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Is spinal mobilization effective for low back pain?: A systematic review

Kosaku Aoyagi[a], David Heller[a], David Hazlewood[b], Neena Sharma[a], Marcio dos Santos[a,*]

[a] Department of Physical Therapy and Rehabilitation Sciences, University of Kansas Medical Center, 3901 Rainbow Blvd/ MS 2002, Kansas City, KS, 66160, USA
[b] Department of Bioengineering, University of Kansas, 1530 West 15th Street, Lawrence, KS, 66045, USA

1. Introduction

Low back pain (LBP) is one of the most common orthopedic conditions, affecting about 80% of population worldwide [1], resulting in hospital visits, missed work days, economic burden, and a decrease in quality of life [1–4]. Among those experiencing LBP, 10–40% of individuals develop chronic LBP, which accounts for 75% of the total treatment costs for LBP, nearing $12.2 to 90.6 billion in healthcare costs in the US alone [5,6]. Thus, the high prevalence of LBP is a serious problem in the US health care system.

LBP is defined as pain or discomfort below the costal margin and above the inferior gluteal folds, with or without referred leg pain [7–9]. Although LBP is a multi-factorial problem [10,11], biomechanical and neurophysiological factors have received considerable attention as the key underlying mechanisms of LBP and its chronicity [12,13]. Many conservative pharmacological and non-pharmacological treatments such as manual therapy, exercise and biopsychosocial approach exist for LBP. Among them, manual therapy has become a recommended treatment option to manage LBP, according to new clinical practical guidelines for American College of Physicians [14,15].

Manual therapy is a common and standard treatment for LBP which has been used by approximately 70% of clinicians such as physical therapists, osteopathic physicians and chiropractors in orthopedic seetings [16–20]. Manual therapy is defined as a continuum of skilled passive movements to the joints that are applied at varying velocity and amplitude [21,22]. Manual therapy for LBP includes spinal mobilization and manipulation at an individual lumbar vertebrae level [23,24]. Spinal mobilization is defined as low-velocity, non-thrust, passive movement within or at the limit of joint range of motion (ROM) while spinal manipulation is defined as high-velocity thrust techniques at the limit of the ROM [25–29]. The terms "mobilization" and "non-thrust manipulation" are used synonymously in the literature [30–32]. Since the use of the term "mobilization" is more common than "non-thrust manipulation" [30,33–40], this paper will use the term "mobilization" to refer to low velocity, non-thrust, passive joint movements.

Both spinal mobilization or manipulation techniques are aimed to decrease joint stiffness, improve muscle spasm, reposition subluxed joints, and free adhesions around the zygapophysial joints [25,26]. They are also used to alleviate mechanical stress causing pain, or to modulate pain via ascending and descending neural pathways [25,26]. Spinal mobilization and manipulation have different definitions as described above and both of them are recommended by clinical guidelines [34,41,42]. Spinal mobilization is generally more commonly used than spinal manipulation in clinical practice [43–45]. Spinal mobilization is easier and safer for clinicians to apply, especially for novices, since it does not involve a high-velocity maneuver at the end of the available movement and therefore more refined manual ability [43–45].

Many original studies and review articles regarding the efficacy of manual therapy have been conducted but all of them have examined combined effects of spinal mobilization and manipulation on LBP [23,24,34,42]. No differentiation is made between these two types of manual techniques when reporting conclusions about the effectiveness of manual therapy [46,47]. Additionally, quite often the terms spinal mobilization and manipulation are used interchangeably to denote manual therapy treatment techniques [28]. For instance, Assendelft et al. (2004) concluded that effects of spinal manipulative therapy are the same as other standard treatments on LBP [48]. However, they treated both spinal mobilization and manipulation as a spinal manipulative therapy even though they acknowledged both manual therapy techniques are performed in a different manner of action [48]. Furthermore, Cecchi et al. (2010) concluded that spinal manipulation is effective on LBP after three weeks of interventions. However, the treatment included both spinal mobilization and manipulation [49]. Although these articles provide important information, there is a lack of data exploring specifically the effect of spinal mobilization without combined manipulation on LBP.

Spinal mobilization and manipulation have different mechanisms of action on pain and movement limitation [27–29]. For instance, mobilization intends to increase soft tissue extensibility and joint mobility with low velocity passive force to achieve pain modulation via reduced hyperexcitability of muscle spindles and endogenous pain inhibition in the central nervous system [34]. Manipulation applies a sudden thrust which intends to make cracking sound to induce cavitation of a joint to achieve improvement of joint mobility and pain modulation via intradiscal pressure changes [50]. In addition, spinal mobilization generally requires longer treatment time, gentler touch by the clinicians and a more comfortable position for the patient than manipulation, which might lead to different effects between these manual therapy

* Corresponding author.
E-mail addresses: msantos@kumc.edu, marciojsantos@yahoo.com (M. dos Santos).

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techniques [34,42]. Thus, these two manual techniques should be considered as different treatment techniques in guiding clinicians to properly select and apply mobilization versus manipulation. Reviewing the effect of spinal mobilization alone on LBP without including spinal manipulation or other manual therapy techniques would improve our knowledge about effectiveness of spinal mobilization on pain and function and guide clinicians to make evidenced-based decisions about their treatment choice for management of LBP [16,27,34,51].

The purpose of this systematic review is to explore current knowledge of the effects of spinal mobilization, without any other combined manual therapy treatment technique on LBP and provide scope for the future research implications to enhance clinical management of LBP. The results of this study will provide clearer evidence for clinicians to perform the evidenced-based mobilization practice.

2. Methods

2.1. Protocol and registration

The current systematic review was registered in PROSPERO (https://www.crd.york.ac.uk/ PROSPERO) with registration number: CRD42017079684.

2.2. Identification of articles

During September and October of 2017 we conducted a literature search to gather publications on the effects of LBP. We drew the articles from the following databases: MEDLINE, PEDro, CINAHL, and Index to Chiropractic Research. We searched terms looking for articles that tested the effects of spinal mobilization on LBP. We performed multiple searches incorporating the following search terms: low back pain, sacroiliac pain, lumbalgia, lumbago, spine, spinal, mobilization, manual therapy, non-thrust manipulation, and manipulative therapy. The investigators grouped the terms with quotations or parentheses when appropriate and then linked the phrases with a Boolean search term (i.e. AND). We restricted the literature search to human studies written in English in the last 20 years.

2.3. Article selection

The study inclusion criteria included: 1) case studies and clinical trials; 2) studies that quantitatively measured the results of treatments using only spinal mobilizations either through pre- and post measurements or using a control group or both; 3) participants with LBP; 4) articles that described explicitly the method of mobilization.

2.4. Assessment of articles

Two groups of two investigators independently evaluated the eligible papers for the risk of bias (quality of the studies) based on a modified version of Sackett's criteria [52]. The criteria comprised:

- Avoided Contamination
- Random Assignment
- Blinded Assessment
- Monitored Intervention
- Accounted for all Subjects
- Reported Reliability of Results
- Reported Validity of Results
- Follow-up

The reviewing investigators assigned one point to each factor that explicitly met the criteria. Conversely, they did not award any points for the factors in which the articles did not report the criteria explicitly. The investigators made an exception for the reliability and validity of the visual analog scale (VAS) and Oswestry Disability Index (ODI) for which their reliability and validity are commonly known even if not explicitly stated. All other study outcomes required explicit descriptions of their reliability and validity. We used a time of ≥3 months to satisfy the follow-up criterion. This follow-up criterion was based on previous studies [53,54] that consider the time of 3 months the threshold period for chronic pain. In addition, the investigators assigned the level of evidence to each paper according to the following criteria by Sackett [52].

