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The clinical utility of cervical range of motion in diagnosis, prognosis, and evaluating the effects of manipulation: a systematic review

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*Abstract

ABSTRACT

Background

Clinicians commonly assess cervical range of motion (ROM), but it has rarely been critically evaluated for its ability to contribute to patient diagnosis or prognosis, or whether it is affected by mobilisation/manipulation.

Objectives

This review summarises the methods used to measure cervical ROM in research involving patients with cervical spine disorders, reviews the evidence for using cervical ROM in patient diagnosis, prognosis, and evaluation of the effects of mobilisation/manipulation on cervical ROM.

Data sources and study selection

A systematic search of MEDLINE, EMBASE, CINAHL, AMED and ICL databases was conducted, addressing one of four constructs related to cervical ROM: measurement, diagnosis, prognosis, and the effects of mobilisation/manipulation on cervical ROM.

Study appraisal and synthesis

Two independent raters appraised methodological quality using the QUADAS-2 tool for diagnostic studies, the QUIPS tool for prognostic studies and the PEDro scale for interventional studies. Heterogeneity of studies prevented meta-analysis.

Results

Thirty-six studies met the criteria and findings showed there is limited evidence for the diagnostic value of cervical ROM in cervicogenic headache, cervical radiculopathy and cervical spine injury. There is conflicting evidence for the prognostic value of cervical ROM, though restricted ROM appears

associated with negative outcomes while greater ROM is associated with positive outcomes. There is conflicting evidence as to whether cervical ROM increases or decreases following mobilisation/manipulation.

Conclusion and Implications of Key Findings

Cervical ROM has value as one component of assessment, but clinicians should be cautious about making clinical judgments primarily on the basis of cervical ROM.

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Key Words

Cervical vertebrae, measurement, physical therapy techniques, manipulation (spinal)

Introduction

Musculoskeletal disorders of the cervical spine are common, with the overall prevalence of neck pain reported as high as 87% in the general population [1]. Consequently, cervical spine disorders are associated with significant economic, societal and personal burden [2]. The costs associated with neck pain range from €30 million annually in Sweden (all spinal conditions [3]), to US $8 billion annually in the US [4]. Therefore, there is an immediate need to develop more effective assessment and treatment regimes to address the symptoms and sequelae associated with cervical spine disorders.

As pathophysiology of the majority of neck pain conditions is not clear [5, 6], treatment usually focuses on addressing physical impairments. One of the most commonly assessed physical impairments in clinical practice is range of motion (ROM) of the cervical spine. Cervical ROM can be assessed with a variety of reliable tools [7], and clinicians generally view it as important and necessary to measure in patients with mechanical neck disorders [8, 9]. However, the clinical utility of ROM is unclear; that is, its predictive validity in the clinical setting for diagnosis, prognosis and treatment outcomes. Further, a variety of methods have been reported for measuring cervical ROM, with little consistency in methods used in published clinical studies. Therefore, the clinical value of different methods of cervical ROM measurement for clinical decision-making remains uncertain. To the best of our knowledge, no previous study has systematically or critically evaluated the clinical utility of cervical ROM in terms of its ability to contribute to accurate patient diagnosis or prognosis, or whether it is affected by various interventions applied by physiotherapists.

One recommended intervention used by physiotherapists to reduce neck pain and associated disability is cervical and thoracic mobilisation and manipulation [6]. The term “mobilisation/manipulation” refers to a “manual therapy technique comprising a continuum of skilled passive movements to the joints and/or related soft tissues that are applied at varying speeds and amplitudes, including a small-amplitude/high-velocity therapeutic movement” [10], and a more detailed description regarding manipulative techniques can be found elsewhere [11]. Though it is commonly believed that cervical ROM should improve after applying a mobilisation or manipulation, it is unknown whether this belief can be substantiated by evidence.

This systematic review aims to critically appraise and summarise the literature related to the use of ROM as an impairment measure in patients with disorders related to the cervical spine. Specifically, this review will (1) summarise the methods used to measure cervical ROM in research studies involving patients with cervical spine disorders, (2) determine the evidence for using cervical ROM in patient diagnosis and prognosis, and (3) determine the potential effects of manipulation (thrust and non-thrust) on cervical ROM. The results of this review will provide evidence to guide clinicians in their evaluation of cervical ROM and its value within their clinical assessment.

Methods

A systematic review of the literature was conducted using AMED, CINAHL, EMBASE, ICL and MEDLINE databases from inception to September 2012. A sensitive search strategy (Appendix 1) was developed incorporating the key study themes of ROM, cervical spine, diagnosis, prognosis and spinal manipulation. The specific search strings used in this study were informed by terms and phrases used in recent reviews on related research topics [12-14].

Identified studies were downloaded into reference management software and duplicate records were removed. Consistent with the objectives of this review, animal, cadaveric, and simulation studies were excluded. Conference proceedings, commentaries, editorials, letters, reviews, n=1 designs, and articles published in languages other than English were also excluded.

To be included, studies needed to address at least one of the following four research questions: (1) how is cervical ROM measured as an outcome of mobilisation/manipulation?, (2) how is cervical ROM used in diagnosis?, (3) how is cervical ROM used in prognosis?, and (4) what is the effect of mobilisation/manipulation on cervical ROM?

The operational definition of ROM employed in this review was the arc through which movement occurs at a joint or a series of joints [10]. For a study to be considered for the research question concerning diagnosis, it needed to have investigated the utility of cervical ROM to distinguish between patients with and without a clinically meaningful diagnosis (e.g., mechanical neck pain, whiplash, headache, cervical radiculopathy). Diagnostic studies that simply examined differences in cervical ROM between symptomatic (ie with a neck disorder) and asymptomatic populations were excluded as this study design is known to overestimate diagnostic accuracy [15, 16]. To be considered for the research question concerning prognosis, studies must have investigated the utility of baseline cervical ROM measurements to predict future patient outcomes (e.g., function, disability, patient-perceived improvement). Prognostic and single cohort prescriptive clinical prediction rule studies where cervical ROM had been investigated as a candidate variable were considered in this category. Finally, clinical trials were considered for the research question concerning mobilisation/manipulation if they satisfied the operational definition of mobilisation/manipulation used in this review which was a manual therapy technique comprising a continuum of skilled passive movements to the joints and/or related soft tissues that are applied at varying speeds and amplitudes, including a small-amplitude and high-velocity therapeutic movement [10]. Consistent with this definition, both thrust manipulation and non-thrust spinal mobilisation techniques were considered for inclusion. To clarify, in this manuscript we use the term “manipulation” to refer specifically to techniques involving a high-velocity low-amplitude thrust, whereas mobilisation refers to techniques performed as lower velocity, passive movements of a joint. Studies employing multi-modal interventions were included provided the independent effect of manipulation was able to be delineated (i.e., groups were similar in every other aspect except for the manipulation). Studies limited to the investigation of the effect of traction, soft tissue massage, neural mobilisation, and peripheral joint mobilisation/manipulation techniques were excluded.

Two independent reviewers screened the titles and abstracts of the identified studies to determine eligibility. Studies judged by either reviewer to be eligible in the first stage of screening were progressed to the second stage in which eligibility was evaluated using the full-text of each study. Two independent reviewers conducted the second round of screening with concordance determining study inclusion and exclusion. Disagreement between the reviewers was resolved by consensus or if needed by a third reviewer. Citation tracking and hand-searching of recent relevant journals were used as supplementary search strategies. The absolute and chance-corrected degree of agreement (κ) between the two reviewers was calculated for each stage of study selection.

Additional eligibility criteria were developed and applied following the initial study selection process in recognition of the heterogeneity and quality variance of the included sample. Studies were excluded post-hoc if the assessment of outcomes was not blinded [17-28], the study samples were asymptomatic (prognostic studies excluded) [29-33], manipulation was applied by the patient [34], or if ROM measures did not include measurements cephalad of C7 [35], as well as survey studies of therapist beliefs and practices [36, 37]. Corresponding authors were contacted as required for clarification to determine a study's eligibility for inclusion, and when no response was received, those studies were excluded [21, 28].

The methodological quality of included studies was appraised by two independent raters using the QUADAS-2 (Quality Assessment Tool for Diagnostic Accuracy Studies) tool [15] for diagnostic studies, the QUIPS (Quality in Prognosis Studies) tool [38] for prognostic studies and the PEDro

(Physiotherapy Evidence Database) scale [39] for interventional studies. Disagreement on the assessment of quality appraisal items was resolved by consensus or if needed by a third rater. A sum methodology score was calculated for each interventional study evaluated with the PEDro scale [40].

No attempt was made to statistically pool the results of individual studies as a consequence of the heterogeneity of the included samples. A synthesis of the key findings is reported with consideration of the risk of bias of individual studies as identified by the quality appraisal.

Results

The database search strategy identified 2124 unique studies, with 104 of these progressing to the second stage of study selection. An additional eight studies were identified via citation tracking and hand-searching of relevant journals. One hundred and twelve studies were therefore evaluated in the second stage of screening by full-text, with 57 determined to be eligible for inclusion. Reasons for study exclusion are detailed in Figure 1. Post-hoc eligibility screening resulted in the further exclusion of 21 studies, the most common reason being the non-blinding of outcome assessment. Consequently, 36 studies comprise the final included sample with seven studies relating to the use of cervical ROM in determining a diagnosis, 14 studies concerning the use of cervical ROM in establishing a prognosis and 15 studies investigating the effect of manipulation on cervical ROM.

The absolute degree of rater agreement for the first and second stages of study selection was 97% and 89% respectively. The chance-corrected degree of agreement was 'moderate' for screening by title and abstract (κ=0.54, 95%CI 0.44-0.64), and 'good' for screening by full-text (κ=0.78, 95%CI 0.67-0.9) [41]. All but two episodes of rater disagreement were resolved by consensus, with the third reviewer later excluding both of these studies.

The methodological quality varied between studies, but was generally fair to good. For diagnostic studies assessed with QUADAS-2, the main risks of bias occurred in patient selection (four of seven studies with high risk of bias) and in the reference standard (four of seven studies with high risk of bias). For prognostic studies evaluated with QUIPS, there was generally low risk of bias for most items. The main risks of bias related to a study's ability to account for potential confounders of the prognostic factor of interest (four of 14 studies with potential bias). Interventional studies evaluated with the PEDro tool received overall scores ranging from six to ten (out of a possible 11). Nine of the 15 interventional studies scored eight or above, indicating moderately high methodological quality [40]. The methodological quality scores for each of the included studies are provided in Appendix 2.

Measurement

The most common instruments used to measure ROM in the included studies are the Cervical Range of Motion (CROM) device (Performance Attainment Associates, Minnesota, IL, USA), the universal goniometer and the inclinometer

(Table 1). All studies reported cervical ROM in two dimensions in the cardinal planes of movement, except for two studies using an orientation sensor [42, 43].

