SYSTEMATIC REVIEW

Effectiveness of Mulligan's Mobilization With Movement Techniques on Range of Motion in Peripheral Joint Pathologies: A Systematic Review With Meta-analysis Between 2008 and 2018

Nikolaos Stathopoulos, PT, MSc, Zacharias Dimitriadis, PT, MSc, PhD, and George A. Koumantakis, PT, MSc, PhD

ABSTRACT

Objectives: The purpose of this study was to provide an updated systematic review and meta-analysis regarding the effectiveness of mobilization with movement (MWM) techniques on range of motion (ROM).

Methods: An electronic search strategy of the Physiotherapy Evidence Database, PubMed, Cochrane Library, Embase, Google Scholar, and CINAHL was performed between August 2008 and January 2018. Two independent reviewers selected the studies. Only randomized controlled trials were included. The methodology was independently assessed by 2 reviewers using the Physiotherapy Evidence Database scale. The Z indicator was considered for the assessment of statistical significance of ROM change, whereas for each meta-analysis referring to a specific joint pathology, the total mean difference (95% confidence interval) was compared against minimum detectable change values from relevant studies conducted in similar populations to assess clinical significance.

Results: Included were 18 studies with 753 participants in 10 separate meta-analyses for ROM. All studies were classified as high quality or medium quality. Peripheral joint MWM seems to produce better therapeutic results in comparison to sham, passive, other active, or no therapeutic approach, regarding improvement of joint ROM in specific peripheral joint pathologies, consistently in all movement directions for shoulder adhesive capsulitis (mean improvement 12.30°-26.09°, $P < .02$) and hip pain (mean improvement 4.50°-14.80°, $P < .0001$).

Conclusion: Mobilization with movement produced a statistically and clinically significant ROM increase consistently in all movement directions for shoulder adhesive capsulitis and hip pain. However, for shoulder impingement, shoulder pain/dysfunction, hamstring tightness, knee osteoarthritis, and chronic ankle instability pathologies, a therapeutic benefit regarding ROM could not be clearly established. Owing to the small number of individual studies included within the separate groups of pathologies examined in our systematic review, methodologically rigorous studies with longer follow-up periods are warranted to better inform the evidence base on the effects of MWM on ROM. (J Manipulative Physiol Ther 2019;42:439-449)

Key Indexing Terms: *Musculoskeletal Manipulations; Systematic Review*

INTRODUCTION

According to the Mulligan Concept, a possible cause of joint dysfunction is "positional fault," described as a malposition of articular surface,[1] which is indirectly verified during special clinical examination.[1-3]

This technique has a variety of mobilization techniques, with applications in the spinal column and the peripheral joints. The main mobilization technique for peripheral joints is mobilization with movement (MWM).[1,3] Mulligan's MWM technique aims to address joint dysfunctions of the upper and lower extremities[4] and focus on the immediate recovery of full, pain-free range of motion (ROM).[1,3,5] Mobilization is applied by a therapist

Physiotherapy Programme, Metropolitan College, Health Sciences Faculty, School of Physiotherapy Athens, Greece – franchised institution with University of East London, London, UK, Athens, Attica, Greece.

Corresponding author: Nikolaos Stathopoulos, PT, MSc, Metropolitan College, 74 Sorou Street, 15125 Marousi, Athens, Greece. Tel.: +30 6938105998.
(e-mail: *nikosstath88@gmail.com*).

Paper submitted August 29, 2018; in revised form April 1, 2019; accepted April 2, 2019.

0161-4754

https://doi.org/10.1016/j.jmpt.2019.04.001

identifying the direction in which it eliminates the patient's usual joint pain, hypothetically because of a biomechanical restoration of the congruency between the joint surfaces, translated to improved joint function.[6] It is possible that the concurrent active repetition of the pain-free motion by the patient under the sustained mobilization applied by the therapist may be a predominant factor leading to sustained therapy results. More precisely, this re-education of the pain-free movement pattern is aimed at the level of the central nervous system,[1,7,8] requiring ample repetition of the movement correction pattern under therapist guidance, as implied in a number of neuroscience theories.[9]

Hing et al[10] performed a systematic review regarding the effectiveness of MWM in relation to peripheral joints, utilizing pain, disability, and ROM as outcome measures. They concluded that MWM therapeutic results are established and widely advocated for various peripheral joints' musculoskeletal pathologies and dysfunctions.[10] Subsequently, another study[11] expanded on this previous study with a systematic review and meta-analysis (August 2008 to August 2017) regarding the effectiveness of MWM in pain and disability of peripheral joints, also reaching similar conclusions.

The aim of our study was to complete a systematic literature review with meta-analysis on the therapeutic results of Mulligan's MWM techniques from August 2008 to January 2018 to assess whether there was a statistical and clinically significant effect in various peripheral joint musculoskeletal pathologies in the recovery of ROM.

Methods

This systematic review and meta-analysis complied with the criteria set by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[12] This review was registered with PROSPERO 2016:CRD42017071595.

Search Strategy

An electronic search strategy of MEDLINE (via PubMed), CINAHL (via EBSCOhost), Embase (via Elsevier), the Physiotherapy Evidence Database (PEDro), the Cochrane Library, and Google Scholar and using specific keywords ("Mulligan concept" OR "Mulligan method" OR "mobilisation with movement" OR "Mulligan technique" OR "mobilization with movement") was applied for the period from August 2008 to January 2018 by 1 reviewer (N. S.). The basic search strategy is presented in Appendix A. In addition, articles in the reference lists of identified studies were hand searched.

Selection Criteria

Two independent reviewers (N.S. and G.A.K.) selected the studies, first assessing their titles and abstracts and subsequently reading the articles' texts meticulously. In case of disagreement between the 2 reviewers, a third one (Z.D.) was involved to resolve discrepancies. All reviewers involved followed the set Patient, Intervention, Comparison, Outcome question (Appendix B).

Regarding the criteria of inclusion and exclusion, the study included only randomized controlled trials (RCTs) because they present high internal validity in the examination of a therapeutic intervention[13] and because systematic reviews and meta-analyses that only include RCTs in their sample rank first among research methodological designs regarding their internal validity.[14] Only studies referring to MWM of peripheral joints, according to Mulligan, published from August 2008 until January 2018 in English were included.

Studies that did not explicitly refer to MWM of peripheral joints or humans or musculoskeletal problems were excluded.

Methodological Assessment of RCTs

The PEDro scale, which is deemed as valid and reliable for assessing RCTs, was used for the sample assessment.[15,16] Regarding grading, studies were divided into 3 categories, regarded as low quality (0-3 of 10), medium quality (4-6 of 10), and high quality (7-10 of 10). An overall assessment of included studies was also performed based on whether each individual criterion was fulfilled.