I. Large Randomized Controlled Trial (N ≥ 100)
II. Small Randomized Trial (N < 100)
III. Nonrandomized Design
IV. Case Series, no control
V. Case Report

The reviewing investigators assigned grades recommendation for each of the major outcomes measures based on the level of supporting evidence. They received a grade of A recommendation if the outcome is supported by at least a Level I study; B if supported by at least a level II study; and C if supported by the levels III, IV and V of evidence [55,56]. The four investigators discussed any discrepancy regarding the scores for the risk of bias and level of evidence.

3. Results

The literature search resulted in a total of 1212 articles for consideration. The four review investigators divided these and examined the titles to determine eligibility of the article. They removed 1101 articles based on their titles. Subsequently, the investigators examined the remaining 111 papers by reading their abstracts, which resulted in a further removal of 78 abstracts. The four review investigators split in two groups of two and divided the remaining 33 articles to assess them for eligibility based on article's entire content. If there was a disagreement or uncertainty between any of the reviewers regarding the eligibility of an article, all four reviewers examined the paper, discussed it and determined its eligibility by mutual agreement. The investigators removed a total of 19 papers during this last review for eligibility, resulting in 14 papers that met our selection criteria (Fig. 1).

3.1. General characteristics

In summary, the fourteen studies were published between 2000 and 2016. All but two studies [57,58] compared a group of subjects who received a mobilization intervention with other groups that received varied interventions. The interventions that the comparison groups received varied from simply lying prone [36,59,60] to active interventions such as press-up exercises [35], Thai massage [61], or thrust manipulation [31,32,62] while the experimental group in the all fourteen studies received spinal mobilization. The number of subjects involved in the fourteen studies varied widely, ranging from 19[59] to 221[62] (mean ± SD: 74 ± 62). Treatment duration averaged 2 ± 2 (mean ± SD) sessions over 3 ± 3 weeks (mean ± SD), however eight studies [35–38,58–61] only analyzed the immediate effect of one mobilization session. Three studies [46,57,59] had variable treatment duration and numbers of sessions, which were determined by the practitioner of the subjects according to the treatment outcomes. Details of the reviewed studies such as year of publication, study designs, level of evidence, interventions and outcomes are detailed in Table 2.

3.2. Quality review

Of the fourteen articles reviewed for risk of bias or study quality based on the 8 criteria by Sackett's, one study met 2 out of the criteria (the lowest quality review), three studies met 3, one study met 7 (the highest quality review). Nine out of the fourteen reviewed articles met 4, 5 or 6 Sackett's criteria, which makes the average of the total criteria

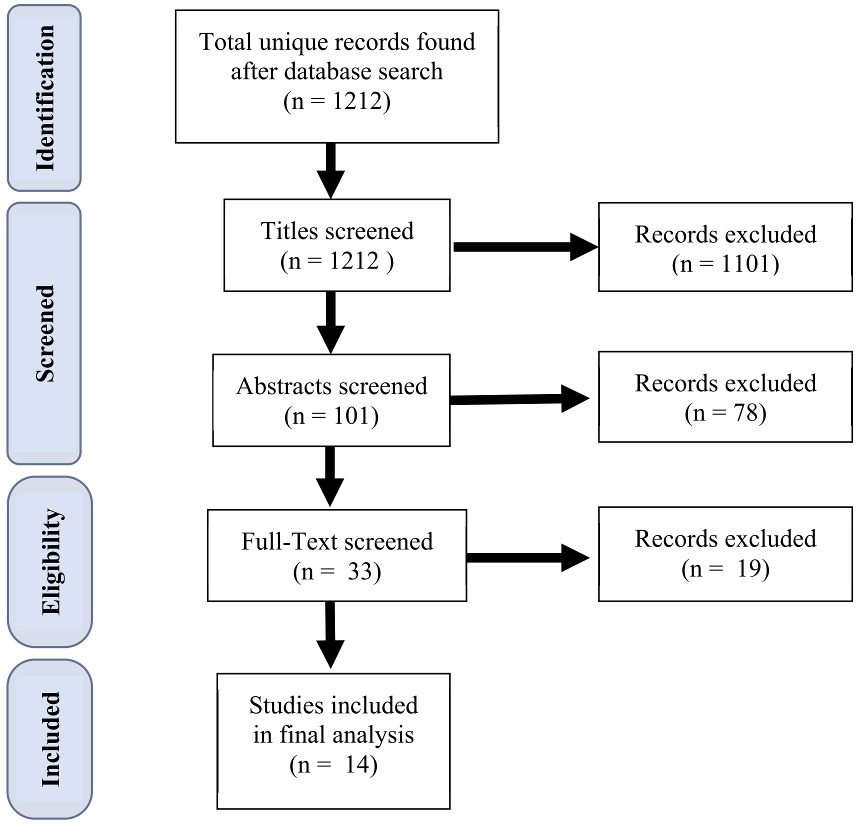

Fig. 1. Summary of search strategy.

Table 1
Quality review.

Authors	Year	Avoided contamination or co-intervention	Random assignment to conditions	Blinded assessment	Monitored intervention	Accounted for all subjects	Reported reliability of measures	Reported validity of measures	Follow-up	Total Criteria Met
Babina et al.	2016	N	Y	Y	N	Y	Y	Y	N	5
Beattie et al.	2009	Y	N	Y	Y	N	Y	N	N	4
Chiradejnant et al.	2002	N	Y	Y	Y	Y	Y	Y	N	6
Chiradejnant et al.	2003	N	Y	Y	Y	Y	Y?	Y?	N	6
Cook et al.	2013	N	Y	Y	N	Y	N	N	N	3
Donaldson et al.	2016	N	Y	Y	Y	Y	Y	Y	Y	7
Ferreira et al.	2007	N	N	N	Y	Y	N	N	N	2
Goertz et al.	2016	Y	Y	Y	Y	Y	N	N	N	5
Goodsell et al.	2000	Y	Y	Y	Y	Y	Y	Y	N	6
Hanrahan et al.	2005	Y	Y	N	Y	Y	Y	Y	N	6
Hanson et al.	2016	Y	N	N	Y	Y	Y	Y	N	5
Learman et al.	2014	N	Y*	Y	N	Y	N	N	N	3
Mackawan et al.	2007	N	Y	N	Y	Y	N	N	N	3
Powers et al.	2008	Y	Y	Y	Y	Y	Y	N	N	6
Average/Totals		6Y, 8N	11Y, 3N	10Y, 3N	11Y, 3N	13Y, 1N	9Y, 5N	9Y, 5N	1Y, 13N	4.8

? = Primary outcome measure(s)' reliability and validity reported, secondary measures may or may not have been; * = secondary analysis of Cook et al. (2013), subset chosen with prediction rules of original RCT.

met above 50% of the possible maximum points (8). Most of the studies met the following criteria: accounted for all subjects (13 studies), random assignment to conditions (11 studies) and monitored intervention (11 studies). The most glaring criterion that was not met by the vast majority of the studies (13 studies) was the follow up analysis. Only one study [46] performed analysis of outcome measures at what we classified to be a true follow up time point (≥3 months) (see Table 1).