Diagnosis

Four studies which included a total of 356 subjects examined the utility of cervical ROM in identifying the presence of cervicogenic headache (i.e., headache symptoms originating from the cervical spine) [44-47]. Two of these (n=238) examined the diagnostic utility of cervical ROM in the cardinal planes (flexion, extension, rotation and lateral flexion) [45, 47]. Both of these studies found that restricted active cervical extension ROM exhibited diagnostic utility for identifying cervicogenic headache if the patient also had pain with manual examination of the upper cervical spine. The remaining two studies (n=118) examined the accuracy of the flexion-rotation test, a multiplanar passive movement assessment tool for identifying patients with cervicogenic headache [44, 46]. In these two studies, a 10 degree or greater reduction in the expected normal range of motion of 44 degrees (visually estimated by the therapist during the flexion-rotation test with subsequent measurement with the CROM) was considered to be positive.

One study (n=82) examined the ability of active cervical ROM to identify patients with cervical radiculopathy [48]. Results demonstrated that cervical flexion less than 55 degrees and cervical rotation toward the side of the symptoms less than 60 degrees were useful in identifying patients with cervical radiculopathy (positive likelihood ratio (LR) 1.5, and 1.8 respectively [49]).

Two studies with large cohorts (n=8924 [50], n=8283 [49]) identified that cervical rotation ROM restriction was able to identify patients with clinically important cervical spine injuries, which were defined as any fracture, dislocation, or ligamentous instability demonstrated by diagnostic imaging [49, 50]. The positive LRs from these two studies were 2.1 and 2.2, while the negative LRs were 0.14 and 0.07. Further details on the studies related to the ability of cervical ROM to assist with making a diagnosis can be found in Table 2.

Prognosis

Two prospective studies were identified that included 245 asymptomatic individuals who had baseline measurements recorded and were then contacted at follow-up to ascertain if they had developed neck pain since the time of the original measurements [51, 52]. Hush et al [2009] [58] demonstrated that at a one-year follow-up, greater cervical flexion and extension ROM at baseline was associated with a reduced likelihood of experiencing neck pain. At a long term follow-up of six years, Salo et al [2012] [51] found that baseline cervical ROM was not associated with the development of neck pain.

Twelve prognostic studies that included patients with neck pain were identified. Four of these found that cervical ROM was not predictive of outcome [53-56] while five found cervical ROM to be predictive of the target outcome [57-61]. The direction and magnitude of range of motion that predicted outcome varied considerably among studies. Overall, when patients exhibited greater ranges of motion at baseline (regardless of magnitude and plane of movement) they were more likely to experience a positive outcome (e.g., self-rated symptom improvement using scales such as the Global Rating of Change or Neck Disability Index, Table 3). When patients exhibited reduced cervical ROM they were more likely to experience a worse outcome (e.g., continued significant pain, or failure to return to usual activity level, Table 3). Two other studies demonstrated that the degree of change of cervical ROM was predictive of between session improvements for the particular movement identified as impaired [42, 43]. Conversely, one study found restricted cervical extension was a prognostic factor for a better outcome [62]. However, this was an initial cohort study and cervical extension limitation was not identified as a prognostic variable in a recent clinical trial [54]. Further details of studies investigating the ability of cervical ROM to assist with making a prognosis can be found in Table 3.

Manipulation Effects

We identified 15 studies investigating the effect of mobilisation/manipulation (cervical, nine studies; thoracic, five studies; both, one study) on cervical ROM [63-77]. Of these studies, 13 examined the effects of mobilisation/manipulation on range of motion in patients with mechanical neck pain [63-69, 71-74, 76, 77]. Of the other two, one examined the effects of mobilisation in a group of patients with cervicogenic dizziness [70] and the other manipulation on patients with cervicogenic headache [75]. All of these studies demonstrated a positive improvement (nine studies) in cervical ROM or no difference between groups (six studies). Of the six studies demonstrating no difference between groups, one study was performed on patients with cervicogenic dizziness [70] and one was performed on patients with cervicogenic headache [75].

Of the nine studies where mobilisation/manipulation was directed at the cervical spine only, [64, 66, 70, 72-77] three demonstrated a statistically significant difference in cervical ROM between groups in favour of mobilisation [71] or manipulation [66, 72, 73]. One of these studies only exhibited a statistically significant difference between groups for flexion in favor of a ‘preferred’ mobilisation technique (unilateral posteroanterior [PA] pressure on the side of symptoms, i.e., ipsilateral) versus a randomly selected technique (central, ipsi- or contralateral unilateral PA mobilisation) [66]. Five studies examined the effects of thoracic spine manipulation on cervical ROM, all of which demonstrated statistically significant group differences with greater improvements in cervical ROM for the manipulation groups [65, 67-69, 71]. The final study used both cervical and thoracic manipulation versus non-thrust mobilisation. In this study, the thrust group demonstrated a significantly greater improvement in cervical ROM [63]. Further details of studies examining the effects of mobilisation/manipulation on cervical ROM can be found in Table 4.

Discussion

This systematic review examines the use of cervical ROM measurement in diagnosis, prognosis and the evaluation of the effects of mobilisation/manipulation in patients with mechanical neck pain. Most studies used commonly available instruments to measure cervical ROM, including goniometers, inclinometers and the CROM instrument. Cervical ROM was reported as useful in diagnosing cervicogenic headache in four studies, cervical radiculopathy in one study and clinically important cervical spine injuries in two studies. Only one of two prospective studies found cervical ROM predictive of the incidence of neck pain in asymptomatic individuals. Five prognostic studies in patients with neck pain found that cervical ROM was predictive of patient outcome (e.g., symptom improvement), with another two reporting it was predictive of ROM changes following treatment. Nine studies found that cervical ROM improves following mobilisation/manipulation, with another six reporting no difference between groups. The results from these studies suggest there is limited evidence for the diagnostic and predictive value of cervical ROM for some neck pain conditions. There is general support for a positive effect on cervical ROM from mobilisation/manipulation, though the evidence is limited. There are more studies supporting thoracic rather than cervical thrust manipulation, and thrust rather than non-thrust techniques for improving cervical ROM. Further research is needed to determine the value of cervical ROM in diagnosis and prognosis, and in evaluating treatment effects. Cervical ROM may be informative to clinical decision making and is moderately valuable when considered as one component within a suite of assessment items.

Measurement

The majority of the instruments used to quantify ROM in studies assessing the effects of manipulation used instruments commonly found in clinical practice, such as goniometers, inclinometers or the CROM device. These methods have demonstrated adequate reliability [78, 79] and are not overly expensive, but cannot evaluate coupled or three-dimensional movement. Assessing coupled and three-dimensional movement may provide greater insight into the potential mechanisms behind the changes that occur following manipulation in the cervical spine.

Diagnosis

In general, the findings from this current systematic review suggest that cervical ROM is potentially a valuable tool for establishing a diagnosis in individuals with cervicogenic headache, cervical radiculopathy and clinically important cervical spine injuries. Restricted cervical extension appears to be useful when classifying individuals with cervicogenic headache if the patient also exhibits pain with manual examination of the upper cervical spine [45, 47]. It should be recognized that when restricted ROM was identified along with the other physical assessment items, the diagnostic accuracy was reasonably high [80]. Additionally, positive findings for the cervical flexion-rotation test have been shown to be useful in differentiating between patients who have cervicogenic headaches or headaches-of other origin [44, 46]. Considering that both Hall et al. [44] and Ogince et al. [44, 46] found the flexion-rotation test helpful in identifying patients with cervicogenic headache, this may be a useful tool in clinical practice to identify individuals who would be appropriate candidates for physical therapy treatment, as it has been shown to be effective in this population [81]. However, it should be recognized that although a positive flexion-rotation test resulted in a moderate to large increase in probability that a patient had a cervicogenic headache in the study by Ogince et al. [44, 46], Hall et al. [44] found that it only resulted in a small increase in probability [80] suggesting future research evaluating this test is needed.

One study was identified that found that reduced cervical flexion and reduced rotation toward a patient's symptomatic side was indicative of cervical radiculopathy [48]. However, these items exhibited small LRs with the lower bound estimate of the 95% CIs approaching one (Table 2). This suggests that restrictions in these movements only alter the probability of the patient having cervical radiculopathy to a small and relatively unimportant degree [80].

Stiell and colleagues developed [50] and validated [49] the Canadian Cervical Spine Rule that contains a number of items from the patient history, as well as observed cervical ROM, and exhibits excellent utility for ruling out a clinically important cervical spine injury if a patient tests negative on the rules. Restricted cervical rotation less than 45 degrees was included in the combination of variables (high risk factors mandating radiographical examination and low risk factors allowing safe assessment of cervical ROM) that comprised the rule. In fact, when a patient could rotate their cervical spine greater than 45 degrees to both the left and right there was a moderate (derivation study [50]) to large (validation study [49]) increase in probability that the patient did not have a cervical fracture, dislocation or ligamentous instability.

Prognosis

It is important to identify predictive factors that could potentially be useful in the clinical decision making process when attempting to prevent neck pain from becoming chronic. If these individuals could be identified, appropriate interventions may be able to prevent chronicity of symptoms. However, it cannot be determined from this systematic review if cervical ROM is beneficial in identifying asymptomatic individuals who are likely to develop neck pain in the future. The two studies that longitudinally followed asymptomatic individuals reported conflicting results. Hush et al. [52] noted that greater ROM was associated with a reduced likelihood of developing neck pain, while Salo et al. [51] found cervical ROM was not prognostic for the future development of neck pain. One of the reasons for these inconsistent findings may be differences in the populations sampled in the two studies. Hush et al. [52] used a sample of office workers, while Salo et al. [51] used a combination of blue and white collar workers and students. Perhaps the office workers in the Hush study were more likely to develop neck pain because of prolonged desk sitting and associated neck flexion postures which have been identified as predictors of neck pain [82], as compared to the mixed sample in the Salo study [51]. The operational definition of neck pain also differed between the two studies, with Salo et al. [51] documenting cases of neck pain lasting greater than seven days, while Hush et al. [52] included patients with symptoms lasting greater than 24 hours. This may also explain the differences in the incidence of neck pain between the Salo et al. [51] and Hush et al. [52] studies of 19% and 49%, respectively. Therefore, more studies are necessary to determine the prognostic value of cervical ROM for determining the likelihood of developing a future episode of neck pain.

Although four studies found cervical ROM was not predictive of patient outcomes [53-56], there were five studies that suggest cervical ROM may have some predictive value. Five prospective cohort studies [57-61] reported that lower ranges of cervical ROM were predictive of a worse prognosis (in terms of patient-reported pain, function or disability), while greater ranges of motion were predictive of a better prognosis. However, the plane of movement, amount of restriction and outcome of interest differs between these studies, making it difficult to make definitive conclusions.

Manipulation

This systematic review identified 15 studies examining the effects of spinal mobilisation/manipulation on cervical ROM. Overall, mobilisation/manipulation may be beneficial in increasing cervical ROM in patients with mechanical neck pain (nine out of 13 studies). Unfortunately, the heterogeneity of the identified articles prevents meta-analysis. It may be argued that in most of the reported studies, the magnitude of the effects of increases in cervical ROM was small when examining between group differences. However, in many circumstances these differences did surpass the minimal detectable change (MDC) scores as identified by Fletcher et al. [83]. It should also be noted that in the majority of the studies the within-group changes in cervical ROM for patients receiving mobilisation/manipulation did exceed these reported MDC values where the comparison group did not. Furthermore, all studies using a population of patients with neck pain either exhibited a significant improvement over the comparison group or no difference between groups. No studies found cervical ROM to be worse in the mobilisation/manipulation group. However, spinal mobilisation/manipulation does not appear to be effective for increasing cervical ROM in patients with cervicogenic dizziness [70] or cervicogenic headache [75].