Data Extraction

The reviewers (N.S. and G.A.K.) collected all the characteristics of the included studies, classified them, and presented their main characteristics in tables (Appendix C). More specifically, the following information was extracted: purpose, sample size/group, interventions/group, details of the therapeutic intervention(s), assessment points (follow-up), outcome measures, statistical analysis, and results.

Meta-analysis

The meta-analysis focused on ROM as the main impairment outcome measure. The mean and the standard deviation change scores before and after the MWM-related therapy or control condition for each group of participants of the included studies. The estimated between-group mean difference for each comparison was designated as the effect size for each study included in the sample and for individual meta-analyses.[17] Moreover, the 95% confidence interval (CI) was also presented for individual meta-analyses.[17] The inverse variance method was used for assigning weights to the studies in the meta-analysis.[18]

The I^2 indicator and χ^2 test (nonsignificant if $P > .05$) were used to evaluate the heterogeneity observed among studies.[18,19] Heterogeneity greater than 75% was designated as high, between 60% and 75% as substantial, between 40% and

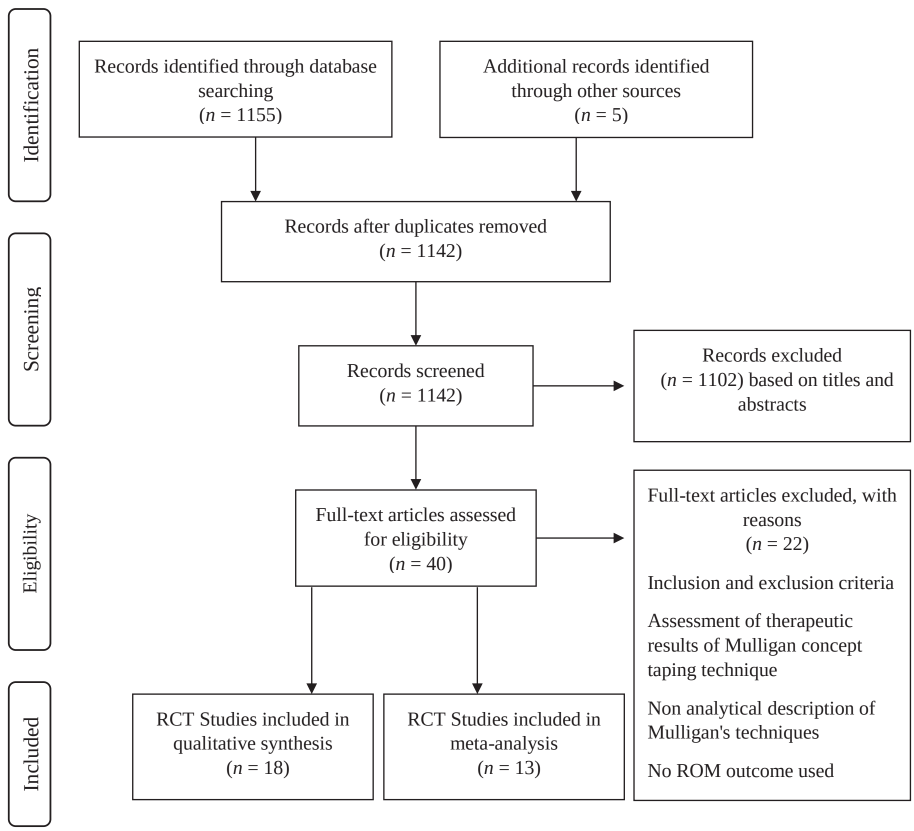

Fig 1. *PRISMA flowchart showing the selection procedure for the studies in this systematic reviewand meta-analysis.* PRISMA, *Preferred Reporting Items for Systematic Reviews and Meta-Analyses;* RCT, *randomized controlled trial;* ROM, *range of motion.*

60% as moderate, and lower than 40% as not important. A random-effects model was used in all meta-analyses because the effects being estimated in the different studies were not considered identical, but followed some distribution.[18]

To evaluate clinical significance, we aimed to use the minimal clinically important difference. However, we found no consensus on minimal clinically important differences for shoulder or hip ROM. For this reason, the Z test was considered for the assessment of statistical significance of the outcomes, and for each meta-analysis the total mean difference (95% CI) was compared to the minimum detectable change (MDC) from relevant studies.[20-23]

Finally, the statistical analysis was conducted with the Review Manager computer program, version 5.3, 2014.

Results

Results of the Literature Search

Eighteen RCTs were included in the systematic review, according to the inclusion and exclusion criteria and the design used for this study, and 13 RCTs were included in a meta-analysis (Fig 1) owing to high heterogeneity. A total of 1160 studies were initially collected, and after screening, according to the set exclusion criteria and the removal of duplicate studies, 23 RCTs were more closely inspected. Of those, the study by Youssef et al[24] was not included in the meta-analysis regarding adhesive capsulitis because it was the only one to compare Mulligan's MWM with mobilizations according to the Maitland method. Also, the studies by Teys et al,[25] Arshad et al,[26] Haider et al,[27] and Neelapala et al[28] were omitted with reason (Fig 1). The characteristics of the studies included in the sample of the present study are listed in Appendix B.

Methodological Assessment of the Sample According to the PEDro Scale

All the studies included in the sample were assessed on the basis of the PEDro scale (Table 1) and classified in 2 categories. More specifically, 8 studies were classified as high quality,[29-36] and 10 of them were assessed as medium quality.[37-46] Although the included studies fulfilled many of the PEDro criteria, most (12 of 18) lacked allocation concealment. Also, a significant number of studies lacked blinding of assessors (5 of 18). These are considered important shortcomings for RCTs.

Meta-analysis

To analyze the therapeutic results of MWM regarding ROM improvement, separate meta-analyses were

Table 1. *PEDro Scale Results*

Authors	Random Allocation	Concealed Allocation	Baseline Comparability	Blind Participants	Blind Therapists	Blind Assessors	Adequate Follow-up	Management as Planned or Intention-to-Treat Analysis	Between-Group Comparisons	Point Estimates and Variability	Total PEDro Score
Kachingwe et al 2008[37]	Yes	No	Yes	Yes	No	Yes	No	No	Yes	Yes	6/10
Hotwani et al 2010[38]	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10
Djordjevic et al 2012[29]	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	8/10
Doner **et al** 2013[39]	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10
Mhatre et al 2013[40]	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5/10
Kage & Ratnam, 2014[41]	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10
Cruz-Diaz et al 2015[30]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10
Delgado-Gil et al 2015[31]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10
Marrón-Gómez et al 2015[42]	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6/10
Romero et al 2015[32]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7/10
Satpute et al 2015[33]	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9/10
Beselga et al 2016[34]	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	8/10
Guimaraes et al 2016[43]	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7/10
Lalnunpuii et al 2016[35]	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	8/10
Yildirim et al 2016[45]	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5/10
Walsh & Kinsella, 2016[44]	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	7/10
Yeole et al 2017[46]	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	5/10
Mutlu et al 2018[36]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7/10

NOTE. The first criterion, "Eligibility Criteria," of the PEDro scale was excluded from the chart. The reason is that it is not a marking criterion. All the research studies of our sample include this criterion. *PEDro*, Physiotherapy Evidence Database.

