impingement for the shoulder joint, and metacarpophalangeal (MCP) strains of the thumb. Only one study has investigated MWM at the wrist for de Quervain's (4%).

All studies have examined the effects of MWMs on genuine pathologies, where the participants presented with the condition, except for the study by Slater et al[37], which induced lateral epicondylalgia. It is important to highlight also that this was the only study that did not conclude with any significant between-group differences in response to the intervention of MWM versus placebo. The genders of the participants varied between studies, although there was approximately equal male and female representation across all the included studies. There was a large variation in the average age of the participants, ranging from 17 to 79 years, which may reflect the six different pathologies investigated, each with their own epidemiological data. MWM treatment durations varied from one day to two months. Only 8 of the 25 studies included some form of follow-up, with all demonstrating significant positive results from MWM use[4,20,30,34-39].

Overall Efficacy of MWMs

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 pain pressure threshold (PPT) or strength was by Slater et al[37], which is also the only study that investigated the efficacy of MWMs on an induced condition. All other studies used 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 upper limb tension tests, and overall function improvements when compared with placebo or control, mainly in lateral epicondylalgia[4,6,7,13-15,20,30,31,34]. No change in temperature pain threshold (TPT) has been found at the elbow[15]. 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 suggesting that a non-opioid mechanism occurs for the analgesic response[6,15]. 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[31]. MWM treatment was also found

TABLE 4. Internal validity—bias analysis via the Downs and Black checklist for methodological quality

Author	15	16	17	18	19	20	21
Bisset et al[30]	0	1	1	1	0	0	1
Kochar & Dogra[4]	0	0	1	1	1	0	1
Slater et al[42]	0	0	1	1	1	0	0
Teys et al[5]	1	1	1	1	1	1	1
Collins et al[3]	1	1	1	1	1	0	1
Paungmali et al[14]	0	1	1	1	1	1	1
Paungmali et al[15]	1	1	1	1	1	1	1
Teys et al[40]	1	1	1	1	1	1	1
Vicenzino et al[7]	1	1	1	1	1	1	1
Vicenzino et al[18]	1	1	1	1	1	1	0
McLean et al[31]	1	0	1	1	1	0	1
Reid et al[32]	0	1	1	1	1	0	1
Yang et al[33]	0	1	1	1	1	0	1
Abbot[13]	0	1	1	1	1	0	1
Abbottet al[41]	0	1	1	1	1	1	1
Paungmali et al[6]	1	1	1	1	1	1	1
O'Brien & Vincenzino[38]	0	0	1	1	1	1	1
Penso[39]	0	0	1	1	0	1	0
Stephens[20]	0	0	1	1	0	0	0
Vincenzino & Wright[34]	0	0	1	1	1	1	1
Backstrom[35]	0	0	1	1	0	0	0
DeSantis & Hasson[16]	0	0	1	1	0	1	1
Folk[36]	0	0	1	1	0	1	0
Hetherington[19]	0	0	0	0	0	0	0
Hsieh et al[37]	0	0	1	1	0	0	0

15. Was an attempt made to blind study subjects to the intervention they have received?
16. Was an attempt made to blind those measuring the main outcomes of the intervention?
17. If any of the results of the study were based on "data dredging," was this made clear?
18. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?
19. Were the statistical tests used to assess the main outcomes appropriate?
20. Was compliance with the intervention/s reliable?
21. Were the main outcome measures used accurate (valid and reliable)?

1 = yes, 0 = no

to be superior in the long term when compared to corticosteroid injection[30]. 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[14]. MWM applied at the elbow has shown to have beneficial effects on shoulder rotation ROM[13].

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[3,5,16,18,19,32,33,35-40]. Again no change in TPT was found at the ankle[3]. 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 even though the positive effects were long lasting[37].

Discussion

Methodological Quality

Overall, the results of this systematic review illustrate a moderate methodological quality among studies that have investigated the use of Mulligan's MWM technique at peripheral joints. RCTs that used participants as own controls had the highest methodological mean score (18.5/28) and the least variability (SD ±1.71). There was greater variability (range = 11–23) in the methodological quality of true RCTs in this area of research, however, this group includes the highest scoring study to date[30]. This study also displayed the highest overall score (23 out of 27), which illustrated consistency in all four categories as compared to all other studies, which had variable scoring in each category of the analysis. This illustrates that more consistently robust research is being produced when participants are used as control groups; however, RCTs with true control groups are considered the highest quality research design. As predicted, case studies and case reports had the lowest mean score; however, both had outliers, with large ranges from 8 to 16, and 4 to 14, respectively. This highlights the variability in the quality of this area of research.

The results from the methodological quality analysis via the Downs and Black critiquing tool displayed an overall low to moderate level of quality across each category (Tables 1–6). The items within external validity and power were the least satisfied followed by internal validity (confounding and selection bias). Contributing to the low level of quality were two studies with the lowest score[19,20], which as outliers resulted in an overall reduction of the mean values and increasing the variability of the data. The study that displayed the highest (Bisset et al[30] with 23 out of 27) demonstrated the highest overall score with consistency in all four categories when compared to the other studies that only excelled in particular categories.

Strengths and Limitations of the Included Studies

This review has highlighted clear strengths and limitations within this area of research. These are clearly related to the analyses of categories and individual items of the Downs and Black critiquing tool, which are detailed in the following sections.