Each of the four studies examining the effects of mobilisation/manipulation on cervical ROM in patients with mechanical neck pain that did not show a difference between groups provided only one treatment session using either cervical thrust manipulation or non-thrust mobilisation. In every study identified where the manipulative intervention included multiple treatment sessions, there was a significant between group difference in cervical ROM. Therefore, it seems reasonable to conclude that multiple treatment sessions may be needed to achieve significant between group differences. A recent study by Fernandez-de-las-Penas et al. [69] demonstrated that repeated applications of thoracic spine thrust manipulation continued to consistently improve cervical spine mobility over five sessions of manipulation, with no plateau effect. Future studies should continue to investigate the dose-response relationship of mobilisation and manipulation on cervical ROM.

Only three of the seven studies examining the effects of cervical mobilisation/manipulation in patients with neck pain demonstrated improvements in cervical ROM over the comparison group [64, 66, 72-74, 76, 77]. However, all the studies that examined the effect of thoracic manipulation revealed improvements in cervical ROM for the manipulation group [65, 67-69, 71]. A number of factors could have resulted in the differences between studies targeting the manipulation to the cervical versus thoracic spine, as it has recently been reported that manipulation may have both a biomechanical and neurophysiologic response [84, 85]. However, the exact physiological mechanism(s) as to how manual therapy works remains to be elucidated. No studies in this review compared the differences between cervical and thoracic manipulation and its effects on cervical ROM, so no inferences can directly be made as to which technique is superior for this particular outcome. Yet it has recently been demonstrated that patients with neck pain receiving cervical manipulation experience greater improvements in pain and function in the short and long-term compared to patients receiving thoracic manipulation [86], possibly suggesting that targeting the area of symptoms with manual therapy might result in improved patient outcomes. This is supported by an additional study investigating biomechanical mechanisms related to manipulation at specific spinal levels [87]. It should be noted however that the findings of the present review relate specifically to improvements in measured cervical ROM only and not other patient or pain-related outcomes.

The results of two studies included in this review suggest that patients receiving thrust manipulation may experience greater improvements in cervical ROM than those receiving a non-thrust mobilisation [63, 72]. Other literature that has examined the effects of thrust manipulation versus non-thrust mobilisation has shown mixed results in terms of improvements in pain and function [88-91]. It also appears that in patients with neck pain, allowing the therapist to direct manual therapy at their preferred segment may result in no better improvements in cervical ROM (with the exception of cervical flexion) compared to a randomly selected segment [64]. These findings are similar to those demonstrated in patients with low back pain. Chiradejnant et al. [92] reported that a manual technique directed at a therapist-selected segment resulted in no greater improvement in lumbar ROM as compared to a group that received manual therapy directed at a randomly selected segment [92].

Limitations

There are a number of limitations to this review that should be considered. Only a small number of studies examining the diagnostic utility of cervical ROM were identified. It is possible that future prospective designs could find different magnitudes of diagnostic utility for cervical ROM in physiotherapy practice than those identified here. The majority of the included prognostic studies were single cohort designs so it is not known if cervical ROM will continue to be identified as a prognostic variable in future studies. The present review only included studies where the effects of mobilisation/manipulation techniques could be ascertained. It is quite possible that mobilisation/manipulation combined with other interventions, such as exercise, may result in greater improvements in cervical ROM than these manual techniques alone. The sample size in some of the studies is fairly small which may limit the ability to generalize to the entire population with neck pain. The study selection was limited to articles published in the English language, which may have resulted in the omission of relevant articles.

Conclusions

The most often used measurement tools for cervical ROM in the studies reviewed were the goniometer, inclinometer and CROM. There is limited evidence that cervical ROM may have utility as one component of assessment used to diagnose cervicogenic headache, cervical radiculopathy and clinically important cervical spine injury. There is conflicting evidence as to whether cervical ROM predicts future neck pain onset and some evidence it has some prognostic value in patients with mechanical neck pain. Limited evidence suggests restricted cervical ROM is associated with negative outcomes and greater cervical ROM is associated with positive outcomes. There is conflicting evidence regarding whether mobilisation/manipulation improves cervical ROM.

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Conflict of Interest

The authors have no conflicts of interest in for this review.

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Table 1. Methods of cervical range of motion measurement used in studies assessing cervical spine diagnosis, prognosis or outcomes of manipulation.

Measurement Method	Publication
Cervical Range of Motion Instrument (CROM)[a]	Castien et al 2012 Dunning et al 2012 Hall et al 2010 Hush et al 2009 Kanlayanaphotporn et al 2009 Kanlayanaphotporn et al 2010 Kasch et al 2001 Kasch et al 2008 Krauss et al 2008 Ogince et al 2007 Reid et al 2008 Yurkiw and Mior 1996
Universal goniometer	Cassidy et al 1992 Cleland et al 2007 (horizontal plane) Fernandez-de-las-Penas et al 2009 Gonzalez-Iglesias et al 2009a Gonzalez-Iglesias et al 2009b Martinez-Segura et al 2006 Mintken et al 2010 (horizontal plane) Nilsson et al 1996 Puentedura et al 2012 Wainner et al 2003 (horizontal plane) Whittingham and Nilsson 2001
Inclinometer (various types)	Cleland et al 2007 (sagittal and frontal planes) Cleland et al 2010 Koes et al 1992 Mintken et al 2010 (sagittal and frontal planes) Wainner et al 2003 (sagittal and frontal planes) Whittingham and Nilsson 2001 (frontal plane)
Cervical Measurement System (CMS)[b]	Borentstein et al 2010 Salo et al 2012
Fastrak System[c]	Amiri et al 2007 Jull et al 2007
Multi-Cervical Unit[TMd]	Keating et al 2005 Lau et al 2011
3-axis orientation sensor[e]	Tuttle 2005 Tuttle et al 2006
Visual estimation	Stiell et al 2001 Stiell et al 2003
Compass	Whittingham and Nilsson 2001 (horizontal plane)
Not specified	Raney et al 2009

[a]Performance Attainment Associates, Minnesota, IL, USA
[b]Kuntoväline Ltd, Helsinki, Finland
[c]Polhemus, Colchester, VT, USA
[d]BTE, Hanover, MD, USA
[e]MicroStrain Inc, Williston, VT, USA

Table 2: Studies investigating the utility of cervical range of motion in diagnosis (n=7).

Publication	Diagnosis	Criterion standard	Measurement of cervical ROM	Sample	Findings
Hall et al [2010]	CGH	Probable CGH as defined by Antonaci et al [2001] [93]	*Visual estimation:* ≥ 10° limitation of expected rotation ROM on flexion-rotation test	n=60 patients (20 CGH, 20 migraine without aura, 20 multiple headache types), mean age 33 years, 63% female	Positive test had accuracy of +LR = 2.3 (95%CI 1.3-4.1) and -LR = 0.43 (95%CI 0.21-0.85)
Amiri et al [2007]	CGH	Symptomatic criteria of the CHISG diagnostic criteria [Sjaastad, et al 1998] [94]	Not specified	n=108 patients with 2 or more concurrent intermittent headache types, mean age 37 years, 73% female, 37% prevalence of target diagnosis	Restricted extension (mean 29.6°) identified as one discriminating variable of CG vs non-CGH; headache classification from physical assessment items had +LR = 10.5 (95%CI 4.7-27.1), -LR = 0.24 (95%CI 0.16-0.39)
Jull et al [2007]	CGH	Symptomatic criteria of the CHISG diagnostic criteria [Sjaastad, et al 1998] [94]	*Fastrak*[a]*:* 3 planes	n=73 patients with single classifiable intermittent headache of >1 year duration, mean age 40 years, 63% female, 25% prevalence of target diagnosis; n= 57 asymptomatic controls, mean age 38 years, 67% female	Restricted extension identified as one discriminating variable of CG vs non-CGH and controls; headache classification from physical assessment items had 100% sensitivity and 94% specificity
Ogince et al [2007]	CGH	Symptomatic criteria of the CHISG diagnostic criteria [Sjaastad, et al., 1998] [94] and symptomatic C1/2 dysfunction [Maitland et al 2001] [95]	*Visual estimation:* ≥ 10° limitation of expected rotation ROM on flexion-rotation test	n=58 patients (23 CGH, 12 migraine with aura, 23 asymptomatic controls), mean age 42 years, 66% female	Positive test had +LR = 10.7 (95%CI 4.1-24.4) & -LR = 0.1 (95%CI 0.02-0.29); calculated from data reported for therapist 1
Stiell et al [2003]	Acute cervical spine injury	Cervical fracture, dislocation or ligamentous instability demonstrated by imaging	*Visual estimation:* restricted active cervical rotation (< 45° in either direction) as item in Canadian C-Spine Rule	n=8283, alert and stable adults with acute head/neck trauma presenting to ER, mean age 38 years, 48% female, 2% prevalence of target diagnosis	Restricted rotation had +LR = 2.1 (95%CI 2-2.2) and -LR = 0.14 (95%CI 0.08-0.23); Canadian C-Spine Rule had +LR = 1.8 (95%CI 1.7-1.8) and -LR = 0.01 (95%CI 0.001-0.09).
Wainner et al [2003]	Cervical radiculopathy	Needle electromyography and nerve conduction study	*Goniometer:* 3 planes	n=82 patients with suspected cervical radiculopathy or carpal tunnel syndrome, mean age 45 years, 50% female, 23% prevalence of target diagnosis	Flexion < 55° had +LR = 1.5 (95%CI 1.2-2) & -LR = 0.27 (95%CI 0.07-1); rotation to the symptomatic side < 60° had +LR = 1.8 (95%CI 1.3-2.4) & -LR = 0.23

					(95%CI 0.06-0.85)
Stiell et al [2001]	Acute cervical spine injury	Cervical fracture, dislocation or ligamentous instability demonstrated by imaging	*Visual estimation:* restricted active cervical rotation (< 45° in either direction) as item in Canadian C-Spine Rule	n=8924, alert and stable adults with acute head/neck trauma presenting to ER, mean age 37 years, 48% female, 1.7% prevalence of target diagnosis	Restricted rotation had +LR = 2.2 (95%CI 2.1-2.3) and -LR = 0.07 (95%CI 0.03-0.16). Derived Canadian C-Spine Rule had +LR = 1.7 (95%CI 1.7-1.7) & -LR = 0.0 (95%CI 0.0-0.07).

Abbreviations: ROM, range of motion; CGH, cervicogenic headache; +LR, positive likelihood ratio; -LR, negative likelihood ratio; CHISG, Cervicogenic Headache International Study Group (CHISG); ER, emergency room.

[a]Polhemus, Colchester, VT, USA

Table 3. Studies investigating the utility of cervical range of motion in prognosis (n=14).