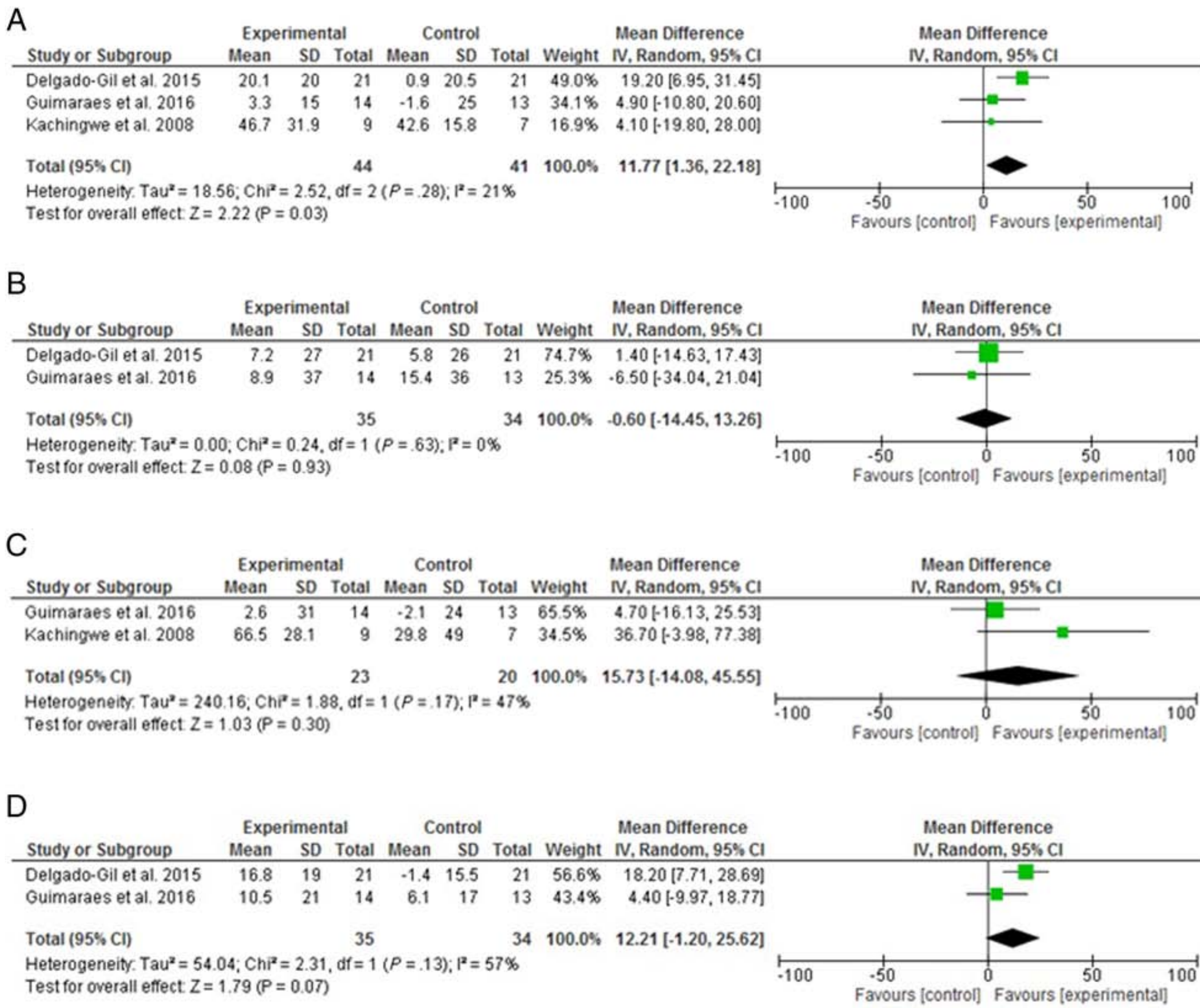

Fig 2. *Forest plots of shoulder (A) flexion, (B) abduction, (C) scaption, and (D) external rotation range of motion differences between MWM Treatment (Experimental) against Control (No, Sham, or Passive Treatment) on shoulder impingement syndrome. Results lower than zero denote better effectiveness of the control conditions and higher than zero better effectiveness of MWM.* CI, *confidence interval;* MWM, *mobilization with movement;* SD, *standard deviation.*

conducted in different peripheral joints and, wherever possible, in different joint pathologies.

Shoulder Joint. Studies referring to different shoulder joint pathologies were separately examined.

Shoulder Impingement Syndrome—MWM (Experimental Group) in Relation to a Control Group (Sham, Passive, or No Treatment) (Fig 2). Assessing the effectiveness of MWM in relation to a sham, passive, or no therapeutic approach on shoulder impingement syndrome, data were collected from 3 studies (n = 3) of the sample for shoulder flexion,[31,37,43] corresponding to a total population of 85 participants (44 of whom received MWM therapy), whereas for scaption, data were collected from 2 studies (n = 2)[37,43] with a population of 43 participants (23 of whom received MWM therapy), and for abduction and external rotation, data were collected from 2 studies (n = 2)[31,43] with a population of 69 participants (35 of whom received MWM therapy).