Reporting

Of the four categories within the Downs and Black critiquing tool, reporting per-

TABLE 5. Internal validity—confounding (selection bias) via the Downs and Black checklist for methodological quality

Author	22	23	24	25	26	27
Bisset et al[30]	1	1	1	1	1	1
Kochar & Dogra[4]	1	0	1	0	0	0
Slater et al[42]	0	0	1	0	0	0
Teys et al[5]	1	0	1	0	1	1
Collins et al[3]	1	0	1	0	0	1
Paungmali et al[14]	1	0	1	0	1	1
Paungmali et al[15]	0	0	1	0	0	1
Teys et al[40]	1	0	1	1	1	1
Vicenzino et al[7]	0	0	1	0	1	1
Vicenzino et al[18]	0	0	1	1	0	1
McLean et al[31]	0	0	1	0	0	0
Reid et al[32]	1	0	1	0	0	1
Yang et al[33]	1	0	1	0	1	1
Abbot[13]	0	0	1	0	0	0
Abbottet al[41]	1	0	1	0	0	1
Paungmali et al[6]	1	0	0	0	1	1
O'Brien & Vincenzino[38]	0	0	0	0	0	1
Penso[39]	1	0	0	0	1	1
Stephens[20]	1	1	0	0	0	1
Vincenzino & Wright[34]	1	1	0	0	0	1
Backstrom[35]	1	1	0	0	0	1
DeSantis & Hasson[16]	1	1	0	0	0	1
Folk[36]	1	1	0	0	0	1
Hetherington[19]	1	0	0	0	0	0
Hsieh et al[37]	1	1	0	0	0	1

22. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?
23. Were the study subjects in different intervention groups (trial and cohort studies) or were the cases and controls (case-control studies) recruited over the same time period?
24. Were the study subjects randomized to intervention groups?
25. Was the randomized intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?
26. Was there adequate adjustment for confounding in the analysis from which the main findings were drawn?
27. Were losses of patients to follow-up taken into account?

1 = yes, 0 = no

formed at the highest level: 90% of the studies included a clear aim and description of inclusion and exclusion criteria, which are important for generalizability of results and also closely relates to the adequate explanation of characteristics (items 1, 3). Consistent and appropriate choice of outcome measures was employed across the studies (item 2); for example, all studies investigating the effects of MWM at the elbow used either pain-free grip strength or maximal grip strength as part of their assessment. In general, interventions were well outlined (item 4); however, explicit details of MWM prescription were variable, which impacted the analysis of findings. Further weaknesses were evident, including documenting confounding variables, adverse effects, and probability values (items 5, 8, 10).

Internal Validity

Internal validity is necessary to determine treatment efficacy. Statistical analysis was performed appropriately in the majority of studies, which illustrates strength of result analysis. Generally, there was high compliance with a low level of dropouts when reported (item 27), possibly reflecting the minimal adverse events documented. Randomization of participants to intervention groups is important in research to diminish possible bias; however it only occurred in 15 of the studies (60%) reviewed here[3-5,7,13-15,18,30-33,40-42] although it should be noted that 9 studies were either case reports or studies and therefore only 16 studies had the potential for randomization (item 24). Although only 9 studies incorporated follow-up assessment to examine long-lasting effects of MWMs, time periods between the intervention and assessment were always consistent (item 18)[4,6,20,30,34-38].

Sixteen of the 25 studies to date have not incorporated any form of control or placebo group. Control groups are important for confirming treatment effectiveness and for reducing the effect of confounding variables. Although 6 studies used participants as their own controls, which decreases the level of internal validity, it is understood that it is not always ethical to have true control groups receiving nil or placebo treatment. Blinding and concealment of intervention groups was a major limiting factor of internal validity within the studies (items 15, 16, 25). Less than 50% of the studies incorporated blinding, with only 7 studies demonstrating double blinding[3,5-7,15,18,40]. The majority of these studies incorporated other forms of physiotherapy treatment in combination with MWMs[16,20,35,36,38]. This highlights how confounding variables have been poorly considered within this research with only 5 studies taking it into account (item 26)[5-7,14,30].

External Validity

External validity was generally poor, as only one study recruited participants that represent the population (items 11, 12)[30]. This is related to the fact that methods of recruitment, assessment, and treatment were poorly documented. The ratio of males and females was relatively equal in general, in conjunction with a large age range (range = 17–79 years), which increases overall external validity. A specific sample size is required to detect a clinically significant change, which is indicated in the power calculation. Only 10 studies demonstrated power of 95% or more, which may reflect the significant number of studies with low participant numbers (item 14)[5,6,14,30-33,40-42]. Because 7 studies

TABLE 6. Study designs, scores, and methodological data variation

Study Design Total n = 25	Authors	Reporting (/11)	External validity and power (/4)	Internal validity—bias (/7)	Internal validity—confounding (/6)	Total (/28)	Quality mean (SD) score	Quality score range
True RCT (4)	Bisset et al[30]	9	4	4	6	23	17.5 (±5.12)	11–23
	Kochar & Dogra[4]	7	1	4	2	14		
	Slater et al[42]	6	1	3	1	11		
	Teys et al[5]	10	1	7	4	22		
RCT with participants as own control (6)	Collins et al[3]	8	0	6	3	17	18.5 (±1.71)	16–21
	Paungmali et al[14]	9	1	6	4	20		
	Paungmali et al[15]	7	0	7	2	16		
	Teys et al[40]	9	0	7	5	21		
	Vicenzino et al[7]	9	0	7	3	19		
	Vicenzino et al[18]	9	0	6	3	18		
Quasi-experimental (3)	McLean et al[31]	7	1	5	1	14	17 (±2.16)	14–19
	Reid et al[32]	10	0	5	3	18		
	Yang et al[33]	9	1	5	4	19		
Non-experimental (3)	Abbot[13]	7	0	5	1	13	17.33 (±3.68)	13–20
	Abbottet al[41]	7	1	6	3	17		
	Paungmali et al[6]	11	1	7	3	22		
Case study (4)	O'Brien & Vincenzino[38]	6	1	5	1	13	12.75 (±2.95)	8–16
	Penso[39]	7	1	3	3	14		
	Stephens[20]	2	1	2	3	8		
	Vincenzino & Wright[34]	7	1	5	3	16		
Case report (5)	Backstrom[35]	5	1	2	3	11	10.4 (±3.38)	4–14
	DeSantis & Hasson[16]	6	1	4	3	14		
	Folk[36]	5	1	3	3	12		
	Hetherington[19]	2	1	0	1	4		
	Hsieh et al[37]	5	1	2	3	11		
Mean (SD)		7.16 (±2.22)	0.84 (±0.78)	4.64 (±1.87)	2.84 (±1.22)	15.48 (±4.54)		
Range		2–11	0–4	0–7	1–6	4–23		