3.3. *Level of evidence*

Nine of the fourteen studies were randomized controlled trials (RCTs) (see Table 2) [32,35,37,38,46,59,61–63]. Four of those nine were classified as large RCTs (N ≥ 100) [32,37,38,62]. Based on Sackett's level of evidence [55], these four studies graded out at level I. Seven studies graded out at level II based on the sample size [31,35,36,46,59,61,63], and two studies graded out at a level III based

Table 2
Study characteristics.

Authors	Year	Study Design	Level of Evidence	Subjects	Mobilization Intervention	Comparison Group(s)	Improved Outcomes			
Babina et al.	2016	RCT	II	62 CLBP (nonspecific)	Maitland mob for thoracic spine: 5x/wk for 2 wks; Home breathing exercises	Home breathing exercises		Yes Yes[1]		Yes Yes[1]
Beattie et al.	2009	Prospective, repeated-measures	III	24 LBP	10 min lumbar joint mob	10 min lying prone				Yes Yes[1]
Chiradejnant et al.	2002	RCT	I	120 non-specific LBP	Central PA pressure mob to symptomatic levels	Central PA pressure mob to random level	Yes No[1]		Yes No[1]	Yes No[1]
Chiradejnant et al.	2003	RCT	I	140 non-specific LBP	Prescribed mob techniques	Random mob technique	Yes Yes[1]		Yes Yes[1]	
Cook et al.	2013	RCT	I	149 LBP	Low velocity oscillations for 2 visits. Home exercises 3x/day	SMT for two visits, Home exercise 3x/day	Yes Yes[1]	Yes Yes[1]		
Donaldson et al.	2016	RCT	II	63 LBP	Therapist selected mob technique	Prescriptive selected mob	Yes No[1]	Yes No[1]		Yes Yes[1]
Ferreira et al.	2007	Non-RCT	III	20 (10 LBP, 10 healthy)	3x Small amplitude rotational end-range (Grade IV) oscillatory mob (1 Hz) at L4/L5 w/ subject in side-lying for 30 s each.	(Same for healthy)	Yes			Yes Yes[1]
Goetz et al.	2016	RCT	I	221 LBP	4 low velocity variable amplitude mobs over two weeks	2 groups: 4 SMT over two weeks or sham				Yes Yes[1]
Goodsell et al.	2000	Random crossover controlled trial	II	26 non-specific LBP	Central PA to the most symptomatic spinal level, 3 × 1 min	Lying in a prone position for 3 mins	Yes Yes[1]		No	
Hanrahan et al.	2005	RCT	II	19 male college athletes, acute LBP	Grade I and II Central PA to the 3 spinous processes surround pathologic areas for 30 s each and standard exercise (cryotherapy and stretching)	Lying in prone position, standard exercise (cryotherapy and stretching)	Yes Yes[1]			Yes Yes[1]
Hanson et al.	2016	Single cohort design	IV	24 CLBP	6 sessions, 1x/week. A novel mob technique, 3–5 sets of 10–15 reps plus 30 mins consultation ea. session	(None)	Yes	Yes		
Learman et al.	2014	Secondary analysis of RCT	II	71 LBP who met clinical prediction rules for SMT	Low velocity oscillations for 2 visits. Home exercises 3x/day	SMT for two visits, Home exercise 3x/day	Yes	Yes		
Mackawan et al.	2007	RCT	II	67 non-specific LBP	Central PA on L2-L5 for 10 mins	Thai massage	Yes			Yes
Powers et al.	2008	RCT	II	30 non-specific LBP	Central PA for 10 mins, 3 × 40 sec on the most painful segment followed by 2 × 40 sec on each of remaining segments	Press-up exercise (n = 15), 30 reps of press up for 10 mins	Yes		Yes	

Yes = Significant improvement within group; Yes[1] = Significant improvement between groups; No = No improvement (within or between group); No[1] = Statistical significance not reported; ROM = Range of motion; RCT = Randomized controlled trial; CLBP = Chronic low back pain; LBP = Low back pain; SMT = Spinal manipulation technique; Mob = Spinal mobilization; central PA = Central posteroanterior mobilization.

Table 3
Pain.

Author (Year)	Intervention	Outcome Measures	Mobilization Intervention						
			Pre		Post		1st Follow Up		2nd Follow Up
			Mean	SD	Mean	SD	Mean	SD	Mean
Chiradejnant et al. (2002)	Central PA pressure to symptomatic or random level	Pain Intensity (numeric rating scale) Current Pain Intensity	-[*]	-[*]	−1.34[*]	1.27[*]	–	–	–
		Pain Intensity (numeric rating scale) During Most Painful Movement	-[*]	-[*]	−1.51[*]	1.61[*]	–	–	–
Chiradejnant et al. (2003)	Prescribed mobilization technique vs. random mobilization	Pain Intensity (numeric rating scale) Current Pain Intensity	4.6	1.5	3.3	1.4	–	–	–
		Pain Intensity (numeric rating scale) During Most Painful Movement	5.8	1.8	4.1	1.7	–	–	–
Cook et al. (2013)	SMT vs. Mob for two visits, Home exercise 3x/day for both groups	Pain Intensity (numeric rating scale)	5.3	1.9[#]	3.7[!]	0.5[!,#]	1.9[@]	1.5[@,#]	–
Donaldson et al. (2016)	Therapist- selected mobilization technique vs. prescriptive selected mobilization	Pain Intensity (numeric rating scale)	4.4	1.9	2.40	1.70	3.0	3.5	2.8
Ferreira et al. (2007)	3x Small amplitude rotational end-range (Grade IV) oscillatory mob (1 Hz) at L4/L5 with subject in side lying for 30 s each	VAS	1.1	1.7	0.7	2.2	–	–	–
Goodsell et al. (2000)	Central PA to spinous process of the most symptomatic spinal level, 3 × 1 min + control intervention: lying in a prone position for 3 mins	VAS- Flexion (mm)	-[*]	-[*]	−6.1	-[c]	–	–	–
		VAS- Extension (mm)	-[*]	-[*]	−7.4	-[c]	–	–	–
		VAS- Worst Pain (mm)	-[*]	-[*]	−13.4	-[c]	–	–	–
		VAS- Stiffness Test (mm)	-[*]	-[*]	−5.7	-[c]	–	–	–
		% Change in Pain	-[*]	-[*]	−24.7	-[c]	–	–	–
Hanrahan et al. (2005)	Grade I and II Central PA to the 3 spinous processes surround pathologic areas for 30 s each. Control: lying in prone position Both underwent standard exercise (cryotherapy and stretching)	McGill Pain Questionnaire sensory subscale	10.5[!]	1.5[!]	4.1[!]	1.5[!]	–	–	–
		VAS-Extension	4.5[!]	1[!]	4.2[!]	1[!]	2.3[!,d]	1[!,d]	–
Hanson et al. (2016)	6 sessions (once a week), A novel mobilization technique, 3–5 sets of 10–15 reps plus 30 mins consultation in each session	Quadruple VAS	6.2	1.1	–	–	3.9[e]	1.8[e]	4.2[e]
Learman et al. (2014)	SMT vs. Mob for two visits, Home exercise 3x/day for both groups, then whatever treatment the PT felt appropriate	Pain Intensity (numeric rating scale)	5[!]	0.75[!,#]	2.9[!]	0.5[!,#]	1.4[!,@]	0.4[!,@,#]	–
Mackawan et al. (2007)	Thai massage (n = 35) and central PA on L2-L5 for 10mins (n = 32)	VAS	4.35	1.71	3.39	1.66	–	–	–
Powers et al. (2008)	Central PA(n = 15) for 10 mins, 3 bouts of 40 sec on the most painful segment followed by 2 bouts of 40 sec on each of remaining segments, vs Press-up exercise (n = 15), 30 reps of press up for 10 mins	VAS	4.1	1.7	2.4	1.8	–	–	–