Comparing MWM in relation to a sham, passive, or no therapeutic approach regarding the improvement of shoulder flexion (Fig 2A) to individuals experiencing impingement syndrome, statistically significant differences favoring MWM were found concerning random effects (mean difference [95% CI]: 11.77° [1.36°-22.18°], Z = 2.22, P = .03), with data presenting no important heterogeneity (I^2: 21%). These results were also clinically significant when compared with the MDC of other studies, found to be 11° (single rater) or 12° (between-raters) when shoulder ROM was examined actively in supine-lying patients with shoulder pathologies.[21]

Abduction ROM improvement (Fig 2B) in individuals of the same population presented no statistically significant differences concerning random effects (mean difference

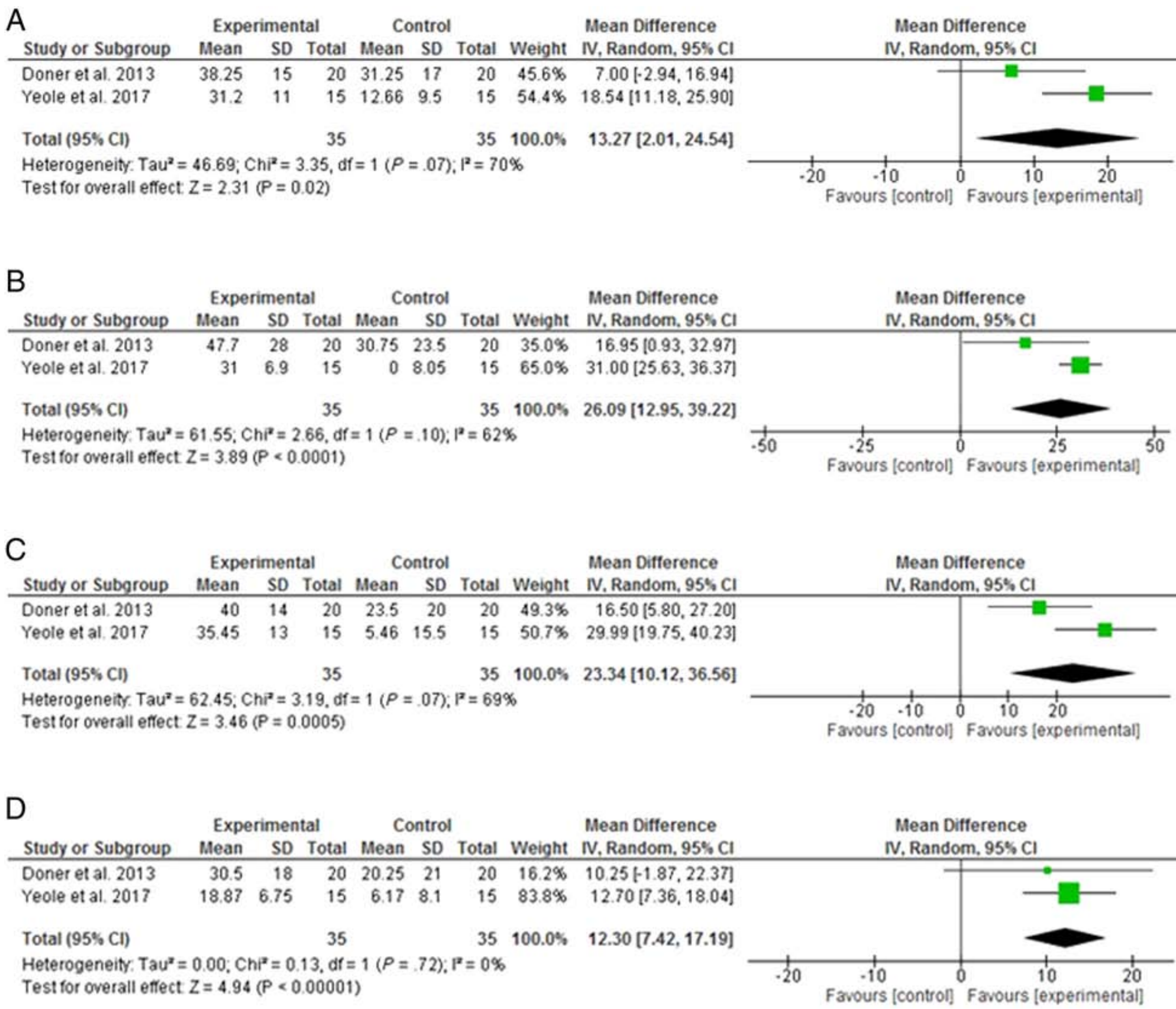

Fig 3. *Forest plot of shoulder (A) flexion, (B) abduction, (C) internal rotation, and (D) external rotation range of motion differences between MWM Treatment (Experimental) against Control (No, Sham, or Passive Treatment) on shoulder adhesive capsulitis. Results lower than zero denote better effectiveness of the control conditions and higher than zero better effectiveness of MWM.* CI, *confidence interval;* MWM, *mobilization with movement;* SD, *standard deviation.*

[95% CI]: -0.60° [-14.45° to 13.26°], Z = 0.08, *P* = .93), with data between studies presenting zero heterogeneity (I^2: 0%).

Similarly, regarding the improvement in scaption (Fig 2C), no statistically significant differences were found concerning random effects (mean difference [95% CI]: 15.73° [-14.08° to 45.55°], Z = 1.03, *P* = .30), with studies presenting moderate heterogeneity (I^2: 47%).

Regarding improvement in external rotation (Fig 2D), no statistically significant differences were found concerning random effects (mean difference [95% CI]: 12.21° [-1.20° to 25.62°], Z = 1.79, *P* = .07), with moderate heterogeneity (I^2: 57%).

Adhesive Capsulitis—MWM (Experimental Group) in Relation to a Control Group (Sham, Passive, or No Treatment) (Fig 3). Assessing the effectiveness of MWM in relation to a sham, passive, or no therapeutic approach on adhesive capsulitis, data were collected from 2 studies (n = 2) of the sample for the movement directions of shoulder flexion, abduction, and internal and external rotation,[39,46] with a total population of 70 participants (35 of whom received MWM therapy).

Comparing MWM to a sham, passive, or no therapeutic approach for the improvement in flexion (Fig 3A) of individuals experiencing adhesive capsulitis revealed statistically significant differences favoring MWM, concerning random effects (mean difference [95% CI]: 13.27° [2.01°-24.54°], Z = 2.31, *P* = .02), but with substantial heterogeneity (I^2: 70%). We did not exclude this meta-analysis because the effect was noted in the same direction in both studies (favoring experimental), the χ^2 test was not statistically significant (*P* = .07), and the heterogeneity was not higher than 75%.