TABLE 7. Characteristics of the included studies

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
Bisset et al[30]	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 ADLs, encourage activity, using analgesic drugs, heat, cold, and braces.	6 weeks and 52 weeks	Global improvement Grip force Assessor's rating of severity Pain (VAS) Elbow disability (pain-free function questionnaire
Kochar & Dogra[4]	True RCT	To compare the effects of a combination of MWM and US versus US alone, followed by an exercise program, 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 program (9 weeks). Group 2: US only on 10 sessions completed in 3 weeks and an exercise program (9 weeks). Group 3 (control): no Rx	US: 3 MHz, 1.5 W/cm^2, 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

TABLE 7. Characteristics of the included studies *(continued)*

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
Slater et al[42]	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 participant's 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[5]	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[3]	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 Belt around PT pelvis and distal tibia and fibula.	Before and after Rx	Weight-bearing DF ROM PPT TPT

					Patient leaned back to create PA glide, with talus and forefoot stabilized 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 stabilizing hand over metatarsals. Control: patient in stance position for 5 mins with no manual contact of PT.		
Paungmali et al[14]	RCT with participants as own control (repeated measures)	To determine whether 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 randomized Rx groups (Rx, placebo, control), at same time of day 48 hrs 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 while 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[15]	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 stabilized 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)

TABLE 7. Characteristics of the included studies *(continued)*

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
Teys et al[40]	RCT with participants as own control (crossover design)	To investigate the initial effects of MWM technique on shoulder ROM in the plane of the scapula and PPT in participants with anterior shoulder pain	24 participants 11 males, 13 females Mean age: 46.1	3 sessions of Rx with 24 hours in between each. Rx was either MWM, sham, or control	MWM: participant seated, therapist on opposite side, one hand placed on the scapula posteriorly while the thenar eminence of the other hand was on the anterior aspect of the humerus. A posterolateral glide to the affected shoulder at the humeral head. The participant then elevated arm in the plane of the scapula to the pain onset only. Sham mobilization: replicated the previous MWM except an anterior glide was performed with hands positioned on the clavicle/sternum and posterior humeral head. Minimal pressure was applied while the patient actively elevated the arm through half of the available pain-free range. Control: participant sat for the same length of time but there was no manual contact between the therapist and participant.	Baseline and after each application of MWM, sham or control	Pain-free ROM in the scapular plane (goniometric measurement) PPT (digital pressure pain algometer)
Vicenzino et al[7]	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 stabilizing the distal humerus, while participant performed pain-free gripping. Placebo: firm manual contact over elbow joint. Control: no manual contact from PT.	Before and after each Rx session PFGS also measured during Rx	PFGS PPT

Vicenzino et al[18]	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 randomized sequence on 3 separate days (at least 48 hours apart).	WB MWM: in standing with therapist manually stabilizing 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 Rx 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[31]	Quasi-experimental—repeated measures (randomization, 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
Reid et al[32]	Quasi-experimental—crossover design (randomization, no control)	To investigate the effect of talocrural joint MWM on DF ROM in participants with decreased range following lateral ankle sprain	23 participants 8 males, 15 females Mean age: 25	Group 1: session 1 = sham mobilization, session 2 = true MWM Group 2: session 1 = MWM, session 2 = sham mobilization 7 day period in between sessions	5 mins warm up of moderate intensity of stationary cycling ensuring full leg extension prior to Ax and Rx (for both sham and MWM). MWM: participant in high kneeling, affected ankle in WB neutral position, belt (pressure biofeedback) at inferior margin of the medial malleolus.	Baseline, and after each application	DF ROM using a WB lunge movement: distance of great toe to the wall (repeated 3 times for each ankle)

TABLE 7. Characteristics of the included studies *(continued) (continued)*

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
					Talus and calcaneus fixed with therapist's hands while belt glided distal tibia anteriorly creating a relative posterior talar glide by the therapist. Sham mobilization: participant prone lying, the knee was passively flexed and extended, ensuring the talocrural joint remained stationary.		
Yang et al[33]	Quasi-experimental-multiple-treatment trial (randomization, no control)	To investigate the effect of mobilization treatment and to determine whether a difference of treatment efficacy exists among three mobilization techniques in patients with frozen shoulder syndrom (FSS)	30 participants 6 males, 24 female. Mean age: 55	Group 1: ABAC (MRM, ERM, MRM, MWM) Group 2: ACAB (MRM, MWM, MRM, ERM)	MWM: Participant sitting in a relaxed position. Belt placed around the head of humerus to glide the humerus head appropriately, with the therapist's hand over the appropriate aspect of the head of humerus. A counter pressure was applied with the other hand at the scapula. ERM: Therapist's hands placed close to the GHJ, and the humerus was brought into a position of max range in different directions. MRM: Participant relaxed in supine with the humerus in resting position, mobilizations applied.	Baseline, and at 3-week intervals for 12 weeks	Disability Ax: FLEX-Sf. Shoulder complex kinematics (FASTRAK motion analysis): scapula orientation, humeral orientation, abduction, hand-to-neck, hand-to-scapula
Abbot[13]	Non-experimental—pre-/post-test (randomization)	To investigate the effects of a single intervention of MWM at the elbow on shoulder ROM for patients with lateral epicondylalgia	23 patients 18 males, 5 females 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