Author (Year)	Mobilization Intervention	Comparison Group								Results		
	2nd Follow Up	Pre		Post		1st Follow Up		2nd Follow Up		Improvement with Mobilization	Group Signifi-cance	Clinical Signifi-cance
	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Chiradejnant et al. (2002)	–	-[*,a]	-[*,a]	−0.9[*,a]	1.4[*,a]	–	–	–	–	Yes	No[&]	No
	–	-[*,a]	-[*,a]	−1.1[*,a]	1.4[*,a]	–	–	–	–	Yes	Yes, Yes[1,a]	No
Chiradejnant et al. (2003)	–	4.7[&]	1.6[&]	3.5[&]	1.7[&]	–	–	–	–	Yes	Yes, Yes[1,a]	No
	–	5.7[&]	1.8[&]	4.3[&]	1.5[&]	–	–	–	–	Yes	No[&,i]	No
Cook et al. (2013)	–	5.1[f]	2.2[f,#]	3.2[!,f]	0.5[!,f,#]	1.8[f,@]	1.8[@,f,#]	–	–	Yes	No[&,i]	No
Donaldson et al. (2016)	2.0	4.67[b]	1.8[b]	3.1[b]	2.1[b]	3.5[b]	2.3[b]	2.8[b]	1.8[b]	Yes	Yes	Yes[j]
Ferreira et al. (2007)	–	–	–	–	–	–	–	–	–	Yes	No[i]	No
Goodsell et al. (2000)	–	-[*]	-[*]	−2	-[c]	–	–	–	–	Yes	No	No
	–	-[*]	-[*]	−3	-[c]	–	–	–	–	Yes	No[i]	No
	–	-[*]	-[*]	−3.5	-[c]	–	–	–	–	Yes	No[i]	No
	–	-[*]	-[*]	6.9	-[c]	–	–	–	–	Yes	Yes[1,i]	No
	–	-[*]	-[*]	−11	-[c]	–	–	–	–	Yes	No[i]	No

(*continued on next page*)

Table 3 (*continued*)

Author (Year)	Mobilization Intervention	Comparison Group								Results		
	2nd Follow Up	Pre		Post		1st Follow Up		2nd Follow Up		Improvement with Mobilization	Group Signifi-cance	Clinical Signifi-cance
	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Hanrahan et al. (2005)	–	11.9[!]	2[!]	9.8[!]	2[!]	–	–	–	–	Yes	No[i]	[k]
	–	4.9[!]	1[!]	3.7[!]	1[!]	4[!,d]	1[!,d]	–	–	Yes	Yes, Yes [1]	Yes[j]
Hanson et al. (2016)	2.1[e]	–	–	–	–	–	–	–	–	Yes	Yes, Yes[1]	Yes
Learman et al. (2014)	–	4.9[!,f]	0.75[!,f,#]	2.9[!,f]	0.5[!,f,#]	1.1[!,f,@]	0.4[!,@,f,#]	–	–	Yes	No[&]	Yes
Mackawan et al. (2007)	–	4.22[g]	1.98[g]	2.45[g]	1.7[g]	–	–	–	–	Yes	Yes, Yes[1,a]	No
Powers et al. (2008)	–	4.0[h]	2.1[h]	2.8[h]	1.5[h]	–	–	–	–	Yes	Yes, Yes[1,a]	No

"Yes" = "within group significance"; "Yes[1]" = "between group significance; * = pre-post mean differences reported; ! = values estimated from graphs; @ = values at "Discharge" (i.e. end of therapy) which averaged 35 days; # = 95% Confidence Intervals; & = comparison group was the group in which mobilization technique and grade was randomly assigned; a = comparison group was the group in which level of mobilization applied was randomly assigned; b = comparison group was the group in which mobilization was uniform for all subjects; c = standard deviations not reported; d = Third test 24 h post "intervention"- not considered a true "follow up"; e = follow ups were at 4 and 8 weeks; f = comparison group was manipulation; g = comparison group was traditional Thai massage intervention; h = comparison group was "Press Up" intervention technique; i = statistical significance of improvement not reported; j = clinically significant improvement only from pre to post; k = no clinical psychometrics established; m = Thai massage comparison group had significantly greater improvement in pain than mobilization; SD = Standard deviation; Central PA = Central posteroanterior mobilization; SMT = Spinal manipulation technique; VAS = visual analog scale; Mob = Spinal mobilization.

on study design [58,60]. Only one study graded out at a level of IV due to the lack of a control group [57]. None of the studies graded out at a level V (case report), the lowest on Sackett's scale [55].

3.4. Outcome measures

We noted commonalities in measuring pain, function, and range of motion (ROM) across the reviewed studies. Many of these studies contained an additional outcome measure or measures that were unique to the other studies (Table 2). As such, in this review we described the study outcomes in four different sections: pain, function, ROM and "other" outcome measures. A summary of the studies measuring Pain, Disability, ROM, and "other" outcome measures are summarized in Tables 3–6. These tables show the interventions performed in the studies, means and standard deviations of the outcome measures, whether the interventions caused improvement, and the statistical and clinical significance of the studies.

3.5. Pain

The most common outcome measure, in eleven of the fourteen selected studies, was pain [3–6,8,10–12,16,18,22]. These studies quantified pain primarily using either a Visual Analog Scale (VAS) [8,10–12,18,22] or Numeric Pain Rating Scale (NPRS) [3–6,16]. These generic measures were applied to many different classifications of pain such as current pain, worst pain, most painful movement, or pain during specific movements such as trunk flexion or extension. Only one study used a different pain metric, the McGill Pain Questionnaire sensory subscale, used by Hanrahan et al. (2005) in addition to the VAS [59].

Every study that measured a change in pain as a result of mobilization showed some improvement in all outcome measures used. Nine measures in seven studies [31,32,35,38,57,59,61] showed statistically significant within-group improvements as a result of mobilization. Only one pain outcome measure in one study by Ferreira et al. (2007) did not show a statistically significant within-group improvement as a result of mobilization [58].