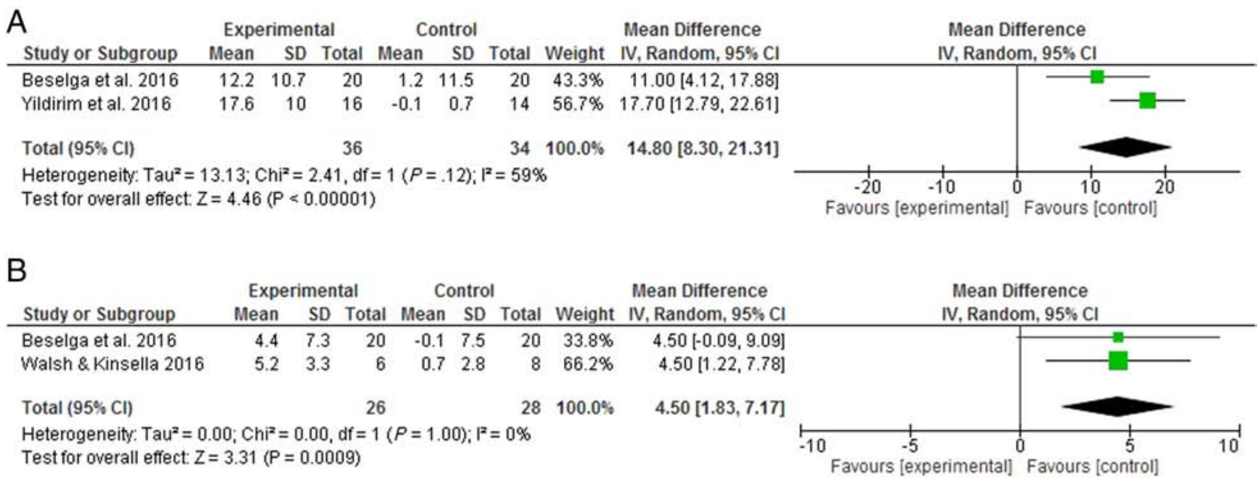

Fig 4. *Forest plot of hip (A) flexion and (B) internal rotation range of motion differences between MWM Treatment (Experimental) against Control (No, Sham, or Passive Treatment). Results lower than zero denote better effectiveness of the control conditions and higher than zero better effectiveness of MWM.* CI, *confidence interval;* MWM, *mobilization with movement;* SD, *standard deviation.*

As for the abduction ROM improvement (Fig 3B) in the same population, statistically significant differences were also found, favoring MWM, concerning random effects (mean difference [95% CI]: 26.09° [12.95°-39.22°], Z = 3.89, $P <$ .0001), with relatively moderate heterogeneity (I^2: 62%).

Moreover, regarding the improvement in internal rotation (Fig 3C), statistically significant differences were found, favoring MWM, concerning random effects (mean difference [95% CI]: 23.34° [10.12°-36.56°], Z = 3.46, $P =$ .0005), with substantial heterogeneity (I^2: 69%). This meta-analysis was performed because the direction of effect was in the same direction (favoring experimental) for both studies, the χ^2 test was nonsignificant (P = .07), and the heterogeneity was not higher than 75%.

Finally, for external rotation ROM improvement (Fig 3D) in the same population, statistically significant differences were found favoring MWM, concerning random effects (mean difference [95% CI]: 12.30° [7.42°-17.19°], Z = 4.94, $P <$ .00001), with zero heterogeneity (I^2: 0%).

These results were also clinically significant regarding flexion, abduction, and internal rotation but were marginally not clinically significant for external rotation compared with MDC values in a relevant study documenting ROM glenohumeral joint test–retest data (intrarater and inter-rater) in the range of 11° to 12° (flexion), 16° to 24° (abduction), 14° to 20° (internal rotation), and 14° to 22° (external rotation).[21]

Hip Joint (Fig 4). Assessing the effectiveness of MWM in relation to a sham, passive, or no therapeutic approach on hip flexion, data were collected from 2 studies (n = 2) of the sample,[34,45] with a total population of 70 participants (36 of whom received MWM therapy), whereas on hip internal rotation, data were collected from 2 studies (n = 2) of the sample,[34,44] with a total population of 54 participants (26 of whom received MWM therapy).

The comparison of the effectiveness of MWM in relation to a sham, passive, or no therapeutic approach for the improvement of hip flexion (Fig 4A) to patients experiencing osteoarthritis[34] or for its restriction[45] led to statistically significant differences in favor of MWM, concerning random effects (mean difference [95% CI]: 14.80° [8.30°-21.31°], Z = 4.46, $P <$ .0001), with moderate heterogeneity (I^2: 59%).

As for the improvement of internal rotation (Fig 4B), statistically significant differences were found, favoring MWM, concerning random effects (mean difference [95% CI]: 4.50° [1.83°-7.17°], Z = 3.31, P = .0009), with relatively zero heterogeneity (I^2: 0%).

These outcomes were also clinically significant for flexion only, when compared with MDC values of 8° presented in other similar studies for hip ROM flexion and internal rotation.[20]

Qualitative Synthesis. Publication bias was not assessed because there were inadequate numbers of included trials to properly assess a funnel plot or more advanced regression-based assessments.

Shoulder Pain and Dysfunction—MWM (Experimental Group) in Relation to a Control Group (Sham, Passive, or No Treatment). Assessing the effectiveness of MWM in relation to a sham, passive, or no therapeutic approach on studies on shoulder "pain" or "dysfunction," data were evaluated from 2 studies (n = 2) of the sample for shoulder flexion and abduction, referring to a total population of 63 participants (32 of whom received MWM therapy),[29,32] while for internal rotation data were collected from 2 studies (n = 2) with a population of 87 participants (44 of whom received MWM therapy).[29,32] Meta-analysis on shoulder pain and dysfunction studies was not performed because of the high heterogeneity (>90%) in the results of the included studies. Also, the effect between studies was in opposite directions.

Hamstring Tightness. Assessing the effectiveness of MWM against another active therapeutic intervention for the improvement of knee extension to individuals who presented reduced flexibility on their hamstrings, data were evaluated from 2 studies (n = 2) of the sample, including a total population of 96 participants (48 of whom received MWM therapy).[40,41] A meta-analysis on knee extension ROM data was not performed because of the high heterogeneity (I^2: 87%) that the included studies presented. However, the effects of both studies were in the same direction (favoring control).

Knee Joint Osteoarthritis. Evaluating the effectiveness of MWM against another active treatment (McConnell and Maitland methods) concerning improvement in knee flexion of individuals who experience knee osteoarthritis, 3 studies (n = 3) were identified, referring to a total population of 154 participants (77 of whom received MWM therapy).[35,36,38] One of the studies had 2 sets of data,[36] separately presented for each knee. Meta-analysis of knee flexion ROM data was not performed because of the high heterogeneity (I^2: 77%) that the included studies presented.