Abbottet al[41]	Non-experimental—pre-/post-test (randomization)	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 (randomized order), in 1 Rx session. If participant's pain could not be eliminated, Rx was stopped	MWM: lateral glide of proximal medial forearm with the distal humerus stabilized, while participant performed previously painful movement (fist, gripping, wrist extension, 3rd finger extension). Either of the following glides were performed depending on participant's 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[6]	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 hrs apart	MWM: patient supine with shoulder in internal rotation, elbow extended and supinated. Therapist stabilized 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-sec rest intervals.	Before and after every Rx	PFGS PPT
O'Brien & Vincenzino[38]	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	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	MWM Rx: posterior glide of distal fibula while participant inverted the ankle. Passive overpressure was applied. Repeated 4 times. 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

TABLE 7. Characteristics of the included studies *(continued)*

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
Penso[39]	Case study	To assess the effect of MWM used for the management of a runner complaining of chronic medial ankle pain	25-year-old female with chronic medial left ankle pain	2 sessions with MWM over a 2-week period Education regarding stretching of calf muscle and running technique	MWM: Initially a PA glide on the distal tibia and fibula was performed in WB; however, was ineffective. An AP glide to the distal tibia, with stabilization to the posterior foot, while the patient performed active DF in WB on a step was then effective.	Baseline, after each MWM, 1 and 4 month follow-ups	Active and passive ROM (DF, PF, inversion, eversion) Gastrocnemius and soleus muscle length Pain-free ROM (DF, PF, inversion, eversion) Function (running, hiking, effective calf stretch)
Stephens[20]	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: MWMs, ice, US, transverse frictions, exercises began after MWM Rx, massage, stretching, HEP	MWM: lateral mobilization 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 mobilized 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 Special test: resisted wrist ext with elbow at 45° Palpation
Vincenzino & Wright[34]	Case study	To investigate effects of a manipulative PT technique on pain and dysfunction of	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	Before Rx, during 2-week Ax phase, and at 6 weeks following Rx	VAS PPT Grip strength Function VAS Pain-free function questionnaire

		a patient with tennis elbow			and gripping exercises. Experimental Rx: MWM—lateral glide applied at the proximal part of the forearm while stabilizing the lateral aspect of the distal humerus (participant in supine, shoulder internal rotation, elbow extended, forearm pronated). Participant was taught self-mobilization and taping (taping was used to replicate the lateral force applied at the elbow by the MWM).		
Backstrom[35]	Case report	Introduce MWM in the Rx 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 and ulna deviation.	Pain (VAS) Observation ROM (goniometer) Wrist flexion, extension, radial Thumb palmer and radial abduction. Strength—isometric and MMT Accessory motion testing Palpation Finklestein test

TABLE 7. Characteristics of the included studies *(continued)*

Author	Design	Purpose	Participants	Intervention	Prescription of MWM/other Rx	Times of Ax	O/C measures
DeSantis & Hasson[16]	Case report	To describe the effects of an MWM Rx 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 stabilizing muscles, improving function, education regarding posture. Each session ended with 10 mins of cryotherapy.	Measurements 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[36]	Case report	To describe the differential diagnosis and Rx techniques for strained 1st MCP joint.	39-year-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.	Measurement 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[19]	Case report	NS People with ankle injuries were examined to detect a positional fault and managed using MWM	NS Patient's post-ankle sprain with limited and painful ROM	Majority of patients were treated only with MWMs 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	Before, during, and after Rx	Pain on inversion ROM One leg standing test (balance—eyes closed) Swelling Gait patterns

		and taping methods			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).		
Hsieh et al[37]	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-MWMs	Self MWM: supinating the proximal phalanx of the thumb using other hand's 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 = randomized controlled trial; PT = physiotherapy; ADLs = activities of daily living; VAS = visual analogue scale; US = ultrasound; MHz = mega hertz; W/cm^2 = watts per centimeter 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 program; 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 = millimeters; cm = centimeters; MRI = magnetic resonance imaging; IPJ = interphalangeal joint; MPJ = metacarpal phalangeal joint.