Publication	Target outcome(s)	Measurement of cervical ROM	Intervention(s)	Sample	Findings
Castien et al [2012]	≥ 50% reduction in headache days and self-rated ≥ 'much improved' at 8 and 26 weeks	*CROM*[a]*:* sum of all directions	Thrust and non-thrust manipulation, exercise and postural education (maximum of 9 sessions)	n=145, chronic tension-type headache patients receiving manual therapy, 77% and 73% prevalence of target outcome at 8 and 26 weeks respectively	Greater baseline ROM positively associated with target outcome at 8 weeks (OR per ° = 1.01, 95%CI 1-1.02) and 26 weeks (OR per ° = 1.01, 95%CI 1-1.01)
Puentedura et al [2012]	≥ 'quite a bit better' on GROC by 3rd visit	*Goniometer:* 3 planes	Cervical thrust manipulation, gentle active ROM exercises and education (3 sessions)	n=82, patients with mechanical neck pain, mean age 38 years, 59% female, 39% prevalence of target outcome	Side-to-side difference in rotation ≥ 10° independently predictive of target outcome (+LR 6.8, 98%CI 3.1-14.6)
Salo et al [2012]	> 7 days of neck pain over 1 year reported 6 years post-baseline	*CMS*[b]*:* passive in 3 planes	None	n=192 (87% follow-up rate), asymptomatic volunteers, 100% female, 19% prevalence of target outcome	Baseline ROM (any plane) not associated with target outcome (AUC sagittal = 0.54 (95%CI 0.44-0.65); horizontal = 0.55 (95%CI 0.46-0.65); frontal = 0.56 (95%CI 0.45-0.76))
Borenstein et al [2010]	Sick leave of any length and sick leave ≥ 30 days at 2.5-3 years post WAD	*CMS:* 3 planes	(1) Exercise +/- MDT (2) Education	n=71, acute WAD grades 0-2, 20% prevalence of sick leave of any length and 15% prevalence of sick leave ≥ 30 days	Greater baseline ROM independently associated with reduced likelihood of target outcome
Cleland et al [2010]	Pain and NDI at 1 week, 4 weeks and 6 months	*Inclinometer:* extension < 30° as variable in 5-item CPR	(1) Thoracic thrust manipulation (1st 2 sessions only) + Exercise; (2) Exercise (5 sessions over 4 weeks)	n=140, patients with neck pain, mean age 40 years, 69% female	No significant 2-way interaction between rule status and time for pain (p = .3) or NDI (p = .7)
Mintken et al [2010]	≥ 'moderately better' on GROC by 3rd visit	*Goniometer & inclinometer:* 3 planes	Cervical non-thrust manipulation, thoracic thrust manipulation, exercise and education (3 sessions)	n=80, patients with shoulder pain, mean age 41 years, 60% female, 61% prevalence of target outcome	Baseline ROM not associated with target outcome in any direction (p>.3)
Hush et al [2009]	Development of an episode of neck pain lasting >24 hours over 1 year	*CROM:* 3 planes	None	n=53, asymptomatic office workers, mean age 42 years, 64% female, incidence of target outcome 49% / year	Greater baseline flexion-extension independently associated with reduced likelihood of target outcome (HR = 0.97, 95%CI 0.94-0.99, p=0.03); no other associations between baseline ROM variables and target outcome

Raney et al [2009]	≥ ‘a great deal better’ on GROC at 3 weeks post baseline	*Measurement not specified:* 3 planes	Intermittent cervical traction and exercises (6 sessions over 3 weeks)	n=68, patients with neck pain, mean age 48 years, 56% female, 44% prevalence of target outcome	No significant bivariate relationship between baseline ROM variables and target outcome (95% CI of corresponding +LR and -LR all cross 1)
Kasch et al [2008]	Continued significant neck pain or disability at 1 year post whiplash injury	*CROM:* 3 planes	(1) Verbal information; (2) Booklet; (3) MDT; (4) Neck collar	n= 688, acute WAD grades 1-3, 64% female	Reduced baseline ROM independently associated with increased risk of target outcome (RR=4.6, CI not reported)
Cleland et al [2007]	≥ 'quite a bit better' on GROC by 3rd visit	*Goniometer & inclinometer:* 3 planes	1. Thoracic thrust manipulation, cervical ROM exercises and patient education.	n=78, primary complaint of neck pain, mean age 42 years, 68% female, 54% prevalence of target outcome	Restricted extension ROM (< 30°) predictive of target outcome (+LR = 2.5, 95%CI 1.3-4.6)
Tuttle et al [2006]	Change in most limited direction between 1st and final session (maximum 6 sessions)	*3-axis orientation sensor[c]:* change in most limited direction between 1st and 2nd session	1. Manual therapy (maximum 6 sessions)	n=29, patients with neck pain, mean age 55 years, 72% female	Significant positive association between change in most limited direction between 1st and 2nd session and target outcome (R^2=0.57, p<0.001)
Keating et al [2005]	≥ 14/100 NDI improvement at discharge (median duration 6 weeks)	*Multi-cervical Unit[d]:* 3 planes	1. Neck strengthening exercises (median duration 6 weeks)	n=122, patients with chronic neck pain, mean age 41 years, 65% female, 56% prevalence of target outcome	No baseline ROM variable was predictive of the target outcome
Tuttle [2005]	Between-session improvement of most limited direction by ≥ 5°	*3-axis orientation sensor[c]: w*ithin-session improvement in most limited direction by ≥ 5°	1. Manual therapy (maximum 6 sessions)	n=29, patients with neck pain, mean age 55 years, 72% female	Within-session improvement (≥ 5°) in most limited direction predictive of target outcome for flexion-extension (OR = 8, 95%CI 2.4-26.8) and rotation (OR = 21.3, 95%CI 4.3-96.1), but not lateral flexion (OR = 2.5, 95%CI 0.6-10.1)
Kasch et al [2001]	Failure to return to usual level of activity or work 1 year post WAD	*CROM:* 3 planes	None	n=141, patients with acute WAD, mean age 34 years, 52% female, 8% prevalence of target outcome	Restricted baseline total ROM ≥ 2 SD below mean of asymptomatic sample predictive of target outcome (73% sensitivity, 91% specificity)

Abbreviations: ROM, range of motion; OR, odds ratio; GROC, Global Rating of Change scale; +LR, positive likelihood ratio; AUC, area under the curve (denotes percentage of randomly drawn pairs of subjects correctly classified by their status on the predictor variable); WAD, whiplash associated disorder; MDT, McKenzie’s Mechanical Diagnosis and Therapy; NDI, Neck Disability Index; CPR, clinical prediction rule; HR, hazard ratio; -LR, negative likelihood ratio; RR, relative risk.
[a]Cervical Range of Motion Instrument, Performance Attainment Associates, Minnesota, IL, USA
[b]Cervical Measurement System, Kuntoväline Ltd, Helsinki, Finland
[c]MicroStrain Inc, Williston, VT, USA
[d]BTE, Hanover, MD, USA

Table 4. Studies investigating the effects of thrust manipulation and non-thrust mobilisation on cervical ROM (n=15).

Publication	Study design	Measurement of cervical ROM	Interventions	Sample	Findings
Dunning et al [2012]	RCT	*CROM*[a]*:* Rotation in end range flexion at baseline and 48 hours post-intervention	(1) Upper cervical/thoracic thrust manipulation; (2) upper cervical/thoracic non-thrust mobilisation (1 session)	n=107, mechanical neck pain, any duration	Significant between group difference (favoring thrust manipulation)
Lau et al [2011]	RCT	*Multi-Cervical Unit*[b]*:* 3 planes at baseline, 4 weeks, 3 months and 6 months	(1) Thoracic thrust manipulation, infrared, education; (2) infrared, education (8 sessions over 4 weeks)	n=120, chronic neck pain	Significant between group difference (favoring thrust manipulation) in flexion, RLF, LLF and RRot at each time point
Kanlayanaphotporn et al [2010]	RCT	*CROM:* 3 planes at baseline and 5 minutes post intervention	(1) Cervical central non-thrust mobilisation; (2) cervical random (central, left or right unilateral) non-thrust mobilisation (1 session)	n=60, central or bilateral mechanical neck pain, any duration	No significant between group difference in ROM change in any direction
Fernandez-de-las-Penas et al [2009]	RCT, secondary analysis	Goniometer: 3 planes pre-and post-treatment within 1st, 3rd and 5th sessions	(1) Thoracic thrust manipulation, TENS, heat, massage; (2) TENS, heat, massage (5 sessions)	n=45, acute mechanical neck pain	Significant between-group differences (favoring manipulation) in the magnitude of within-session ROM change in all directions
Gonzalez-Iglesias et al [2009a]	RCT	*Goniometer:* 3 planes at baseline and 5 weeks (2 weeks post discharge)	(1) Thoracic thrust manipulation, TENS, heat, massage; (2) TENS, heat, massage (5 sessions)	n=45, acute mechanical neck pain	Significantly greater improvement in all directions in manipulation group
Gonzalez-Iglesias et al [2009b]	RCT	*Goniometer:* 3 planes at baseline and 4 weeks (1 week post discharge)	(1) Thoracic thrust manipulation, TENS, heat, massage; (2) TENS, heat, massage (6 sessions)	n=45, acute mechanical neck pain	Significantly greater improvement in all directions in manipulation group
Kanlayanaphotporn et al [2009]	RCT	*CROM:* 3 planes at baseline and 5 minutes post intervention	(1) Preferred non-thrust cervical mobilisation on symptomatic side; (2) random non-thrust cervical mobilisation (1 session)	n=60, unilateral neck pain of > 1 week duration	No significant between group difference in ROM change, except for increased flexion in the 'preferred mobilisation' group
Krauss et al [2008]	RCT	*CROM:* Bilateral rotation at baseline and immediately post intervention.	(1) Thoracic thrust translatoric spinal manipulation (1 session); (2) No treatment	n=32, mechanical neck pain aggravated by cervical rotation	Significant between-group difference (favouring manipulation) in the magnitude of change in

					RRot and LRot
Reid et al [2008]	RCT	*CROM:* 3 planes at baseline, 4 and 12 weeks	(1) Cervical SNAG in provocative direction; (2) detuned laser (4-6 sessions)	n=34, chronic cervicogenic dizziness	No significant between-group difference in ROM change across time
Martinez-Segura et al [2006]	RCT	*CROM:* 3 planes at baseline and 5 minutes post-intervention	(1) Cervical thrust manipulation; (2) cervical non-thrust manipulation (sustained hold) (1 session)	n=70, mechanical neck pain of > 1 month duration	Significant between-group difference (favouring thrust manipulation) in the magnitude of ROM change in all directions
Whittingham and Nilsson [2001]	RCT, cross-over (3 week phases)	*Inclinometer:* horizontal and frontal planes at baseline, 3,6,9 and 12 weeks	(1) Cervical thrust manipulation (toggle-recoil); (2) sham manipulation with deactivated instrument; (3) no treatment (3 sessions)	n=105, chronic cervicogenic headache	Significant favorable changes in RLF, LLF, RRot and LRot following the spinal manipulation phase
Nilsson et al [1996]	RCT	*Goniometer:* 3 planes (passive) at baseline and 1 week post-intervention	(1) Cervical thrust manipulation; (2) low-level laser therapy and massage (6 sessions)	n=39, cervicogenic headache	No significant between-group difference in any ROM direction
Yurkiw and Mior [1996]	RCT	*CROM:* Lateral flexion at baseline and 5 minutes post-intervention	(1) Cervical manipulation (diversified technique); (2) Activator adjusting instrument (1 session)	n=14, subacute unilateral neck pain	No significant between group difference in ROM change
Cassidy et al [1992]	RCT	*Goniometer:* 3 planes at baseline and 5 minutes post-intervention	(1) Cervical thrust manipulation; (2) muscle energy technique (single session)	n=100, mechanical unilateral neck pain	No significant between-group difference in ROM change post-intervention
Koes et al [1992]	RCT	*Inclinometer:* most limited spinal movement at baseline, 3, 6 and 12 weeks	(1) 'Physiotherapy' – exercises, massage and electro-thermotherapeutic modalities; (2) spinal thrust manipulation and non-thrust mobilisation; (3) GP management; (4) Placebo – detuned SWD/US (maximum 3 months)	n=256, pain or self-reported limited range of motion in the back or neck for > 6 weeks	Changes in spinal mobility among the 4 groups were small and showed no consistent pattern

Abbreviations: ROM, range of motion; RCT, randomized controlled trial; RLF, right lateral flexion; LLF, left lateral flexion; RRot, right rotation; TENS, transcutaneous electrical nerve stimulation; SNAG, sustained natural apophyseal glide; LRot, left rotation; SWD/US, shortwave diathermy/ultrasound.