Chronic Instability of Ankle Joint. Assessing the effectiveness of MWM with a "placebo" treatment for the improvement of ankle joint dorsiflexion in individuals experiencing chronic instability, 2 studies (n = 2) of the sample were evaluated, including a total population of 93 participants (48 of whom received MWM therapy).[30,42] Meta-analysis on chronic ankle instability (CAI) ROM data was not performed because of the high heterogeneity ($I^{2:}$ 95%) that the included studies presented. However, the effects of those studies were in the same direction (favoring experimental).

Discussion

This study evaluated the therapeutic benefit of MWM in a variety of musculoskeletal conditions of peripheral joints. Although the main premise for the delivery of certain manual therapy techniques like the MWM is the same,[1,3-6] the effectiveness noted may differ when applied in joints with different form, function, and pathologies. Therefore, more individualized analysis of the therapeutic processes involved may be required, per joint and joint pathology, to verify whether certain techniques can be universally applied with equal effectiveness.

Meta-analysis

Peripheral joint MWM, as described by Mulligan, produced better therapeutic results in comparison to a sham, passive, or no therapeutic approach, regarding the improvement of joint ROM, according to 7 of the 10 comparisons performed. Hing et al[10] reached similar conclusions to our study, with MWM appearing to have greater therapeutic benefit in the ROM of peripheral joints.

Our study revealed that MWM offered better therapeutic results, which are both statistically and clinically important, in relation to a sham, passive, or no therapeutic approach regarding shoulder flexion in patients with shoulder impingement syndrome. However, comparisons regarding shoulder abduction or abduction at the level of scapula and external rotation for the same category of patients were statistically nonsignificant. The methodological ratings of RCTs in patients with shoulder impingement syndrome were 6, 7, and 8 of 10.

On the other hand, MWM produced better therapeutic results in comparison to a sham, passive, or no therapeutic approach regarding the improvement in ROM of all shoulder movements considered (flexion, abduction, internal and external rotation) in patients experiencing adhesive capsulitis. Therapeutic results of MWM in this category of patients were more clearly shown, positively influencing the ROM restriction overall, possibly because this specific glenohumeral condition category presents greater limitations in joint movements in all movement directions, as compared to other conditions. What remains debatable is the extent to which MWM affects the extensibility of capsular and ligamentous structures or whether their effect is due to neurophysiological stimuli that indirectly affect the improvement of pain-disability-reduced mobility complex.[8,47,48] These results are also clinically significant.[21] However, the methodological rating of the 2 RCTs in patients with shoulder adhesive capsulitis was 5 of 10 in each, limiting the strength of the results in this patient group.

As far as the hip joint is concerned, MWM offers more important therapeutic results in comparison to a sham, passive, or no therapeutic approach regarding the improvement of flexion and internal rotation on the particular joint. This result was based on 3 studies (n = 3)[34,45,49] that refer to a total population of 80 participants (34 of whom received MWM therapy). Improvement in hip ROM flexion was also clinically significant. The methodological ratings of the 3 RCTs in patients with hip dysfunctions were 5, 7, and 8 of 10, with 1 study[45] included in the flexion ROM meta-analysis failing to fulfill several methodological criteria.

Qualitative Synthesis

High heterogeneity became the reason for no quantitative analysis of studies included in the qualitative analysis.

Results on the effectiveness of MWM techniques compared with sham, passive, or no treatment for the 2 available studies[29,32] in patients with shoulder pain and dysfunction were inconclusive. Also, from the data available from 2 studies,[40,41] MWM does not produce better therapeutic results for the hamstring tightness musculoskeletal condition. Those 2 studies that examined the effectiveness of "bent-leg-raise" technique[40,41] and another one included in the meta-analysis of hip joint pathologies that examined the therapeutic results of traction straight leg raise technique according to Mulligan[45] were included in the sample. Mulligan has not classified those techniques under one of the aforementioned categories (MWM, Sustained Natural Apophyseal GlideS, Natural Apophyseal GlideS, reverse Natural Apophyseal GlideS).[3] However, these constitute 2 techniques that include the simultaneous movement of the hip and can be considered MWM of this joint.[3]

However, the effects of all 3 studies in knee osteoarthritis[35,36,38] were in agreement (favoring experimental), apart from the left knee data of 1 study.[36] The methodological ratings of the 3 RCTs in patients with knee osteoarthritis were 4, 7, and 8 of 10. Also, MWM in the 2 available studies in patients with CAI[30,42] has better therapeutic results than a placebo intervention. The methodological ratings of the 2 RCTs in patients with CAI were 6 and 8 of 10.

More RCTs examining the effectiveness of MWM in these clinical conditions are required to confirm the applicability of those techniques in those 4 clinical conditions.

Limitations Presented in RCTs Included in the Systematic Review and Meta-analysis

Follow-up reassessment of 3 and 6 months, respectively, was only carried out on participants in 2 studies.[30,39] No additional RCTs were found that examined the long-term therapeutic results of MWM according to Mulligan on peripheral joints. Thus, it seems that the time in which the therapeutic results of MWM act and last on peripheral joints has not been clarified yet.

Second, RCTs examining the effectiveness of the specific group of therapeutic techniques regarding shoulder, elbow, hip, knee, and ankle peripheral joints were included in the sample. No studies of such a methodological design have been conducted regarding the wrist joint or the peripheral joints of foot. Even so, more studies of high methodological rating are required in the joint pathologies already examined in this review to establish further the results obtained.

At the same time, the effectiveness of a significant number of MWM techniques described in the Mulligan method regarding peripheral joints was examined in the RCTs included in the present study. However, there are still a number of MWM techniques[1,3] that no research study of a similar methodological design has examined.

In addition, the Mulligan method emphasizes the importance of applying MWM of peripheral joints in functional positions, such as in standing.[3] Only 3 RCTs studying such techniques in weight-bearing positions were found.[30,38,42] Moreover, self-treatment techniques are important within the Mulligan method. The only study to examine this question was the study conducted by Walsh and Kinsella,[44] which constitutes a pilot RCT.

Limitations of This Study

A limitation of this study was that its sample exclusively consisted of RCTs to increase its internal validity. As a result, a significant number of studies that used a different methodological design were excluded. Also, only studies published in English were included. Furthermore, we did not measure publication bias, which may cause our meta-analysis to lose validity. Also, our categorization of the included studies resulted in direct comparisons of a small number of studies within each joint and pathology category.