TABLE 8. Statistics, results, strengths, and limitations of the included studies

Author	Statistical analysis	Results	Strengths	Limitations
Bisset et al[30]	Between-group differences analyzed: Relative risk reduction. Numbers needed to treat. 6-point improvement (Likert scale)	Corticosteroid injection showed sig better effects at 6 weeks but with high recurrence rates thereafter (47/65 regressed) and sig poorer outcomes in long-term compared with PT. PT was superior to wait and see at 6 weeks, but there was no difference at 52 weeks with both reporting a successful outcome. PT was superior to injections after 6 weeks. Thus, corticosteroid Rx should be avoided due to its high recurrence, and PT should be implemented due to its superior benefit and decrease in NSAIDS purchasing	• Randomized controlled trial • Single blinding • Large sample size • Follow-up measures • Confounding variables and adverse events were taken into consideration • Main findings of study clearly described • Drop-outs described • Good external validity and power	• Rx procedure for PT group not clearly defined (referred to another study for prescription explanation) • Only single blinding
Kochar & Dogra[4]	One-way ANOVA. Two-way ANOVA. Chi square testing. 5% level of probability adopted	Subjective: Rx group 1 pain decreased by 5.9cm ($p < 0.01$), and in Rx group 2 by 1.67cm ($p < 0.01$). Rx group 1 was superior to the control and group 2 in the Ax score at 12 weeks. Objective: Rx group 1 was able to lift heavier weights than group 2 and control group ($p<0.01$) from the 2nd week onwards. Grip strength in group 1 improved from 22.74kg–31.57kg in the 3 weeks, and was sig different from the control. No sig differences were found in group 2. Overall, control group showed no statistically sig changes in any parameter. Most patients in the intervention groups showed complete recovery. 5 recurrences in the US group	• Very similar participant characteristics between groups and baseline measurements • Randomization, control group • Valid outcome measures • Appropriate statistical analysis • Clear Rx process • Clear inclusion/exclusion criteria • Follow-up measures	• Blinding was not stated • The 2 Rx groups were randomized but the control group was not • Control group received no Rx, i.e., no placebo group • Learning effect of lifting the weights may have occurred • Drop-outs were not indicated
Slater et al[42]	Shapiro-Wilk normality tests. Mann Whitney-U test. Two-way repeated measures ANOVA. Post-hoc tests. Student Newman Keuls (SNK) test	During saline-induced pain and in response to the intervention of MWM or placebo, there were no sig between-group differences in VAS, pain distributions, induced deep tissue hyperalgesia, and force production. Overall, data suggests that MWM does not activate mechanisms associated with analgesia or force augmentation in people with induced lateral epicondylalgia	• Randomized control trial • Placebo, and intervention group • Appropriate statistical analysis • Valid outcome measures	• No blinding • Effect of the provoked DOMS and injected hypertonic saline • No follow-up measures • Possible excessive amount of exercise to induce DOMS, with no indication of what the amount was based on • Induced pathology • No recruitment process documented • No drop-out or compliance documented
Teys et al[5]	Two-way ANOVA. Post-hoc tests	ROM: mean increase of 16°, 4°, and 0° for MWM, placebo, and control group, respectively. PPT: mean increase of 63kPa, 26kPa, and 20kPa for MWM, placebo, and control group, respectively	• Randomized, control, and placebo groups • Double blinding • Clear description of different intervention levels	• No follow-up • Limited outcome measures • Subjects may not represent the population

			• Appropriate statistical analysis • No drop-outs • Valid outcome measures • Clear inclusion/exclusion criteria	from which they were recruited
Collins et al[3]	Paired sample *t*-test. One-way ANOVA	DF ROM: sig increase in only the MWM Rx group. PPT and TPT: no sig results, except an increase in PPT in the placebo group post-Rx	• Randomization, placebo, and control • Appropriate statistical analysis • Valid outcome measures • Double blinding • Clear inclusion/exclusion criteria and different groups	• No follow-up measurements • Study did not discuss drop-outs • Inadequate power
Paungmali et al[14]	2 way ANOVA. 3 way ANOVA. Post-hoc analyses. Paired *t* tests with bonferroni adjustment	The MWM technique illustrated hypoalgesic effects with simultaneous sympathoexcitation (physiological effects similar to those reported with spinal MWMs). PFGS increased from 127.1N to 166.2N during Rx and then 174.1N post-Rx (only during and after in Rx group, not placebo and control). PPT only increased in the Rx group. TPT did not change in the Rx or placebo group but decreased in the control. MWM only produced mean increases of 4.1% HR, 3.5% systolic BP, 3.1% diastolic BP. SNS function (skin conductance, cutaneous blood flux, and temp) were all activated in the Rx group only (MWM)	• Rx's randomized to participants • Control and placebo groups • Assessor blinded • Sample size adequate to produce a high power • Main findings of study clearly described • Rx procedure clearly described • Although crossover, allowed for at least 48-hour interval between sessions	• Patients, however, acted as control/placebo (crossover) • Only single blinding • Testing took place in a controlled environment (not realistic) • No follow-up measures
Paungmali et al[15]	One-way ANOVA	No sig difference between groups with different IV injections. All groups improved on scores post-MWM with averages being 29%, 18%, 1.6%, and 0.2% for PFGS, PPT, ULTT, and TPT, respectively	• Randomization and control • Double blinding • No drop-outs • Compliance was measured via a questionnaire • Valid outcome measures	• The study did not discuss how long naloxone may take to have effects, and Rx/Ax were taken immediately after administration • Carr-over effect of Rx • No significance levels were indicated when comparing pre- and post-Rx • Poor external validity. • No information as to where participants were recruited from • No follow-up
Teys et al[40]	ANOVA. Post-hoc tests on each dependent variable. Pearson's correlation coefficient	Significant and clinically meaningful improvements in both ROM (15.3%, F (2,46) = 16.31 P = 0.00) and PPT (20.2%, F (2, 46) = 3.44, P = 0.04) occurred immediately post-Rx. Nil significant differences in PPT pre-application. The change in ROM was not related to improvement in PPT (R = 0.29, P = 0.17)	• Randomization of Rx • Double blinding • Clear Rx process • Clear inclusion/exclusion criteria • Valid and reliable outcome measures • Control group inclusion • No loss to follow-up	• Nil follow up or long term Ax • Participants received all three Rx's–?carry-over effect due to same Rx on participants with only a 24-hour wait • Decreased external validity due to controlled laboratory environment

TABLE 8. Statistics, results, strengths, and limitations of the included studies *(continued)*