[a]Cervical Range of Motion Instrument, Performance Attainment Associates, Minnesota, IL, USA

[b]BTE, Hanover, MD, USA

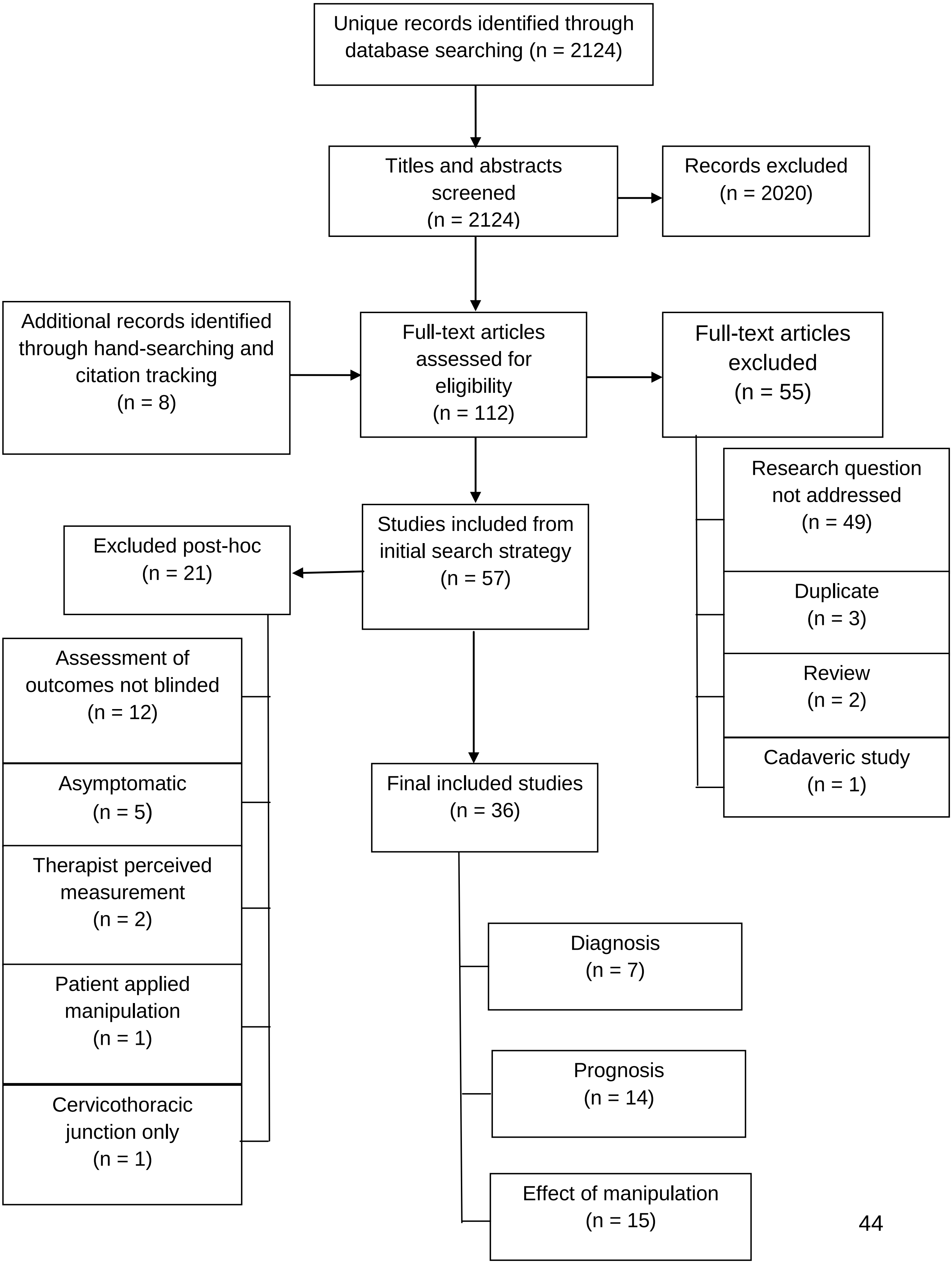
Table 5. Summary of results of review.

Construct	Conclusion
Measurement of cervical ROM as an outcome of mobilisation/manipulation in patients with neck pain	Commonly available instruments were used most often (e.g., such as goniometer, inclinometer or CROM[a]), with few studies utilizing sensors or other devices. All included studies reported measurements in two dimensions in the cardinal planes of movement, with no studies including three dimensional, coupled or functional movements.
Cervical ROM in diagnosis	There is limited evidence from seven studies that cervical ROM may have diagnostic utility as a component of assessments used to diagnose cervicogenic headache (4 studies), cervical radiculopathy (1 study) and clinically important cervical spine injuries[b] (2 studies).
Cervical ROM in prognosis	There is conflicting evidence from two prospective studies that restricted cervical ROM may or may not be associated with a future onset of neck pain in a population asymptomatic at baseline. There is limited evidence that restricted cervical ROM is associated with negative outcomes (3 studies) and greater cervical ROM is associated with positive outcomes (2 studies).
Effects of mobilisation/ manipulation on cervical ROM	There is limited evidence from nine studies that suggests mobilisation/manipulation may be beneficial in increasing cervical ROM in patients with mechanical neck pain, however, more than a single session is necessary. There were more studies reporting increased cervical ROM following thoracic thrust manipulation (5 studies) than cervical thrust manipulation (3 studies) or both (1 study). This evidence conflicted with studies reporting that cervical ROM does not change following cervical thrust manipulation (3 studies) or cervical non-thrust mobilisation (3 studies).

Abbreviation: ROM, range of motion.

[a]Cervical Range of Motion Instrument, Performance Attainment Associates, Minnesota, IL, USA
[b]Clinically important cervical spine injuries were defined as any fracture, dislocation, or ligamentous instability demonstrated by diagnostic imaging

Figure 1. Flow chart of search strategy and study selection



Appendix 1. Search strategy.

AMED via Ovid (1985 to September 2012)

MEDLINE via Ovid (1946 to September 2012)

Embase via Ovid (1974 to September 2012)

1	exp spine/ or spine.mp or spinal.mp
2	range of motion, articular/ or range of movement.mp or range of motion.mp
3	1 and 2
4	limit 3 to english language
5	limit 4 to humans
6	exp diagnosis/ or diagnos$.mp
7	5 and 6
8	remove duplicates from 7
9	exp prognosis/ or prognos$.mp or outcome.mp
10	5 and 9
11	remove duplicates from 10
12	spinal manipulation.mp or exp Manipulation, Spinal/ or exp Manipulation, Chiropractic/ or exp Chiropractic/ or chiropractic.mp or exp Manipulation, Osteopathic/ or osteopath$.mp or exp Osteopathic Medicine/ or exp Physical Therapy Modalities/ or physical therapy.mp or physiotherapy.mp or exp Musculoskeletal Manipulations/ or craniosacral therapy.mp or exp Manipulation, Orthopedic/ or muscle energy technique.mp or neuromuscular facilitation.mp or manual therapy.mp or (cervical adj3 mobili$).mp or (cervical adj3 manipul$).mp or (thoracic adj3 mobili$).mp or (thoracic adj3 manipul$).mp or (lumbar adj3 mobili$).mp or (lumbar adj3 manipul$).mp or (spin$ adj4 manipulat$).mp or manipulation.mp or "physical therapy (specialty)"/ or (manual adj2 therap$).mp or mobilisation$.mp or mobilization$.mp
13	5 and 12
14	remove duplicates from 13
15	8 or 11 or 14
16	remove duplicates from 15
17	exp cervical vertebrae/ or exp neck/ or cervical.mp or neck.mp or cervico$.mp
18	16 and 17

CINAHL via EBSCO Host

S1	mh spine+ or spine or spinal
S2	mh range of motion or range of motion or range of movement
S3	S1 and S2
S4	mh diagnosis+ or diagnos*
S5	S3 and S4
S6	mh prognosis+ or prognos* or outcome
S7	S3 and S6
S8	spinal manipulation or mh manual therapy+ or mh manipulation, chiropractic+ or mh chiropractic+ or chiropractic or mh manipulation, osteopathic+ or osteopath* or mh osteopathic medicine+ or mh physical therapy+ or physical therapy or physiotherapy or craniosacral therapy or mh manipulation, orthopedic+ or muscle energy technique or neuromuscular facilitation or manual therapy or (cervical n3 mobili*) or (cervical n3 manipul*) or (thoracic n3 mobili*) or (thoracic n3 manipul*) or (lumbar n3 mobili*) or (lumbar n3 manipul*) or (spin* n4 manipulat*) or manipulation or (manual n2 therap*) or mobilisation* or mobilization*
S9	S3 and S8
S10	S5 or S7 or S9
S11	mh cervical vertebrae+ or mh neck pain or mh neck or cervical or neck or cervico*
S12	S10 and S11

Index to the Chiropractic Literature

S1	Subject:"spine" or spine or spinal
S2	Subject:"Range of Motion, Articular/physiology" or range of motion or range of movement
S3	S1 and S2
S4	Subject:"Back Pain / diagnosis" or diagnos*
S5	S3 and S4
S6	Subject:"Prognosis" or prognos* or outcome
S7	S3 and S6
S8	Subject:"Manipulation, Cervical" or Subject:"Manipulation, Chiropractic" or Subject:"Manipulation, Joint" OR Subject:"Manipulation, Orthopedic" OR Subject:"Manipulation, Osteopathic" or Subject:"Manipulation, Spinal" OR Subject:"Musculoskeletal Manipulations" OR Subject:"Physical Therapy" OR Subject:"Physical Therapy Modalities" OR Subject:"Physical Therapy Techniques" or Subject:"Osteopathic Medicine" or manipulation* or mobilisation* or mobilization* or manual therap*
S9	S3 and S6
S10	S5 or S7 or S9
S11	Subject:"Cervical Vertebrae" or Subject:"Neck" or Subject:"Neck Injuries" or Subject:"Neck Pain" or neck or cervical or cervico*
S12	S10 and S11