Six measures in four studies [36,38,59,61] showed statistically significant between-group differences comparing mobilization to another group. The study by Chiradejnant et al. (2002) compared mobilizations at the symptomatic spinal level compared to a random level. Both groups showed improvement with the symptomatic level showing greater improvement [38]. The study by Mackawan et al. (2007) compared mobilization to Thai massage and found that, while both groups improved with regard to pain, the group receiving Thai massage improved statistically significantly more than the mobilization group [61]. Six studies [32,35–37,46,61] did not show statistically significant between-group differences between the mobilization and comparison groups. Two studies [57,58] were unable to make between-group comparisons either because pain was not measured in the comparison group [58] or there was no comparison group [57].

Clinical significance of the change in pain measures in subjects with back pain using the VAS and NPRS vary from 2.0 mm (2 points on the NPRS) to 3.5 mm (3.5 points on the NPRS), depending on if the pain is acute or chronic and if the pain is increasing or decreasing [64]. An improvement of −2.0 mm (or −2 points) in pain as a result of a mobilization intervention was clinically significant in four outcome measures in four studies [31,46,57,59]. In two of those studies, the clinical significance of the improvement was present in the post-intervention measure and had slipped above the −2.0 mm/ −2 points threshold at follow up [46,59].

3.6. Function

The second most popular outcome measure was function, quantified in some way in five of the fourteen studies [31,32,46,57,63]. These

Table 4
Function.

Author (Year)	Intervention	Outcome Measures	Mobilization Intervention								Comparison Group								Results		
			Pre		Post		1st follow up		2nd follow up		Pre		Post		1st follow up		2nd follow up		Improvement with Mobilization	Group Signi-ficance	Clinical Signi-ficance
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Babina et al. (2016)	Both groups received home breathing exercises. One group received Maitland mobilization for thoracic spine. 2 wks, 5x/week	Oswestry Disability Index	62.62	3.85	29.5	2.85	–	–	–	–	61.6	3.13	39.6	2.7	–	–	–	–	Yes	Yes, Yes^{1}	Yes
Cook et al. (2013)	SMT vs. Mob for two visits, Home exercise 3x/day for both groups, then whatever treatment the PT felt appropriate	Oswestry Disability Index	32.6	17.1#	27$^{!}$	4$^{!,\#}$	17.2$^{@}$	13.1$^{@,\#}$	–	–	28.7^{f}	14.2$^{f,\#}$	23$^{!,f}$	4$^{!,f,\#}$	14.9$^{f,@}$	13.9$^{@,f,\#}$	–	–	Yes	Yes	No
Donaldson et al. (2016)	Therapist- selected mobilization technique vs. prescriptive selected mobilization	Oswestry Disability Index	30.26	10.5	16.6	12.6	16.5	13.8	15.2	13.5	27.1^{b}	8.0^{b}	18.1^{b}	11^{b}	17.8^{b}	11^{b}	14.8^{b}	11^{b}	Yes	Yes	Yes
Hanson et al. (2016)	6 sessions (once a week), A novel Mob technique, 3–5 sets of 10–15 reps plus 30 mins consultation in each session	Oswestry Disability Index	36.7	9.9	–	–	20.7^{e}	13^{e}	21.5^{e}	15^{e}	–	–	–	–	–	–	–	–	Yes	Yes	Yes
		Patient Specific Functional Scale	6.7	1.2	–	–	3.3^{e}	2.4^{e}	3.6^{e}	2.6^{e}	–	–	–	–	–	–	–	–	Yes	Yes	Yes
Learman et al. (2014)	SMT vs. Mob for two visits, Home exercise 3x/day for both groups, then whatever treatment the PT felt appropriate	Oswestry Disability Index	29$^{!}$	5$^{!,\#}$	21!	5$^{!,\#}$	14$^{!,@}$	3$^{!,@,\#}$	–	–	27$^{!,f}$	5$^{!,f,\#}$	19$^{!,f}$	5$^{!,f,\#}$	8$^{!,f,@}$	3$^{!,@,f,\#}$	–	–	Yes	Yes	No

“Yes” = "within group significance"; “Yes^{1}” = “between group significance; ! = values estimated from graphs; @ = values at "Discharge" (i.e. end of therapy) which averaged 35 days; # = 95% Confidence Intervals; b = "control" group was the group in which mobilization was uniform for all subjects; e = follow ups were at 4 and 8 weeks; f = "control" group was manipulation; SD = Standard deviation; SMT = Spinal manipulation technique; Mob = Spinal mobilization.

Table 5
Range of motion.

Author (Year)	Intervention	Outcome Measures	Mobilization Intervention				Comparison Group				Results		
			Pre		Post		Pre		Post		Improvement with Mobilization	Group Significance.	Clinical Significance
			Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Chiradejnant et al. (2002)	Central PA pressure to symptomatic or random level	ROM- Modified fingertip-to-floor (°)	$-^{*}$	$-^{*}$	1.50^{*}	3.77^{*}	$-^{*,a}$	$-^{*,a}$	$1.04^{*,a}$	$2.49^{*,a}$	Yes	Yes[a]	No
		ROM- Flexion (°)	$-^{*}$	$-^{*}$	-1.80^{*}	4.03^{*}	$-^{*,a}$	$-^{*,a}$	$-1.30^{*,a}$	$3.36^{*,a}$	Yes		^{k}
		ROM- Extension (°)	$-^{*}$	$-^{*}$	-2.48^{*}	2.80^{*}	$-^{*,a}$	$-^{*,a}$	$-2.02^{*,a}$	$2.85^{*,a}$	Yes		^{k}
		ROM- Right lateral Flexion (°)	$-^{*}$	$-^{*}$	-2.57^{*}	2.92^{*}	$-^{*,a}$	$-^{*,a}$	$-2.37^{*,a}$	$2.59^{*,a}$	Yes		^{k}
		ROM- Left lateral Flexion (°)	$-^{*}$	$-^{*}$	-2.75^{*}	2.85^{*}	$-^{*,a}$	$-^{*,a}$	$-2.08^{*,a}$	$2.39^{*,a}$	Yes		^{k}
		ROM- Worst Movement (°)	$-^{*}$	$-^{*}$	-2.83^{*}	3.94^{*}	$-^{*,a}$	$-^{*,a}$	$-2.95^{*,a}$	$2.99^{*,a}$	Yes		^{k}
Chiradejnant et al. (2003)	Prescribed mobilization technique vs. random mobilization	ROM- Modified fingertip-to-floor (°)	19.6	18	21.6	2.6	$16.8^{\&}$	$15.2^{\&}$	$17.3^{\&}$	$5.6^{\&}$	Yes	$No^{\&,i}$	No
		ROM- Flexion (°)	55.4	18	51.9	3.8	$55.1^{\&}$	$16.2^{\&}$	$53.2^{\&}$	$6.5^{\&}$	Yes		^{k}
		ROM- Extension (°)	19	8	16.8	2.9	$18.5^{\&}$	$7.3^{\&}$	$15.9^{\&}$	$2.8^{\&}$	Yes		^{k}
		ROM- Right lateral Flexion (°)	24.6	7.2	22.6	2.6	$24.9^{\&}$	$7.1^{\&}$	$23^{\&}$	$2.7^{\&}$	Yes		^{k}
		ROM- Left lateral Flexion (°)	25.2	7.9	23	2.6	$25.9^{\&}$	$7.3^{\&}$	$23.7^{\&}$	$2.6^{\&}$	Yes		^{k}
		ROM- Worst Movement (°)	30.3	20	27.1	3.2	$32.5^{\&}$	$20^{\&}$	$30.4^{\&}$	$6.3^{\&}$	Yes		^{k}
Goodsell et al. (2000)	Central PA to spinous process of the most symptomatic spinal level, 3 × 1 min vs. lying in a prone position for 3 mins	ROM- Fingertip-to-floor (cm)	$-^{*}$	$-^{*}$	1.9	$-^{c}$	$-^{*}$	$-^{*}$	1.8	$-^{c}$	Yes	No	No
		ROM- Flexion (°)	$-^{*}$	$-^{*}$	0.9	$-^{c}$	$-^{*}$	$-^{*}$	1.4	$-^{c}$	Yes		^{k}
		ROM- Extension (°)	$-^{*}$	$-^{*}$	0.9	$-^{c}$	$-^{*}$	$-^{*}$	1.4	$-^{c}$	Yes		^{k}
Powers et al. (2008)	Central PA (n = 15) for 10 mins, 3 bouts of 40 sec on the most painful segment followed by 2 bouts of 40 sec on each of remaining segments vs. Press-up exercise (n = 15), 30 reps of press up for 10 mins	Total lumber extension (⁰)	20.2	5.2	23.8	6.5	22.2^{h}	3.9^{h}	24.9^{h}	6.0^{h}	Yes	Yes	^{k}