Author	Statistical analysis	Results	Strengths	Limitations
Vicenzino et al[7]	One-way, two-way, three-way ANOVA	Rx group had a sig increase in PFGS and PPT post-Rx, compared to placebo and control. The unaffected arm had a decrease in PFGS post all Rx levels	• Blinding of participant and outcome measurer • Control and placebo • Took into account confounding factors with a questionnaire • No drop-outs or adverse effects • Appropriate statistical analysis • Clear Rx processes	• Limited outcome measures • No follow-up measures • Inadequate power • Poor external validity (patients not representative of the population)
Vicenzino et al[18]	One-way ANOVA. Post hoc tests. Effect size calculations. Pearson correlations	WB and NWB MWM Rx techniques both produced sig changes in posterior talar glide (effect sizes: 0.8, 0.9). Reduced posterior talar glide deficit by 50% and 55% for the affected side respectively—sig greater than control (p=.003). WB DF was improved in all three groups (WB, NWB, control groups), effect size—0.4, 0.3, 0.1. MWMs reduced affected side deficit by approx 26% compared to 9% reduction in control group. There was a sig and substantial correlation between posterior talar glide and WB DF following the WB MWM but no correlation following the NWB MWM. Overall, MWMs improved dependent variables immediately after Rx in patients with chronic recurrent lateral ankle sprain	• Randomization of Rx conditions • Had a control condition • Double blinding • No drop-outs/high compliance • Appropriate statistical testing • Clear Rx procedure • Equal female/male representation • Repeated measures	• No true control/placebo group—patients experienced all 3 Rx conditions (crossover design) • Poor sample size • No outcome measure validity or reliability • No follow-up measurements for analysis of long-term effects
McLean et al[31]	Single-tailed, paired t-test. Orthogonal a priori contrasts for repeated measures analysis	Mean raw force data ranged from 36.8N—113N. Mean standardized force data was 1.2N/cm and 3.8N/cm. The 2 lower standardized force level scores (1.2 and 1.9N/cm) caused a drop in PFGS, whereas the higher two (2 and 3.8N/cm) caused an increase in PFGS. A priori contrasts showed no sig change in PFGS between the 2 lower force levels but was sig greater for the 3rd (66%) force level. Overall, level of force applied during an MWM determines the hypolagesic effects. Grip strength changes observed = 15–18%	• Subject was blinded to the PFGS scores throughout • Randomization of the Rx forces given • Valid outcome measures • Clear inclusion/exclusion criteria • Appropriate statistical analysis	• Small sample size • No control/placebo • Only 1 outcome measure • Short-term study • No follow-up measures • Different forces were applied with only 2 minute rest (possible accumulative effect of pain relief) • No blinding of therapists • No indication of recruitment process
Reid et al[32]	Paired t-test. Shapiro-Wilk test. Also: independent t-test (exclusion of second Rx findings)	Significantly greater improvement in talocrural joint DF ROM with the true WB mobilization (t (22) = 2.523, P = 0.019). Mean difference between the true and sham mobilization Rx scores was equal to 0.45cm (95% confidence interval = 0.08—0.82cm). Between-group analyses was equal 0.65cm increase in ROM (95% confidence interval = 0.15—1.2cm)	• Increased washout period (7 days) to reduce carry-over effect • Use of pressure biofeedback to ensure same force for same participant • Randomization to Rx • Blinding of the assessor • Clear Rx process • Clear inclusion/exclusion criteria	•?carry-over effect despite 7 day washout period •?effect of warm up and measurement of intensity per participant •? clinical relevance due to small change detected—however, only 2 Rx's performed • No true control group

Yang et al[33]	ANOVA Independent *t*-tests	Significant improvements ($p<.01$) in FLEX-SF, arm elevation, scapulo-humeral rhythm, humeral external rotation, humeral internal rotation for both ERM and MWM Rx. No significant difference between ERM and MWM except for scapulo-humeral rhythm restoration	• Randomization • Intention to treat analysis • Thorough statistical analysis • Blinding of the assessor • Clear Rx process • Clear inclusion/exclusion criteria	• Participants weren't blinded • Participants received all three Rx's - ?carry-over effect
Abbot[13]	One tailed *t*-test	92% responded to MWM Rx (i.e., Rx was pain-free). PFGS and max grip strength were sig increased post-Rx, for the affected limb only. PFGS was found to be more responsive to change versus max grip strength	• Rx and Ax of left or right arms was randomly assigned • Outcome measure was reliable • Clear results • Valid statistical testing for a pre-/post-test design	• Only pre-/post-test design, i.e., no group comparison of findings over time • Only 1 outcome measure • Participants were not blinded • No follow-up measures • Sample size was not large and predominantly male • Sample recruitment was not explained
Abbottet al[41]	One-tailed *t*-test	92% responded to MWM Rx (i.e., Rx was pain-free). PFGS and max grip strength were sig increased post-Rx, for the affected limb only. PFGS was found to be more responsive to change versus max grip strength	• Sufficient power to detect a clinically sig change • Attempt to blind outcome measurer • Randomization of limb • Rx order • Outcome measures were appropriate and well investigated • Good description of Rx protocol and adaptations	• Convenience sample • No follow-up measures • Only one Rx session (for a chronic condition) • Only one intervention level • No comparison, control, or placebo
Paungmali et al[6]	Own formula: maximal possible effect to investigate the tolerance of the hypoalgesic effect. One way ANOVA	The hypoalgesic effect of MWM at the elbow did not reduce with repeated applications of the Rx technique during 6 successive sessions. All Rx sessions resulted in hypoalgesic effects, indicated by an increase in PFGS and PPT. PFGS sig increased over the sessions but PPT remained similar	• Blinding was administered • Valid outcome measures • Clear Rx process • Clear inclusion/exclusion criteria • Confounding variables and adverse events were taken into consideration • No drop-outs/high compliance • Calculation of effect size	• Number of sets was not stated in MWM Rx • No control group or randomization • Participants were not randomly selected for the study (volunteers)
O'Brien & Vincenzino[38]	Pearson correlation	ROM: (inversion) improved during MWM and to a lesser extent post Rx. DF improved post MWM Rx. Pain: improved during MWM and to a lesser extent post Rx. Function: increased with Rx. Functional performance: strong positive correlation between MWM Rx and function. Strong correlations between functional performance and function, pain and function, functional performance and pain, functional performance and DF, DF and function. Moderate correlations with pain and function, inversion and DF, functional performance and inversion, inversion and function	• Clear Rx process • Appropriate outcome measures • Strong and sig correlations (performed some statistical analysis as only a case study) • Patients treated in an environment that represents normal PT Rx	• Inadequate power (only 2 subjects) • No data documented for control periods • Subjects do not represent the general population (both sport players/ athletes) • No blinding or randomization • No follow-up measures