Appendix 2.1

Diagnostic Studies

Study	Risk of Bias in Patient Selection	Risk of Bias in Index Test(s)	Risk of Bias in Reference Standard	Risk of Bias in Flow and Timing
Amiri et al, 2007	High	Low	High	Low
Hall et al, 2010	High	Low	High	Low
Jull et al, 2007	High	Low	High	Low
Ogince et al, 2007	High	Low	High	Low
Stiell et al, 2001	Low	Low	Low	High
Stiell et al, 2003	Low	Low	Low	High
Wainner et al, 2003	Low	High	Low	Low

Appendix 2.2

Prognostic Studies

Study	Study Participation The study sample represents the population of interest on key characteristics, sufficient to limit potential bias to the results.	Study Attrition Loss to follow-up is not associated with key characteristics (ie, the study data adequately represent the sample), sufficient to limit potential bias	Prognostic Factor Measurement The prognostic factor of interest is adequately measured in study participants to sufficiently limit potential bias.	Outcome Measurement The outcome of interest is adequately measured in study participants to sufficiently limit potential bias.	Confounding measurement and account Important potential confounders are appropropriately accounted for, limiting potential bias with respect to the prognostic factor of interest	Analysis The statistical analysis is appropriate for the design of the study, limiting potential for presentation of invalid results.
Borensteinet al, 2010	Partly	Partly	Yes	Partly	Yes	No
Castien et al, 2012	Yes	Yes	Partly	Yes	Yes	Yes
Cleland et al, 2007	Yes	Yes	Partly	Yes	Yes	Yes
Cleland et al, 2010	Yes	Yes	Yes	Yes	No	Yes
Hush et al, 2009	Partly	Yes	Yes	Yes	Yes	Yes
Kasch et al, 2001	Yes	Yes	Yes	Yes	Yes	Yes
Kasch et al, 2008	Yes	Yes	Yes	Yes	Yes	Partly
Keating et al, 2005	Partly	Partly	Yes	Yes	Yes	Yes
Mintken et al, 2010	Yes	Yes	Yes	Yes	Yes	Yes
Puentedura et al, 2012	Yes	Yes	Partly	Yes	Yes	Yes
Raney et al, 2009	Partly	Partly	No	Yes	Yes	Yes
Salo et al, 2012	Partly	Yes	Partly	Partly	No	Partly
Tuttle, 2005	Partly	Unsure	Yes	Yes	No	Partly
Tuttle et al, 2006	Partly	Unsure	Yes	Yes	No	Partly

Appendix 2.3

Interventional Studies

Study	1 Eligibility criteria were specified	2 Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which to treatments were received)	3 Allocation was concealed	4 The groups were similar at baseline regarding the most important prognostic indicators	5 There was blinding of all subjects	6 There was blinding of all therapists who administered the therapy	7 There was blinding of all assessors who measured at least one key outcome	8 Measures of at least one key outcome were obtained from more than 85% of the subjects initiatially allocated to groups	9 All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	10 The results of between-group statistical comparisons are reported for at least one key outcome	11 The study provides both point measures and measures of variability for at least one key outcome	Score
Cassidy et al, 1992	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes	6
Dunning et al, 2012	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	9
Fernandez-De-Las-Penas et al, 2009	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	9
Gonzalez-Iglesias et al, 2009	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	10
Gonzalez-Iglesias et al, 2009	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	8
Kanlayanaphotporn et al, 2009	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7
Kanlayanaphotporn et al, 2010	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	8
Koeset al, 1992	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	9
Krauss et al, 2008	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	7
Lau et al, 2011	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	9
Martinez-Segura et al, 2006	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	6
Nilsson et al, 1996	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	Yes	6
Whittingham et al, 2001	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	7
Reid et al, 2008	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	10
Yurkiw et al, 1996	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	8

ABSTRACT

Background

Clinicians commonly assess cervical range of motion (ROM), but it has rarely been critically evaluated for its ability to contribute to patient diagnosis or prognosis, or whether it is affected by mobilisation/manipulation.

Objectives

This review summarises the methods used to measure cervical ROM in research involving patients with cervical spine disorders, reviews the evidence for using cervical ROM in patient diagnosis, prognosis, and evaluation of the effects of mobilisation/manipulation on cervical ROM.

Data sources and study selection

A systematic search of MEDLINE, EMBASE, CINAHL, AMED and ICL databases was conducted, addressing one of four constructs related to cervical ROM: measurement, diagnosis, prognosis, and the effects of mobilisation/manipulation on cervical ROM.

Study appraisal and synthesis

Two independent raters appraised methodological quality using the QUADAS-2 tool for diagnostic studies, the QUIPS tool for prognostic studies and the PEDro scale for interventional studies. Heterogeneity of studies prevented meta-analysis.

Results

Thirty-six studies met the criteria and findings showed there is limited evidence for the diagnostic value of cervical ROM in cervicogenic headache, cervical radiculopathy and cervical spine injury. There is conflicting evidence for the prognostic value of cervical ROM, though restricted ROM appears

associated with negative outcomes while greater ROM is associated with positive outcomes. There is conflicting evidence as to whether cervical ROM increases or decreases following mobilisation/manipulation.

Conclusion and Implications of Key Findings

Cervical ROM has value as one component of assessment, but clinicians should be cautious about making clinical judgments primarily on the basis of cervical ROM.

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Key Words

Cervical vertebrae, measurement, physical therapy techniques, manipulation (spinal)

Introduction

Musculoskeletal disorders of the cervical spine are common, with the overall prevalence of neck pain reported as high as 87% in the general population [1]. Consequently, cervical spine disorders are associated with significant economic, societal and personal burden [2]. The costs associated with neck pain range from €30 million annually in Sweden (all spinal conditions [3]), to US $8 billion annually in the US [4]. Therefore, there is an immediate need to develop more effective assessment and treatment regimes to address the symptoms and sequelae associated with cervical spine disorders.

As pathophysiology of the majority of neck pain conditions is not clear [5, 6], treatment usually focuses on addressing physical impairments. One of the most commonly assessed physical impairments in clinical practice is range of motion (ROM) of the cervical spine. Cervical ROM can be assessed with a variety of reliable tools [7], and clinicians generally view it as important and necessary to measure in patients with mechanical neck disorders [8, 9]. However, the clinical utility of ROM is unclear; that is, its predictive validity in the clinical setting for diagnosis, prognosis and treatment outcomes. Further, a variety of methods have been reported for measuring cervical ROM, with little consistency in methods used in published clinical studies. Therefore, the clinical value of different methods of cervical ROM measurement for clinical decision-making remains uncertain. To the best of our knowledge, no previous study has systematically or critically evaluated the clinical utility of cervical ROM in terms of its ability to contribute to accurate patient diagnosis or prognosis, or whether it is affected by various interventions applied by physiotherapists.

One recommended intervention used by physiotherapists to reduce neck pain and associated disability is cervical and thoracic mobilisation and manipulation [6]. The term “mobilisation/manipulation” refers to a “manual therapy technique comprising a continuum of skilled passive movements to the joints and/or related soft tissues that are applied at varying speeds and amplitudes, including a small-amplitude/high-velocity therapeutic movement” [10], and a more detailed description regarding manipulative techniques can be found elsewhere [11]. Though it is commonly believed that cervical ROM should improve after applying a mobilisation or manipulation, it is unknown whether this belief can be substantiated by evidence.

This systematic review aims to critically appraise and summarise the literature related to the use of ROM as an impairment measure in patients with disorders related to the cervical spine. Specifically, this review will (1) summarise the methods used to measure cervical ROM in research studies involving patients with cervical spine disorders, (2) determine the evidence for using cervical ROM in patient diagnosis and prognosis, and (3) determine the potential effects of manipulation (thrust and non-thrust) on cervical ROM. The results of this review will provide evidence to guide clinicians in their evaluation of cervical ROM and its value within their clinical assessment.

Methods

A systematic review of the literature was conducted using AMED, CINAHL, EMBASE, ICL and MEDLINE databases from inception to September 2012. A sensitive search strategy (Appendix 1) was developed incorporating the key study themes of ROM, cervical spine, diagnosis, prognosis and spinal manipulation. The specific search strings used in this study were informed by terms and phrases used in recent reviews on related research topics [12-14].

Identified studies were downloaded into reference management software and duplicate records were removed. Consistent with the objectives of this review, animal, cadaveric, and simulation studies were excluded. Conference proceedings, commentaries, editorials, letters, reviews, n=1 designs, and articles published in languages other than English were also excluded.

To be included, studies needed to address at least one of the following four research questions: (1) how is cervical ROM measured as an outcome of mobilisation/manipulation?, (2) how is cervical ROM used in diagnosis?, (3) how is cervical ROM used in prognosis?, and (4) what is the effect of mobilisation/manipulation on cervical ROM?

The operational definition of ROM employed in this review was the arc through which movement occurs at a joint or a series of joints [10]. For a study to be considered for the research question concerning diagnosis, it needed to have investigated the utility of cervical ROM to distinguish between patients with and without a clinically meaningful diagnosis (e.g., mechanical neck pain, whiplash, headache, cervical radiculopathy). Diagnostic studies that simply examined differences in cervical ROM between symptomatic (ie with a neck disorder) and asymptomatic populations were excluded as this study design is known to overestimate diagnostic accuracy [15, 16]. To be considered for the research question concerning prognosis, studies must have investigated the utility of baseline cervical ROM measurements to predict future patient outcomes (e.g., function, disability, patient-perceived improvement). Prognostic and single cohort prescriptive clinical prediction rule studies where cervical ROM had been investigated as a candidate variable were considered in this category. Finally, clinical trials were considered for the research question concerning mobilisation/manipulation if they satisfied the operational definition of mobilisation/manipulation used in this review which was a manual therapy technique comprising a continuum of skilled passive movements to the joints and/or related soft tissues that are applied at varying speeds and amplitudes, including a small-amplitude and high-velocity therapeutic movement [10]. Consistent with this definition, both thrust manipulation and non-thrust spinal mobilisation techniques were considered for inclusion. To clarify, in this manuscript we use the term “manipulation” to refer specifically to techniques involving a high-velocity low-amplitude thrust, whereas mobilisation refers to techniques performed as lower velocity, passive movements of a joint. Studies employing multi-modal interventions were included provided the independent effect of manipulation was able to be delineated (i.e., groups were similar in every other aspect except for the manipulation). Studies limited to the investigation of the effect of traction, soft tissue massage, neural mobilisation, and peripheral joint mobilisation/manipulation techniques were excluded.

Two independent reviewers screened the titles and abstracts of the identified studies to determine eligibility. Studies judged by either reviewer to be eligible in the first stage of screening were progressed to the second stage in which eligibility was evaluated using the full-text of each study. Two independent reviewers conducted the second round of screening with concordance determining study inclusion and exclusion. Disagreement between the reviewers was resolved by consensus or if needed by a third reviewer. Citation tracking and hand-searching of recent relevant journals were used as supplementary search strategies. The absolute and chance-corrected degree of agreement (κ) between the two reviewers was calculated for each stage of study selection.