"Yes" = "within group significance"; "Yes[1]" = "between group significance; * = pre-post mean differences reported; # = 95% Confidence Intervals; & = comparison group was the group in which mobilization technique and grade was randomly assigned; a = comparison group was group in which level of mobilization applied was randomly assigned; c = standard deviations not reported; h = comparison group was "Press Up" intervention technique; i = statistical significance of improvement not reported; k = no clinical psychometrics established, SD = Standard deviation; ROM = Range of motion; central PA = Central posteroanterior mobilization.

Table 6
Other outcome measures.

Author (Year)	Intervention	Outcome Measures	Mobilization Intervention						Comparison Group						Results		
			Pre		Post		1st follow up		Pre		Post		1st follow up		Improvement with Mobilization	Group Signifi-cance	Clinical Signifi-cance
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Babina et al. (2016)	Both groups received home breathing exercises. One group received Maitland mobilization for thoracic spine. 2 wks, 5x/week	Forced Vital Capacity	1.13	0.06	2.9	0.13	–	–	1.02	0.07	1.45	0.11	–	–	Yes	Yes	Yes
		Sustained Maximal Inspiratory Pressure	13.42	3.08	64.16	8.94	–	–	15.1	2.97	32.9	5.89	–	–	Yes		[k]
		Chest Wall Expansion	1.83	0.19	4.28	0.27	–	–	1.76	0.19	3.03	0.28	–	–	Yes		[k]
Beattie et al. (2009)	1 × 10 min lumbar joint mob. 4–7 wks later, 10 min prone lying	MRI- "apparent diffusion coefficient" (mean estimate of water diffusion), 5 spinal levels, normal and "decreased" discs	1.53[q]	0.35[q]	1.87[q]	0.15[q]	–	–	1.71[q]	0.43[q]	1.70[q]	0.25[q]	–	–	Yes[n]	No[o,p]	[k]
Chiradejnant et al. (2002)	Central PA pressure to symptomatic or random level	Global perceived effect	-[*]	-[*]	1.28[*]	1.36[*]	–	–	-[*,a]	-[*,a]	1.09[*,a]	1.93[*,a]	–	–	Yes	Yes[a]	No
Ferreira et al. (2007)	3x Small amplitude rotational end-range (Grade IV) oscillatory mob (1 Hz) at L4/L5 with subject in side lying for 30 s ea.	EMG, 4 muscles, 8 epochs, pre and post mobilization	[r]	[r]	[r]	[r]	–	–	[r]	[r]	[r]	[r]	–	–	Yes[r]	Yes, Yes[1,s,t]	[k]
Goetz et al. (2016)	3 groups: SMT, Mob, Sham	13 sway variables	2.86[u]	1.42[u]	3.27[u]	0.48[u,#]	3.37[u,i]	0.45[u,#,i]	2.94[u]	1.46[u]	3.27[u]	0.46[u,#]	3.47[u,i]	0.445[u,#,i]	Yes[v]	No[u]	[k]
Goodsell et al. (2000)	Central PA to spinous process of the most symptomatic spinal level,	PA Response- Stiffness constant (N/mm)	-[*]	-[*]	−0.31	-[c]	–	–	-[*]	-[*]	0.16	-[c]	–	–	No	No	No
	3 × 1 min + control intervention: lying in a prone position for 3 mins	PA Response- distance between 0.5 and 30 N (mm)	-[*]	-[*]	−0.14	-[c]	–	–	-[*]	-[*]	0.13	-[c]	–	–	No	No	No
Hanrahan et al. (2005)	Grade I and II Central PA to the 3 spinous processes surround pathologic areas for 30 s ea. Control: lying in prone position	Force Production	17.8[!]	2[!]	19.1[!]	2[!]	20.3[!,d]	2[!,d]	19[!]	2[!]	18.9[!]	2[!]	18.9[!,d]	2[!,d]	Yes	Yes, Yes[1]	[k]
Mackawan et al. (2007)	Thai massage and central PA on L2-L5 for 10mins	Saliva levels of Substance P (pg/ml)	80.61	85.3	56.27	72.7	–	–	73.86[g]	62.31[g]	50.43[g]	64.39[g]	–	–	Yes	Yes	[k]

"Yes" = "within group significance"; "Yes[1]" = "between group significance; * = pre-post mean differences reported; ! = values estimated from graphs; # = 95% Confidence Intervals; a = comparison group was the group in which level of mobilization applied was randomly assigned; c = standard deviations not reported; d = Third test 24 h post intervention-not considered a true "follow up"; g = comparison group was traditional Thai massage intervention; i = follow up was two weeks; k = no clinical psychometrics established; n = improvement in 8/10 outcome variables as a result of mobilization; o = significant improvement in 1/10 outcome variables as a result of mobilization; p = between group significance not calculated; q = showing only decreased apparent diffusion coefficient of L5-S1 intervertebral discs as this was the only significant finding out of 20 outcome variables; r = 12/64 total comparisons were significantly different post mobilization: see article for details; s = 2/4 muscles showed significant improvement due to mobilization; t = 3/4 muscles showed significant group differences; u = presented here are the only significant finding: medial-lateral excursion on a soft surface between pre and 2 weeks post for both mobilization and manipulation (comparison) groups; v = 4/6 outcome measures improved post mobilization, 2/6 at 2 weeks; SD = Standard deviation; MRI = Magnetic resonance imaging; EMG = Electromyography; SMT = Spinal manipulation technique; Mob = Spinal mobilization; central PA = Central posteroanterior mobilization; PA = Posteroanterior.

studies primarily used the Oswestry Disability Index (ODI) to quantify function. The lone exception is the study by Hanson et al. (2016) [57] which used a Patient Specific Function Scale (PSFS) in addition to the ODI.