Finally, although most studies used a universal goniometer for ROM measurement (13 of 18 total RCTs and 6 of 8 that contributed to the meta-analyses), 1 study on hip pain used a bubble inclinometer to measure hip internal rotation in sitting,[44] whereas another[45] used a digital goniometer to measure hip flexion. Both of those studies' flexion and internal rotation ROM data were compared with data from another study[34] that used a universal goniometer. Because differences have been documented between universal goniometric measurements with bubble inclinometric methods[49] for hip ROM measurement, direct comparison of data measured with different equipment may have lacked validity in absolute terms. However, because measurements within each of the RCTs used for the meta-analyses were performed with the same equipment, the overall outcome of the meta-analyses would not have been compromised in relative terms by the differences in measuring instruments and methods between studies. Another study also used a digital goniometer to measure ROM in patients with knee osteoarthritis,[36] and the 2 studies on CAI[30,42] used the same method of a distance measure as an estimate of ankle dorsiflexion ROM. However, in absolute terms, to be able to compare data between meta-analyses, measuring equipment should be the same between studies, with measurements recorded from identical initial joint angles and body positions. Also, examiners' experiences and the conditions under which measurements take place may have a significant role in measurement error.[48]

Suggestions for Further Research

The study of additional MWM techniques of the Mulligan method, within the pathology categories examined in this study and in additional pathologies that remain unexplored regarding their effectiveness on peripheral joints, is required. Examination of these techniques from functional positions and RCTs with longer follow-up periods is recommended. Furthermore, future studies could prioritize examining self-treatment techniques (self-MWM) of the Mulligan method, a group of techniques the effectiveness of which yet remains unexplored; however, their study would be quite useful because these could maintain and enhance further the therapeutic effect of these techniques.

Conclusion

The therapeutic benefit of MWM in relation to sham, passive, "placebo," or no therapeutic intervention regarding

ROM improvement was evaluated for different peripheral joints and joint pathologies. Mobilization with movement produced a statistically and clinically significant ROM increase consistently in all movement directions for shoulder adhesive capsulitis and hip pain. However, for other shoulder conditions (impingement, pain or dysfunction), hamstring tightness, knee osteoarthritis, and chronic ankle instability pathologies, a therapeutic benefit regarding ROM could not be clearly established. Owing to the rather small number of individual studies included within the separate groups of pathologies examined in our systematic review, further evaluation of MWM effectiveness is recommended.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): N.S.
Design (planned the methods to generate the results): N.S., G.A.K.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): N.S.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): N.S.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): N.S., Z.D., G.A.K.
Literature search (performed the literature search): N.S.
Writing (responsible for writing a substantive part of the manuscript): N.S.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): N.S., G.A.K.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jmpt.2019.04.001.

Practical Applications

- A statistical and clinical significant effect of Mulligan's MWM techniques on ROM in peripheral joints was shown for some of the clinical conditions analyzed.
- Further study is required to include larger RCTs with longer follow-up periods.

References

1. Hing W, Hall T, Rivett D, Vicenzino B, Mulligan B. *The Mulligan Concept of Manual Therapy. Textbook of Techniques*. 1st ed. Sydney, Australia: Elsevier; 2015.
2. Mallo-Urries M, Hidalgo-Garcia C, Bueno-Gracia E, Estebanez-de-Miguel E, Lucha-Lopez O, Tricas-Moreno JM. Clinical and ultrasonographic evidence of a proximal positional fault of the radius A case report. *Man Ther.* 2014;19(3):264-269.
3. Mulligan B. *Manual Therapy: NAGS, SNAGS, MWMS, etc.* 6th ed. Wellington, New Zealand: Plane View Services; 2010.
4. May J, Krzyzanowicz R, Nasypany A, Baker R, Seegmiller J. Mulligan concept use and clinical profile from the perspective of American certified Mulligan practitioners. *J Sport Rehabil.* 2015;24(4):337-341.
5. Exelby L. Peripheral mobilisations with movement. *Man Ther.* 1996;1(3):118-126.
6. Vicenzino B, Hing WA, Rivett D, Hall T. *Mobilisation with Movement: The Art and the Science*. 1st ed. Sydney, Australia: Elsevier; 2011.
7. Myers KM, Davis M. Behavioral and neural analysis of extinction. *Neuron.* 2004;36(4):567-584.
8. Zusman M. Mechanisms of musculoskeletal physiotherapy. *Phys Ther Rev.* 2004;29(9):39-49.
9. Cano-de-la-Cuerda R, Molero-Sanchez A, Carratala-Tejada M, et al. Theories and control models and motor learning: clinical applications in neurorehabilitation. *Neurologia.* 2015;30(1):32-41.
10. Hing W, Bigelow R, Bremner T. Mulligan's mobilization with movement: a systematic review. *J Man Manipulative Ther.* 2009;17(2):39-66.
11. Stathopoulos N, Dimitriadis Z, Koumantakis GA. Effectiveness of Mulligan's mobilization with movement techniques in peripheral joints: a systematic review with meta-analysis between 2008-2017. *Physiotherapy.* 2019;105(1):1-9.
12. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. *PLoS Med.* 2009;6(7):e1000097.
13. Saturni S, Bellini F, Braido F, et al. Randomized controlled trials and real life studies. Approaches and methodologies: a clinical point of view. *Pulm Pharmacol Ther.* 2014;27(2):129-138.
14. Portney GL, Watkins PM. *Foundations of Clinical Research: Applications to Practice*. 3rd ed. Philadelphia, PA: F.A. Davis Co; 2009.
15. Moseley MA, Herbert DR, Sherrington C, Maher GC. Evidence for physiotherapy practice: a survey of the Physiotherapy Evidence Database (PEDro). *Austr J Physiother.* 2002;48:43-49.
16. Armijo-Olivo S, Da Costa RB, Cummings GG, et al. PEDro or Cochrane to assess the quality of clinical trials? A meta-epidemiological study. *PloS One.* 2015;10(7):1-14.
17. Israel H, Richter R. A guide to understanding meta-analysis. *J Orthop Sports Phys Ther.* 2011;41(7):496-504.
18. Higgins JPT, Green S. *Cochrane Handbook for Systematic Reviews of Interventions*. West Sussex, England: The Cochrane Collaboration and John Wiley & Sons Ltd; 2008.
19. Sedgwick P. How to read a forest plot. *BMJ.* 2012;345:1-2.
20. Pua Y, Wrigley TW, Cowan SM, Bennell KL. Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. *Arch Phys Med Rehabil.* 2008;89(6):1146-1154.