TABLE 8. Statistics, results, strengths, and limitations of the included studies *(continued)*

Author	Statistical analysis	Results	Strengths	Limitations
Penso[39]	No statistical analysis reported	Immediate relief of pain with accessory PA movement and WB DF. Increase in ankle DF and eversion ROM. Increase in gastrocnemius and soleus muscle length. Patient was able to run pain-free	• Clear description of case study with thorough initial Ax • Follow-up measures • Patient Rx as in a "real-life" setting	• No control, randomization, or blinding • No statistical analysis • Not all results were reported on follow-up • Only one participant; therefore poor external validity
Stephens[20]	No statistical analysis reported	Decrease in pain immediately after MWM, which lasted 1–2 days. When pain was aggravated, self-mobilizations eliminated the pain. After 4 weeks, elbow was still TOP, TrP still tender on massage, increase in strength and endurance. D/C after 23 Rx's. At D/C, patient reported successful self -x for relieving pain 100% of the time, had progressed exercises to pain-free. Repeated movements and heavy lifting at work still exacerbated symptoms. Mobilizations still effective in decreasing pain	• Literature review on condition (lateral epicondylitis) and Rx choices • Clear case history • Represents real-life situation in regards to Rx received	• No randomization, control, or blinding • Rx is not reproducible • Study did not state their aim • Only 1 subject, so results are not generalizable and inadequate power • Did not include data for outcome measures • Did not discuss compliance with HEP • No statistical analysis • Did not discuss reliability or validity of outcome measures • No follow-up measures
Vincenzino & Wright[34]	Pearson correlation coefficients. Linear regression model	Little progress made with initial PT Rx prior to the study. PFGS increased during Rx phases B and C. All 6 items on the pain-free function questionnaire, which caused pain before, had improved following Rx. Improvement in grip strength was correlated with improvements in function and decrease in pain. At 6 weeks: no pain, full function, a strong correlation was illustrated that as function increased, pain decreased ($r= -0.92$, $p <0.0001$)	• Clear case history, outcome measures, Rx procedures and results • Validity and reliability of outcome measures stated • Adverse events stated	• Single case study limits generalizability of findings • Many different Rx's applied; therefore difficult to determine which solely produced effects • No randomization, control group • No long-term follow-up measures
Backstrom[35]	No statistical analysis reported	Rapid reduction in pain level: 25% after first session, and 50% after 3rd session. After 12 sessions (2 month Rx period), all impairments resolved except 0.5cm of swelling at the right wrist There were no painful limitations for ADLs. At 12-month follow-up, there was still no evidence of wrist/thumb pain or functional deficits	• Clear outcome measures • Clear Rx protocol • Follow-up measures at 4 months and 12 months • Represents realistic PT Rx for a patient with complicated de Quervain's tenosynovitis	• No randomization or control • Inadequate power as only 1 participant • No statistical analysis • No blinding of outcome measurer or participant

				• Unable to generalize results to population as only 1 participant • Unclear of study design (whether is was a case report or study, as terms were used inter-changeably) • Notes were not complete for all outcome measures
DeSantis & Hasson[16]	No statistical analysis reported	During each MWM session, NRPS score was reduced by 2–3 points. Rx sessions 4–6 of MWM improved pain-free ROM by 30–45°; by the last session = 175° (overall increase = 80°) (clinically sig). MWM stopped on 7th session as participant no longer reported pain during active abduction, had achieved near-full AROM, and had very little pain on overhead activities. Overall, at D/C the patient had no positive impingement tests, improved function, improvement (>10%) on disability scales	• Clear case history, outcome measures, Rx procedures and results • Continuous Ax reported • Relevant improvements of symptoms pre- and post- • Represents realistic PT Rx for shoulder impingement • Reported validity and reliability of outcome measures	• Case report (non-experimental) • No randomization, control group, blinding, or group comparisons • Single case report does not provide comparison of Rx effects • Many different Rx's applied; therefore difficult to determine which solely produced effects • No statistical testing reported
Folk[36]	No statistical analysis reported	OT Rx had not improved patient's symptoms overall over past 10 months. Patient had persistent loss of motion, tenderness, trigger symptoms, and loss of daily function. Patient's preoperative symptoms had not improved after the operation. Once referred to PT and performed MWM Rx, 1 session of MWM Rx abolished pain with MCP extension and the patient cancelled 2nd PT appointment, as all activities were now symptom-free. At follow-up (2 months and 1 year), the patient confirmed she had remained symptom-free post-the MWM Rx	• Clear case history, outcome measures, Rx procedures, and results • Continuous assessment reported • Follow-up communication 2 months, then 1 year later • Sig improvements of symptoms pre- and post-MWM Rx with sustainability up to a year	• Case report (non-experimental) • No randomization, control group, blinding, or group comparisons • Single case report does not provide comparison of Rx effects • Many different Rx's applied; therefore difficult to determine which solely produced effects • No reported statistical testing • No reported reliability or validity of outcome measures stated
Hetherington[19]	No statistical analysis reported	Re-evaluation of pain-free movement after the MWMs resulted in a marked increase in pain-free ROM. One-legged standing test (eyes closed) post-MWMs and taping revealed increased balance equal to that of the uninjured side. Gait patterns also substantially improved	• Clear Rx procedure with effective results • Some appropriate outcome measures used	• Only a retrospective case series review • No randomization, blinding, or control • Study is not reproducible due to lack of information and poor methodological quality

TABLE 8. Statistics, results, strengths, and limitations of the included studies *(continued)*