Additional eligibility criteria were developed and applied following the initial study selection process in recognition of the heterogeneity and quality variance of the included sample. Studies were excluded post-hoc if the assessment of outcomes was not blinded [17-28], the study samples were asymptomatic (prognostic studies excluded) [29-33], manipulation was applied by the patient [34], or if ROM measures did not include measurements cephalad of C7 [35], as well as survey studies of therapist beliefs and practices [36, 37]. Corresponding authors were contacted as required for clarification to determine a study’s eligibility for inclusion, and when no response was received, those studies were excluded [21, 28].

The methodological quality of included studies was appraised by two independent raters using the QUADAS-2 (Quality Assessment Tool for Diagnostic Accuracy Studies) tool [15] for diagnostic studies, the QUIPS (Quality in Prognosis Studies) tool [38] for prognostic studies and the PEDro

(Physiotherapy Evidence Database) scale [39] for interventional studies. Disagreement on the assessment of quality appraisal items was resolved by consensus or if needed by a third rater. A sum methodology score was calculated for each interventional study evaluated with the PEDro scale [40].

No attempt was made to statistically pool the results of individual studies as a consequence of the heterogeneity of the included samples. A synthesis of the key findings is reported with consideration of the risk of bias of individual studies as identified by the quality appraisal.

Results

The database search strategy identified 2124 unique studies, with 104 of these progressing to the second stage of study selection. An additional eight studies were identified via citation tracking and hand-searching of relevant journals. One hundred and twelve studies were therefore evaluated in the second stage of screening by full-text, with 57 determined to be eligible for inclusion. Reasons for study exclusion are detailed in Figure 1. Post-hoc eligibility screening resulted in the further exclusion of 21 studies, the most common reason being the non-blinding of outcome assessment. Consequently, 36 studies comprise the final included sample with seven studies relating to the use of cervical ROM in determining a diagnosis, 14 studies concerning the use of cervical ROM in establishing a prognosis and 15 studies investigating the effect of manipulation on cervical ROM.

The absolute degree of rater agreement for the first and second stages of study selection was 97% and 89% respectively. The chance-corrected degree of agreement was ‘moderate’ for screening by title and abstract (κ=0.54, 95%CI 0.44-0.64), and ‘good’ for screening by full-text (κ=0.78, 95%CI 0.67-0.9) [41]. All but two episodes of rater disagreement were resolved by consensus, with the third reviewer later excluding both of these studies.

The methodological quality varied between studies, but was generally fair to good. For diagnostic studies assessed with QUADAS-2, the main risks of bias occurred in patient selection (four of seven studies with high risk of bias) and in the reference standard (four of seven studies with high risk of bias). For prognostic studies evaluated with QUIPS, there was generally low risk of bias for most items. The main risks of bias related to a study’s ability to account for potential confounders of the prognostic factor of interest (four of 14 studies with potential bias). Interventional studies evaluated with the PEDro tool received overall scores ranging from six to ten (out of a possible 11). Nine of the 15 interventional studies scored eight or above, indicating moderately high methodological quality [40]. The methodological quality scores for each of the included studies are provided in Appendix 2.

Measurement

The most common instruments used to measure ROM in the included studies are the Cervical Range of Motion (CROM) device (Performance Attainment Associates, Minnesota, IL, USA), the universal goniometer and the inclinometer

(Table 1). All studies reported cervical ROM in two dimensions in the cardinal planes of movement, except for two studies using an orientation sensor [42, 43].

Diagnosis

Four studies which included a total of 356 subjects examined the utility of cervical ROM in identifying the presence of cervicogenic headache (i.e., headache symptoms originating from the cervical spine) [44-47]. Two of these (n=238) examined the diagnostic utility of cervical ROM in the cardinal planes (flexion, extension, rotation and lateral flexion) [45, 47]. Both of these studies found that restricted active cervical extension ROM exhibited diagnostic utility for identifying cervicogenic headache if the patient also had pain with manual examination of the upper cervical spine. The remaining two studies (n=118) examined the accuracy of the flexion-rotation test, a multiplanar passive movement assessment tool for identifying patients with cervicogenic headache [44, 46]. In these two studies, a 10 degree or greater reduction in the expected normal range of motion of 44 degrees (visually estimated by the therapist during the flexion-rotation test with subsequent measurement with the CROM) was considered to be positive.

One study (n=82) examined the ability of active cervical ROM to identify patients with cervical radiculopathy [48]. Results demonstrated that cervical flexion less than 55 degrees and cervical rotation toward the side of the symptoms less than 60 degrees were useful in identifying patients with cervical radiculopathy (positive likelihood ratio (LR) 1.5, and 1.8 respectively [49]).

Two studies with large cohorts (n=8924 [50], n=8283 [49]) identified that cervical rotation ROM restriction was able to identify patients with clinically important cervical spine injuries, which were defined as any fracture, dislocation, or ligamentous instability demonstrated by diagnostic imaging [49, 50]. The positive LRs from these two studies were 2.1 and 2.2, while the negative LRs were 0.14 and 0.07. Further details on the studies related to the ability of cervical ROM to assist with making a diagnosis can be found in Table 2.

Prognosis

Two prospective studies were identified that included 245 asymptomatic individuals who had baseline measurements recorded and were then contacted at follow-up to ascertain if they had developed neck pain since the time of the original measurements [51, 52]. Hush et al [2009] [58] demonstrated that at a one-year follow-up, greater cervical flexion and extension ROM at baseline was associated with a reduced likelihood of experiencing neck pain. At a long term follow-up of six years, Salo et al [2012] [51] found that baseline cervical ROM was not associated with the development of neck pain.

Twelve prognostic studies that included patients with neck pain were identified. Four of these found that cervical ROM was not predictive of outcome [53-56] while five found cervical ROM to be predictive of the target outcome [57-61]. The direction and magnitude of range of motion that predicted outcome varied considerably among studies. Overall, when patients exhibited greater ranges of motion at baseline (regardless of magnitude and plane of movement) they were more likely to experience a positive outcome (e.g., self-rated symptom improvement using scales such as the Global Rating of Change or Neck Disability Index, Table 3). When patients exhibited reduced cervical ROM they were more likely to experience a worse outcome (e.g., continued significant pain, or failure to return to usual activity level, Table 3). Two other studies demonstrated that the degree of change of cervical ROM was predictive of between session improvements for the particular movement identified as impaired [42, 43]. Conversely, one study found restricted cervical extension was a prognostic factor for a better outcome [62]. However, this was an initial cohort study and cervical extension limitation was not identified as a prognostic variable in a recent clinical trial [54]. Further details of studies investigating the ability of cervical ROM to assist with making a prognosis can be found in Table 3.

Manipulation Effects

We identified 15 studies investigating the effect of mobilisation/manipulation (cervical, nine studies; thoracic, five studies; both, one study) on cervical ROM [63-77]. Of these studies, 13 examined the effects of mobilisation/manipulation on range of motion in patients with mechanical neck pain [63-69, 71-74, 76, 77]. Of the other two, one examined the effects of mobilisation in a group of patients with cervicogenic dizziness [70] and the other manipulation on patients with cervicogenic headache [75]. All of these studies demonstrated a positive improvement (nine studies) in cervical ROM or no difference between groups (six studies). Of the six studies demonstrating no difference between groups, one study was performed on patients with cervicogenic dizziness [70] and one was performed on patients with cervicogenic headache [75].

Of the nine studies where mobilisation/manipulation was directed at the cervical spine only, [64, 66, 70, 72-77] three demonstrated a statistically significant difference in cervical ROM between groups in favour of mobilisation [71] or manipulation [66, 72, 73]. One of these studies only exhibited a statistically significant difference between groups for flexion in favor of a 'preferred' mobilisation technique (unilateral posteroanterior [PA] pressure on the side of symptoms, i.e., ipsilateral) versus a randomly selected technique (central, ipsi- or contralateral unilateral PA mobilisation) [66]. Five studies examined the effects of thoracic spine manipulation on cervical ROM, all of which demonstrated statistically significant group differences with greater improvements in cervical ROM for the manipulation groups [65, 67-69, 71]. The final study used both cervical and thoracic manipulation versus non-thrust mobilisation. In this study, the thrust group demonstrated a significantly greater improvement in cervical ROM [63]. Further details of studies examining the effects of mobilisation/manipulation on cervical ROM can be found in Table 4.

Discussion

This systematic review examines the use of cervical ROM measurement in diagnosis, prognosis and the evaluation of the effects of mobilisation/manipulation in patients with mechanical neck pain. Most studies used commonly available instruments to measure cervical ROM, including goniometers, inclinometers and the CROM instrument. Cervical ROM was reported as useful in diagnosing cervicogenic headache in four studies, cervical radiculopathy in one study and clinically important cervical spine injuries in two studies. Only one of two prospective studies found cervical ROM predictive of the incidence of neck pain in asymptomatic individuals. Five prognostic studies in patients with neck pain found that cervical ROM was predictive of patient outcome (e.g., symptom improvement), with another two reporting it was predictive of ROM changes following treatment. Nine studies found that cervical ROM improves following mobilisation/manipulation, with another six reporting no difference between groups. The results from these studies suggest there is limited evidence for the diagnostic and predictive value of cervical ROM for some neck pain conditions. There is general support for a positive effect on cervical ROM from mobilisation/manipulation, though the evidence is limited. There are more studies supporting thoracic rather than cervical thrust manipulation, and thrust rather than non-thrust techniques for improving cervical ROM. Further research is needed to determine the value of cervical ROM in diagnosis and prognosis, and in evaluating treatment effects. Cervical ROM may be informative to clinical decision making and is moderately valuable when considered as one component within a suite of assessment items.

Measurement

The majority of the instruments used to quantify ROM in studies assessing the effects of manipulation used instruments commonly found in clinical practice, such as goniometers, inclinometers or the CROM device. These methods have demonstrated adequate reliability [78, 79] and are not overly expensive, but cannot evaluate coupled or three-dimensional movement. Assessing coupled and three-dimensional movement may provide greater insight into the potential mechanisms behind the changes that occur following manipulation in the cervical spine.

Diagnosis

In general, the findings from this current systematic review suggest that cervical ROM is potentially a valuable tool for establishing a diagnosis in individuals with cervicogenic headache, cervical radiculopathy and clinically important cervical spine injuries. Restricted cervical extension appears to be useful when classifying individuals with cervicogenic headache if the patient also exhibits pain with manual examination of the upper cervical spine [45, 47]. It should be recognized that when restricted ROM was identified along with the other physical assessment items, the diagnostic accuracy was reasonably high [80]. Additionally, positive findings for the cervical flexion-rotation test have been shown to be useful in differentiating between patients who have cervicogenic headaches or headaches-of other origin [44, 46]. Considering that both Hall et al. [44] and Ogince et al. [44, 46] found the flexion-rotation test helpful in identifying patients with cervicogenic headache, this may be a useful tool in clinical practice to identify individuals who would be appropriate candidates for physical therapy treatment, as it has been shown to be effective in this population [81]. However, it should be recognized that although a positive flexion-rotation test resulted in a moderate to large increase in probability that a patient had a cervicogenic headache in the study by Ogince et al. [44, 46], Hall et al. [44] found that it only resulted in a small increase in probability [80] suggesting future research evaluating this test is needed.