Every study that measured a change in function as a result of mobilization showed improvement in ODI and PSFS from pre-to post intervention. Additionally, all outcome measures, in the five studies showed statistically significant within-group improvements as a result of mobilization. However, only one measure in the study by Babina et al. (2016) showed a statistically significant between-group difference in the disability score when comparing mobilization to another group that received breathing exercises [63]. Three studies [31,32,46] did not show statistically significant between-group differences between the mobilization and comparison groups. The study by Hanson et al. (2016) was a single cohort design and therefore could not make between-group comparisons [57].

Vianin et al. (2008) report that a clinically significant change in the ODI is 10 points [65]. Using this standard, improvement in function as a result of a mobilization intervention was clinically significant in three of the five studies [46,57,63]. Regarding the PSFS, Hefford et al. (2012) [66] found the Minimum Important Difference in scores to be 1.2 points while Nichols et al. (2012) [67] report the Minimum Clinically Important Difference (MCID) to be 2.3 points in patients with LBP. Using the latter standard, the improvement in function quantified by the PSFS in the study by Hanson et al. (2016) was clinically significant [57].

3.7. Range of motion (ROM)

The other outcome measure assessed in multiple studies (four out of the fourteen) was ROM [35–38]. ROM was quantified using goniometry as well as the simple "fingertip-to-floor method" and was measured during trunk flexion, extension, and lateral flexion movements.

While there is some debate as to what constitutes "improvement" in ROM, every study that measured a change in ROM as a result of mobilization showed improvement in all their outcome measures. Four studies included measures of ROM as their outcome measures; altogether they measured sixteen ROM measures. Two studies [35,38] showed statistically significant within-group improvements as a result of mobilization in at least one of their ROM outcomes. Three ROM outcome measures in one study by Goodsell et al. (2000) did not show a statistically significant within-group improvement as a result of mobilization. In the study by Chiradejnant et al. (2003) [37], within-group statistics were not reported for six outcome measures as the focus of the study was to compare improvements as a result of a random mobilization compared to a mobilization prescribed by a practitioner [37]. None of the four studies showed statistically significant between-group differences in ROM measures when comparing mobilization to another group.

For the most part, clinical significance of the change in ROM measures of the spine has not been established. Nonetheless, functional ROM, such as what is measured using the fingertip-to-floor method, has been analyzed for clinical significance by Ekedahl et al. (2012) who found that the Minimum Detectable Change (MDC) was 4.5 cm [68]. None of the three studies using this measure found a clinically significant improvement in ROM (for both within and between groups) as quantified with the fingertip-to-floor method [36–38].

3.8. Other outcome measures

In addition to the common outcome measures of pain, function, and ROM, eight of the fourteen studies [36,38,58–63] measure additional outcomes that were unique to their particular study.

The type of "other" outcome measures varied widely, including measures of respiration [63], intervertebral disc water content [60], muscle activity [58], postural sway [59], and the biomarker Substance P [61]. As such, general statements regarding overall trends of the effect of mobilization on unique outcomes should be regarded with caution. Nonetheless, often other measures different from pain, function and ROM were the focus of the study and so warrant reporting. With the exception of Goodsell et al.'s study measuring the effect of mobilization on stiffness and displacement of the vertebrae [36], every "other" outcome measure in every study that measured a change as a result of mobilization showed improvement. Eight studies included additional outcome measures besides pain, function and ROM. Seven studies [38,58–63] showed statistically significant within-group improvements as a result of mobilization in at least one condition in which the outcome was measured. One exception was the aforementioned study by Goodsell et al. (2000) [36]. Three of the studies [58,60,62] took multiple measures (as high as 64 different comparison) and found a mixture of statistically significant and insignificant within-group results.

Three studies [58,59,63] showed statistically significant between-group improvements in the mobilization group compared to another group. Four studies [36,38,61,62] did not show statistically significant between-group differences in their diversified outcome variables between the mobilization and comparison groups. The study by Chiradejnant et al. (2002) compared two groups receiving mobilization at either the symptomatic spinal level or a random level [38]. Both groups showed improvement in Global Perceived Effect (GPE), a general assessment of symptoms, as a result of the mobilization. The study by Beattie et al. (2009) did not report between-group comparisons of water diffusion of the intervertebral discs after mobilization or after simply lying prone for 10 min [60].

Due to the rarity or outright uniqueness of the "other" outcome measures studied, clinical significance for many of the measures has yet to be established. The exceptions are Forced Vital Capacity (FVC) measured by Babina et al. (2016) [63] and GPE measured by Chiradejnant et al. (2002) [38]. While clinically significant parameters for FVC have not been determined for subjects with LBP specifically, Lachmann and Schoser (2013) report that for subjects with respiratory pathologies, the upper limit of the MCID for FVC is roughly 6% [69]. The improvement seen in the study by Babina et al. (2016) [63] in FVC post-intervention in the mobilization group was 256% and, as such, is clinically significant. Kamper et al. (2009) [70] found the MDC and the Minimum Clinically Important Change to be 0.45 and 2 points, respectively, on an 11-point scale such as the one used by Chiradejnant et al. (2002) [38]. Chiradejnant et al. (2002) [38] failed to achieve clinical significance in GPE as a result of mobilization using the threshold of 0.45. Clinical significance of "other" outcome measures as a result of mobilization is regarding the study by Goodsell et al. (2000) did not show any improvement in their kinematic or kinetic parameters [36]. Hence there was no clinically significant improvement as a result of mobilization in the study by Goodsell et al. (2000) [36].

4. Discussion

We reviewed the effects of spinal mobilization without any other additional manual therapy techniques for patients with LBP. Fourteen articles met the study criteria and were assessed their evidence levels and study qualities. Of those articles, quality level ranged from 2 to 7 and the level of evidence ranged from I to IV (Level I: 4 studies, level II: 7 studies, level III: 2 studies, and level IV: 1 study). Overall, spinal mobilization was effective on pain, function, ROM and other outcomes pre- and post the intervention. In the following sections, we are reporting and discussing the effects of spinal mobilization in these 14 articles based on each of the major outcomes.

4.1. Pain

Eleven out of the fourteen studies assessed pain [31,32,35–38,46,58,59,61,71] using numeric rating scale and/or visual analog scale (VAS). Of those studies, seven studies

[31,32,35,37,59,61,71] showed significant pain improvement after spinal mobilization and three studies [36,37,59] showed significant pain improvement compared to control groups. Furthermore two studies [31,71] demonstrated pain improvement exceeding the MCID.

Since three of these studies were given level I evidence [32,37,38], a grade "A" recommendation was given for the effect of spinal mobilization on pain. However, this grade might need to be viewed with caution because between groups differences were only seen in four out of the eleven studies and the follow up assessment are lacking in all these studies except for one [46]. Therefore, the long term effect of spinal mobilization is still debatable.