Author	Statistical analysis	Results	Strengths	Limitations
				• No statistical analysis • No follow-up measures • No data produced for outcome measures • No reliability or validity discussed • No characteristics or baseline measures oparticipants stated
Hsieh et al[37]	No statistical analysis reported	During MWM, positional fault was corrected (under MRI). End of week 1—still had pain, limited ROM, pain on distraction, pain with PROM. End of week 2—pain, limited ROM, pain with distraction. End of week 3—no pain, normal ROM, normal grip strength, pain-free distraction. MRI demonstrated patient had had a positional fault.	• Blinding of person interpreting MRI • Follow-up at 3 weeks • Appropriate outcome measures • Clear Rx process • Clear description of case history	• No statistical analysis • Poor power, as only one participant • No blinding, control, or randomization • Unable to generalize results to population as only one participant • Participant performed self Rx, and there was no mention of compliance

Note: sig = significant; PT = physiotherapy; NSAIDS = non-steroidal anti-inflammatories; Rx = treatment; ANOVA = analysis of variance; cm = centimeters; p = probability; Ax = assessment; kg = kilogram; US = ultrasound; i.e. = therefore; MWM = mobilization with movement; DOMS = delayed onset muscle soreness; PPT = pressure pain threshold; VAS = visual analogue scale; ROM = range of motion; kPa = kilopascal; DF = dorsiflexion; TPT = thermal pain threshold; PFGS = pain-free grip strength; N = newtons; HR = heart rate; BP = blood pressure; SNS = sympathetic nervous system; IV = intravenous; ULTT = upper limb tension test; WB = weight-bearing; NWB = non-weight-bearing; approx = approximately; max = maximum; N/cm^2 = newtons per centimeter squared; TOP = tender on palpation; TrP = trigger point; D/C = discharge; HEP = home exercise program; ADLs = activities of daily living; NRPS = numeric pain rating scale; AROM = active range of motion; OT = occupational therapy; MCP = metacarpophalangeal; PROM = passive range of motion; MRI = magnetic resonance imaging.

(28%) were case studies or reports with only one participant, this decreases the overall level of power and therefore validity of the results in general[16,20,23,35-37].

Characteristics and Efficacy

As discussed previously, there are many established effects of MWMs at various joints, whether it is positional fault correction or hypoalgesic effects. A recent review discusses the different concepts of the effects of an MWM in relation to positional faults and pain relief[12]. It is evident that many joints are yet to be examined including, for example, the hip and knee. The majority of studies (12/25; 48%) reviewed here examined elbow joint-related pathology (lateral epicondylagia), followed by ankle sprains (6/25; 24%), shoulder joint dysfunction (4/25; 16%), MCP strains (2/25; 8%), and de Quervain's at the wrist (1/25; 4%). Research has not been limited to age with subjects ranging from 17 to 79 years of age, which exemplifies the technique's effects on various populations. In general, the efficacy of MWM as a manual therapy technique, as analyzed, is well established with positive results in 24 out of 25 studies. The most common effects studied to date include increases in strength, reduction in pain levels, increase in PPT, improved neural tests, and improved function. The clinical benefit of this technique is therefore confirmed and well supported by research.

Strengths and Limitations of this Systematic Review

The specific aims of this systematic review have been clearly outlined, which originated from a global search surrounding Mulligan manual therapy techniques. The need for the investigation into the commonly prescribed MWM technique was indicated, as it had not yet been reviewed and it was evident that it is generally an ill-defined area. The methods of critiquing and analyzing have been consistently and thoroughly performed by two researchers throughout in an attempt to reduce bias. Extensive use of search terms, databases, and cross-referencing ensured that all possible studies relative to MWM prescription at peripheral joints were included for analysis. A valid and reliable critical appraisal checklist to assess the methodological quality of randomized and non-randomized studies was employed, and previous categorization of the tool was located.

This systematic review consists of some unavoidable limitations. This includes the access of only-English written articles and a search performed up until August 2008. This leads to the possibility of the exclusion of other studies that may be pertinent to this review and, therefore, the guidelines for clinical practice. Lastly, this review lacks a complete statistical analysis that may, to an extent, weaken the interpretation of results. However, the primary focus of this systematic review was a descriptive analysis in order to fulfill the outlined purposes.

Future Research

Subsequent to the extensive research and analysis undertaken for this systematic review, it is evident that there are inconsistencies, gaps, and methodological limitations within the literature surrounding MWM treatment at peripheral joints.

The methodological quality of future research needs to be more robust in order to build an improved evidence base in this commonly used area of manual therapy, as currently it is of a moderate level. Internal validity of studies can be strengthened via the use of randomized controlled trials, optimally including double blinding and placebo groups. The external validity can be enhanced by the inclusion of a greater number of participants, who are representative of populations that may benefit from MWM treatment. This will contribute to creating sufficient power and, therefore, the detection of clinically significant results. A limiting factor that can be easily resolved is the reporting within studies. This needs to be improved by documenting adverse events, dropouts, confounding variables, and specific explanation of methods of recruitment, assessment, and the MWM treatment procedure. Inclusion of follow-up assessment will further examine the long-lasting effects of MWMs. Outcome measures used in studies should aim to be valid and reliable to further increase consistency of results and therefore internal validity.

Conclusion

Mulligan's peripheral MWM techniques are commonly used within musculoskeletal physiotherapy. This systematic review of the MWM prescription at peripheral joints highlighted that this area of research has an overall moderate methodological quality, with evident strengths, limitations, and inconsistencies. The specific parameters identified for MWM prescription in the literature are variable and in general inconsistently implemented and explained. The efficacy of MWMs is well established for various joints and pathologies; however, due to the methodological quality of the studies, it is apparent that further research is warranted into the specific parameters of MWMs.

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

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