21. Muir WS, Correa LC, Beaupre L. Evaluating change in clinical status: reliability and measures of agreement for the assessment of glenohumeral range of motion. *N Am J Sports Phys Ther.* 2010;5(3):98-110.
22. Hoch M, McKeon PO. Joint mobilization improves spatiotemporal postural control and range of motion in those with chronic ankle instability. *J Orthop Res.* 2011;29(3):326-332.
23. Mehta SP, Barker K, Bowman B, Galloway H, Oliashirazi N, Oliashirazi A. Reliability, concurrent validity, and minimal detectable change for iPhone goniometer app in assessing knee range of motion. *J Knee Surg.* 2017;30(6):577-584.
24. Youssef RA, Ibrahim AMA, Ayad EK. Mulligan mobilization is more effective in treating diabetic frozen shoulder than the Maitland technique. *Int J Physiother.* 2015;2(5):804-810.
25. Teys P, Bisset L, Collins N, Coombes B, Vicenzino B. One-week time course of the effects of Mulligan's mobilisation with movement and taping in painful shoulders. *Man Ther.* 2013;18(5):372-377.
26. Arshad SH, Shah HI, Nasir HR. Comparison of Mulligan mobilization with movement and end-range mobilization following Maitland techniques in patients with frozen shoulder in improving range of motion. *Int J Sci Res.* 2013; 4(4):2761-2767.
27. Haider R, Ahmad A, Zahra S, Kamran HM. To compare effects of Maitland and Mulligan's mobilization techniques in the treatment of frozen shoulder. *Ann King Edward Med Univ*. 2014;(20)3:257-264.
28. Neelapala YVR, Reddy YRS, Danait R. Effect of Mulligan's posterolateral glide on shoulder rotator strength, scapular upward rotation in shoulder pain subjects – a randomized controlled trial. *J Musculoskelet Res.* 2016;19(3):1650014.
29. Djordjevic CO, Vukicevic D, Katunac L, Jovic S. Mobilization with movement and kinesiotaping compared with a supervised exercise program for painful shoulder: results of a clinical trial. *J Manipulative Physiol Ther.* 2012;35(6): 454-463.
30. Cruz-Díaz D, Lomas Vega R, Osuna-Pérez MC, Hita-Contreras F, Martínez-Amat A. Effects of joint mobilization on chronic ankle instability: a randomized controlled trial. *Disabil Rehabil.* 2015;37(7):601-610.
31. Delgado GJA, Prado-Robles E, De-Souza RPD, Cleland AJ, De-la-Penas FC, Alburquerque-Sendín F. Effects of mobilization with movement on pain and range of motion in patients with unilateral shoulder impingement syndrome: a randomized controlled trial. *J Manipulative Physiol Ther.* 2015;38(4): 245-252.
32. Romero CL, Lacomba MT, Montoro YC, et al. Mobilization with movement for shoulder dysfunction in older adults: a pilot trial. *J Chiropr Med.* 2015;14(4):249-258.
33. Satpute KH, Bhandari P, Hall T. Efficacy of hand behind back mobilization with movement for acute shoulder pain and movement impairment: a randomized controlled trial. *J Manipulative Physiol Ther.* 2015;37(5):324-334.
34. Beselga C, Neto F, Alburquerque-Sendín F, Hall T. Immediate effects of hip mobilization with movement in patients with hip osteoarthritis: a randomised controlled trial. *Man Ther.* 2016;22:80-85.
35. Lalnunpuii A, Sarkar B, Alam S, Equebal A, Biswas A. Efficacy of Mulligan mobilisation as compared to Maitland mobilization in females with knee osteoarthritis: a double blind randomized controlled trial. *Int J Ther Rehabil Res.* 2016;6(2):37-45.
36. Mutlu EB, Ercin E, Ozdincler AR, Ones N. A comparison of two manual therapy approaches and electrotherapy modalities for patients with knee osteoarthritis: a randomized three arm clinical trial. *Physiother Theory Pract.* 2018;34(8):600-612.
37. Kachingwe FA, Phillips B, Sletten E, Plunkett WS. Comparison of manual therapy techniques with therapeutic exercise in the treatment of shoulder impingement: a randomized controlled pilot clinical trial. *J Man Manipulative Ther.* 2008;16(4):238-247.
38. Hotwani R, Metgud S, Ganesh BR. Comparison of McConnell patellar taping versus mobilisation with movement in chronic knee osteoarthritis: a randomized clinical trial. *Ind J Physiother Occup Ther.* 2010;4(4):132-136.
39. Doner G, Guven Z, Celiker R. Evaluation of Mulligan's technique for the adhesive capsulitis of the shoulder. *J Rehabil Med.* 2013;45(8):87-91.
40. Mhatre SB, Singh LY, Tebhekar YJ, Mehta A. Which is the better method to improve "perceived hamstrings tightness" – Exercises targeting neural tissue mobility or exercises targeting hamstrings muscle extensibility? *Int J Osteopath Med.* 2013;16(3):153-162.
41. Kage V, Ratnam R. Immediate effect of active release technique versus Mulligan bent leg raise in subjects with hamstrings tightness: a randomized controlled trial. *Int J Physiother Res.* 2014;2(1):301-304.
42. Marrón-Gómez D, Rodríguez-Fernández ÁL, Martín-Urrialde JA. The effect of two mobilization techniques on dorsiflexion in people with chronic ankle instability. *Phys Ther Sport.* 2015;16(1):10-15.
43. Guimarães JF, Salvini F, Siqueira L. Immediate effects of mobilization with movement vs sham technique on range of motion, strength, and function in patients with shoulder impingement syndrome: randomized clinical trial. *J Manipulative Physiol Ther.* 2016;39(9):605-615.
44. Walsh R, Kinsella S. The effects of caudal mobilisation with movement (MWM) and caudal self-mobilisation with movement (SMWM) in relation to restricted internal rotation in the hip: a randomised control pilot study. *Man Ther.* 2016;22: 9-15.
45. Yildirim AY, Ozyurek S, Tosun O, Uzer S, Gelecek N. Comparison of effects of static, proprioceptive neuromuscular facilitation and Mulligan stretching on hip flexion range of motion: a randomized controlled trial. *Biol Sport.* 2016;33(1): 89-94.
46. Yeole UL, Dighe PD, Gharote GM, Panse RS, Shweta A, Pawar PA. Effectiveness of movement with mobilisation in adhesive capsulitis of shoulder: randomized controlled trial. *Ind J Med Res Pharmaceut Sci.* 2017;4(2):1-8.
47. Brukner R, Khan K. *Clinical Sports Medicine*. Revised 3rd ed. Australia: McGraw-Hill Australia Pty Ltd; 2009.
48. Magee JD. *Orthopedic Physical Assessment*. 6th ed. St. Louis, MO: Elsevier; 2014.
49. Roach S, San Juan JG, Suprak DN, Lyda M. Concurrent validity of digital inclinometer and universal goniometer in assessing passive hip mobility in healthy subjects. *Int J Sports Phys Ther.* 2013;8(5):680-688.