Some of the reviewed studies speculated the mechanisms of spinal mobilization on pain being biomechanical and/or neurophysiological [31,35,58,61,71]. For example, Powers et al. (2008) speculated that spinal mobilization might distribute synovial fluid over the cartilage which might reduce the mechanical stress, and/or trigger dorsal horn activation to inhibit painful stimulus at the spinal cord level, resulting in pain reduction [35]. The biomechanical and neurophysiological effect of manual therapy disregarding whether it is from mobilization or manipulation have also been reported in the literature. Forces applied by manual therapy to targeted vertebral segments seems to lead to biomechanical changes in the joint and its surrounding structures, resulting in improvement of pain [16]. In addition, manual therapy potentially initiates a cascade of neurophysiological responses through central nervous system (CNS) to inhibit the pain perception [16,72,73]. These neurophysiological responses were found to occur via different mechanisms in the CNS. For instance, manual therapy potentially activates the descending inhibitory pain systems through involvement of endogenous opioids, serotonin, and norepinephrine from the midbrain to the spinal cord level, leading to the analgesic effects [16,34,73,74]. While both mobilization and manipulation and other types of interventions reviewed in the present study showed to decrease pain, it is still unknown which are the specific mechanisms of analgesia generated by spinal mobilization. Furthermore, one potential explanation of no between group differences might be different main underlying mechanisms of effects of spinal mobilization and other interventions to achieve the outcomes. This warrants further investigations.

4.2. Function

Five of the fourteen articles examined functionality as an outcome. All of these articles used ODI as the measurement of function. Hanson et al. (2016) additionally used a patient specific scale to measure functionality in addition to ODI [57]. There was one level I study, three level II studies and one level IV study. All five of the studies found a statistically significant improvement in ODI scores after mobilization interventions. Three of the five studies explicitly noted improvement at clinically significant levels. The remaining studies did not explicitly state this, and their levels of improvement had to be estimated from graphically presented data. The studies that compared mobilization against thrust manipulation did not show statistically significant differences between groups in measures of functionality as well.

Using combined treatments, and thus, not included in the present review, Balthazard et al. (2012) have shown that either spinal mobilization or manipulation plus active exercise significantly improved function level as measured by ODI compared to the baseline [75]. Dougherty et al. (2014) have also shown that the combination of spinal mobilization and manipulation improved the function levels from baseline to 12 weeks' follow-up in older veterans with chronic LBP [76]. Therefore, it seems that spinal mobilization and combined spinal mobilization and manipulation have similar effects on function especially when measured by ODI.

Due to the results of our systematic review, we have assigned a grade of "A" to mobilization causing an improvement in functionality. It should be noted however that there was only one level I study, and the only study that investigated the long-term follow-up was the level IV study. Further research should be developed to examine the long-term efficacy of mobilization in the treatment of LBP. Additionally, it should be noted that while mobilization has been shown to be effective in the treatment of LBP, the data does not suggest that it is superior to manipulation as there were no statistically significant differences between groups which underwent mobilization and those who underwent manipulation in measures of functionality.

4.3. Range of motion (ROM)

Four of the fourteen studies measured ROM using goniometry and/or the "fingertip-to-floor method" during trunk flexion, extension, and lateral flexion [35–38]. Every study showed improvement in ROM as a result of mobilization and most of these improvements exhibited significant within-group difference. Past studies using combined manipulation and mobilization are in agreement with the results of the present study [77,78]. For instance, Aure et al. (2003) have demonstrated that the intervention program over a course of 8 weeks including the combination of spinal mobilization and manipulation (not reviewed by this study) demonstrated significant improvement in lumbar range of motion both within- and between-groups [77].

Two out of the four studies measuring ROM were relatively high quality [37,38] rating a I, and two studies [35,36] rating a II on Sackett's Levels of Evidence [55]. For this reason, an "A" grade of recommendation is given for improving trunk ROM in the sagittal and frontal planes as a result of mobilization. Notably, the one study that found no statistically significant improvement in ROM measures both within- and between-groups was also the only study with a true control group [36]. More studies with a true control or sham group should be performed to clearly elucidate the effectiveness of mobilization on trunk ROM. Additionally, all of the studies measuring ROM as an outcome only performed one mobilization session and none of the studies had any follow up measurements. Future studies should investigate if this improvement in flexibility is transient by performing long term follow up measurements.

Finally, it is interesting to note that the two studies found that neither the level (symptomatic vs. random) nor the type of mobilization (prescribed vs. random) had any statistically significant influence on improving trunk ROM despite the latter's significance in improving pain [37,38]. This would imply that improvement in ROM has a weak, if any, dependence on the specific characteristics of mobilization intervention itself. The interesting results warrant further investigations.

4.4. Other outcome measures

Eight of the fourteen studies [36,38,58–63] measured outcomes that were unique to their particular study. The broad variance of the type of measures in this proverbial "other" category makes it impossible to give a grade of recommendation as to whether they are improved as a result of a mobilization intervention, nor is it prudent to make statements regarding general trends in the types of studies quantifying these measures. Additionally, the clarity of the results for these measures displays a broad range as well. With the exception of the Goodsell et al.'s study measuring the effect of mobilization on stiffness and displacement of the vertebrae [36], every other outcome measure in every study that measured a change as a result of mobilization showed improvement. Within-group and between-group statistically significant improvements again showed a wide range of results including three studies [58,60,62] using larger number of outcomes and making multiple comparisons (as high as 64). None of the studies in this systematic review corrected for multiple comparisons which raises the issue of the increased possibility of a type I error and false positive findings of an effect provided by mobilization intervention when, in fact, none exists.

4.5. Study limitations

Despite a wide variety of spinal mobilization techniques being applied in clinical practice, the selected studies used limited types of spinal mobilization such as central posteroanterior mobilization [32,35–38,46,58–60,63]. Furthermore, mobilization types or methods such as grade, direction of the manual force, duration of mobilization, frequency and treatment duration across the studies varied widely or they were not described in detail. Thus, this systematic review cannot make inferences regarding the influence of varied mobilization techniques on the studies' outcomes. Secondly, some important contributing factors for the effects of spinal mobilization such as provider's clinical experience, training level and subject's profile were not mentioned in most of the studies and could influence the studies' results. Although our systematic review has shown scientific evidence for using spinal mobilization in clinical practice, it has also revealed the necessity of conducting further studies to address these limitations.

5. Conclusion

Spinal mobilization is effective for patients with LBP, primarily improving pain, function and ROM. Numeric rating scale, VAS, ODI were common measures to assess pain and function respectively across the reviewed studies, which allowed us to sufficiently compare the outcomes. The quality of these studies was moderate to high, and we assigned an “A” recommendation for the effect of spinal mobilization on the above outcome measures. These results, however, should be viewed with caution since many of these studies showed only within-group differences and the outcome measures improved for both mobilization group and other varied interventions (including manipulation) of the comparison groups. Therefore, spinal mobilization for LBP is as good as other types of treatments such as Tai Chi, spinal manipulation and standard exercises. Finally, only one out of fourteen studies performed a follow-up analysis, which does not allow a conclusion as to whether spine mobilizations have a lasting effect on LBP. This systematic review has also revealed a lack of current evidence regarding effects of specific types and/or methods of spinal mobilization techniques such as grades and duration of mobilization. In addition, the psychological effects of spinal mobilization were not tested and discussed in the majority of the reviewed studies, which could explain in part the lack of specific effects of spinal mobilization for improving pain, function and ROM. Future studies should fill in these gaps by comparing the effects of spinal mobilization by itself to placebo and other types of intervention as well as test its long-term effects in patients with LBP for a better understanding of one of the most common manual therapy techniques in clinical practice.

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