One study was identified that found that reduced cervical flexion and reduced rotation toward a patient's symptomatic side was indicative of cervical radiculopathy [48]. However, these items exhibited small LRs with the lower bound estimate of the 95% CIs approaching one (Table 2). This suggests that restrictions in these movements only alter the probability of the patient having cervical radiculopathy to a small and relatively unimportant degree [80].

Stiell and colleagues developed [50] and validated [49] the Canadian Cervical Spine Rule that contains a number of items from the patient history, as well as observed cervical ROM, and exhibits excellent utility for ruling out a clinically important cervical spine injury if a patient tests negative on the rules. Restricted cervical rotation less than 45 degrees was included in the combination of variables (high risk factors mandating radiographical examination and low risk factors allowing safe assessment of cervical ROM) that comprised the rule. In fact, when a patient could rotate their cervical spine greater than 45 degrees to both the left and right there was a moderate (derivation study [50]) to large (validation study [49]) increase in probability that the patient did not have a cervical fracture, dislocation or ligamentous instability.

Prognosis

It is important to identify predictive factors that could potentially be useful in the clinical decision making process when attempting to prevent neck pain from becoming chronic. If these individuals could be identified, appropriate interventions may be able to prevent chronicity of symptoms. However, it cannot be determined from this systematic review if cervical ROM is beneficial in identifying asymptomatic individuals who are likely to develop neck pain in the future. The two studies that longitudinally followed asymptomatic individuals reported conflicting results. Hush et al. [52] noted that greater ROM was associated with a reduced likelihood of developing neck pain, while Salo et al. [51] found cervical ROM was not prognostic for the future development of neck pain. One of the reasons for these inconsistent findings may be differences in the populations sampled in the two studies. Hush et al. [52] used a sample of office workers, while Salo et al. [51] used a combination of blue and white collar workers and students. Perhaps the office workers in the Hush study were more likely to develop neck pain because of prolonged desk sitting and associated neck flexion postures which have been identified as predictors of neck pain [82], as compared to the mixed sample in the Salo study [51]. The operational definition of neck pain also differed between the two studies, with Salo et al. [51] documenting cases of neck pain lasting greater than seven days, while Hush et al. [52] included patients with symptoms lasting greater than 24 hours. This may also explain the differences in the incidence of neck pain between the Salo et al. [51] and Hush et al. [52] studies of 19% and 49%, respectively. Therefore, more studies are necessary to determine the prognostic value of cervical ROM for determining the likelihood of developing a future episode of neck pain.

Although four studies found cervical ROM was not predictive of patient outcomes [53-56], there were five studies that suggest cervical ROM may have some predictive value. Five prospective cohort studies [57-61] reported that lower ranges of cervical ROM were predictive of a worse prognosis (in terms of patient-reported pain, function or disability), while greater ranges of motion were predictive of a better prognosis. However, the plane of movement, amount of restriction and outcome of interest differs between these studies, making it difficult to make definitive conclusions.

Manipulation

This systematic review identified 15 studies examining the effects of spinal mobilisation/manipulation on cervical ROM. Overall, mobilisation/manipulation may be beneficial in increasing cervical ROM in patients with mechanical neck pain (nine out of 13 studies). Unfortunately, the heterogeneity of the identified articles prevents meta-analysis. It may be argued that in most of the reported studies, the magnitude of the effects of increases in cervical ROM was small when examining between group differences. However, in many circumstances these differences did surpass the minimal detectable change (MDC) scores as identified by Fletcher et al. [83]. It should also be noted that in the majority of the studies the within-group changes in cervical ROM for patients receiving mobilisation/manipulation did exceed these reported MDC values where the comparison group did not. Furthermore, all studies using a population of patients with neck pain either exhibited a significant improvement over the comparison group or no difference between groups. No studies found cervical ROM to be worse in the mobilisation/manipulation group. However, spinal mobilisation/manipulation does not appear to be effective for increasing cervical ROM in patients with cervicogenic dizziness [70] or cervicogenic headache [75].

Each of the four studies examining the effects of mobilisation/manipulation on cervical ROM in patients with mechanical neck pain that did not show a difference between groups provided only one treatment session using either cervical thrust manipulation or non-thrust mobilisation. In every study identified where the manipulative intervention included multiple treatment sessions, there was a significant between group difference in cervical ROM. Therefore, it seems reasonable to conclude that multiple treatment sessions may be needed to achieve significant between group differences. A recent study by Fernandez-de-las-Penas et al. [69] demonstrated that repeated applications of thoracic spine thrust manipulation continued to consistently improve cervical spine mobility over five sessions of manipulation, with no plateau effect. Future studies should continue to investigate the dose-response relationship of mobilisation and manipulation on cervical ROM.

Only three of the seven studies examining the effects of cervical mobilisation/manipulation in patients with neck pain demonstrated improvements in cervical ROM over the comparison group [64, 66, 72-74, 76, 77]. However, all the studies that examined the effect of thoracic manipulation revealed improvements in cervical ROM for the manipulation group [65, 67-69, 71]. A number of factors could have resulted in the differences between studies targeting the manipulation to the cervical versus thoracic spine, as it has recently been reported that manipulation may have both a biomechanical and neurophysiologic response [84, 85]. However, the exact physiological mechanism(s) as to how manual therapy works remains to be elucidated. No studies in this review compared the differences between cervical and thoracic manipulation and its effects on cervical ROM, so no inferences can directly be made as to which technique is superior for this particular outcome. Yet it has recently been demonstrated that patients with neck pain receiving cervical manipulation experience greater improvements in pain and function in the short and long-term compared to patients receiving thoracic manipulation [86], possibly suggesting that targeting the area of symptoms with manual therapy might result in improved patient outcomes. This is supported by an additional study investigating biomechanical mechanisms related to manipulation at specific spinal levels [87]. It should be noted however that the findings of the present review relate specifically to improvements in measured cervical ROM only and not other patient or pain-related outcomes.

The results of two studies included in this review suggest that patients receiving thrust manipulation may experience greater improvements in cervical ROM than those receiving a non-thrust mobilisation [63, 72]. Other literature that has examined the effects of thrust manipulation versus non-thrust mobilisation has shown mixed results in terms of improvements in pain and function [88-91]. It also appears that in patients with neck pain, allowing the therapist to direct manual therapy at their preferred segment may result in no better improvements in cervical ROM (with the exception of cervical flexion) compared to a randomly selected segment [64]. These findings are similar to those demonstrated in patients with low back pain. Chiradejnant et al. [92] reported that a manual technique directed at a therapist-selected segment resulted in no greater improvement in lumbar ROM as compared to a group that received manual therapy directed at a randomly selected segment [92].

Limitations

There are a number of limitations to this review that should be considered. Only a small number of studies examining the diagnostic utility of cervical ROM were identified. It is possible that future prospective designs could find different magnitudes of diagnostic utility for cervical ROM in physiotherapy practice than those identified here. The majority of the included prognostic studies were single cohort designs so it is not known if cervical ROM will continue to be identified as a prognostic variable in future studies. The present review only included studies where the effects of mobilisation/manipulation techniques could be ascertained. It is quite possible that mobilisation/manipulation combined with other interventions, such as exercise, may result in greater improvements in cervical ROM than these manual techniques alone. The sample size in some of the studies is fairly small which may limit the ability to generalize to the entire population with neck pain. The study selection was limited to articles published in the English language, which may have resulted in the omission of relevant articles.

Conclusions

The most often used measurement tools for cervical ROM in the studies reviewed were the goniometer, inclinometer and CROM. There is limited evidence that cervical ROM may have utility as one component of assessment used to diagnose cervicogenic headache, cervical radiculopathy and clinically important cervical spine injury. There is conflicting evidence as to whether cervical ROM predicts future neck pain onset and some evidence it has some prognostic value in patients with mechanical neck pain. Limited evidence suggests restricted cervical ROM is associated with negative outcomes and greater cervical ROM is associated with positive outcomes. There is conflicting evidence regarding whether mobilisation/manipulation improves cervical ROM.

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Conflict of Interest

The authors have no conflicts of interest in for this review.

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Table 1. Methods of cervical range of motion measurement used in studies assessing cervical spine diagnosis, prognosis or outcomes of manipulation.

Measurement Method	Publication
Cervical Range of Motion Instrument (CROM)[a]	Castien et al 2012 Dunning et al 2012 Hall et al 2010 Hush et al 2009 Kanlayanaphotporn et al 2009 Kanlayanaphotporn et al 2010 Kasch et al 2001 Kasch et al 2008 Krauss et al 2008 Ogince et al 2007 Reid et al 2008 Yurkiw and Mior 1996
Universal goniometer	Cassidy et al 1992 Cleland et al 2007 (horizontal plane) Fernandez-de-las-Penas et al 2009 Gonzalez-Iglesias et al 2009a Gonzalez-Iglesias et al 2009b Martinez-Segura et al 2006 Mintken et al 2010 (horizontal plane) Nilsson et al 1996 Puentedura et al 2012 Wainner et al 2003 (horizontal plane) Whittingham and Nilsson 2001
Inclinometer (various types)	Cleland et al 2007 (sagittal and frontal planes) Cleland et al 2010 Koes et al 1992 Mintken et al 2010 (sagittal and frontal planes) Wainner et al 2003 (sagittal and frontal planes) Whittingham and Nilsson 2001 (frontal plane)
Cervical Measurement System (CMS)[b]	Borentstein et al 2010 Salo et al 2012
Fastrak System[c]	Amiri et al 2007 Jull et al 2007
Multi-Cervical Unit[TMd]	Keating et al 2005 Lau et al 2011
3-axis orientation sensor[e]	Tuttle 2005 Tuttle et al 2006
Visual estimation	Stiell et al 2001 Stiell et al 2003
Compass	Whittingham and Nilsson 2001 (horizontal plane)
Not specified	Raney et al 2009

[a]Performance Attainment Associates, Minnesota, IL, USA
[b]Kuntoväline Ltd, Helsinki, Finland
[c]Polhemus, Colchester, VT, USA
[d]BTE, Hanover, MD, USA
[e]MicroStrain Inc, Williston, VT, USA

Table 2: Studies investigating the utility of cervical range of motion in diagnosis (n=7).

Publication	Diagnosis	Criterion standard	Measurement of cervical ROM	Sample	Findings
Hall et al [2010]	CGH	Probable CGH as defined by Antonaci et al [2001] [93]	*Visual estimation:* ≥ 10° limitation of expected rotation ROM on flexion-rotation test	n=60 patients (20 CGH, 20 migraine without aura, 20 multiple headache types), mean age 33 years, 63% female	Positive test had accuracy of +LR = 2.3 (95%CI 1.3-4.1) and -LR = 0.43 (95%CI 0.21-0.85)
Amiri et al [2007]	CGH	Symptomatic criteria of the CHISG diagnostic criteria [Sjaastad, et al 1998] [94]	Not specified	n=108 patients with 2 or more concurrent intermittent headache types, mean age 37 years, 73% female, 37% prevalence of target diagnosis	Restricted extension (mean 29.6°) identified as one discriminating variable of CG vs non-CGH; headache classification from physical assessment items had +LR = 10.5 (95%CI 4.7-27.1), -LR = 0.24 (95%CI 0.16-0.39)
Jull et al [2007]	CGH	Symptomatic criteria of the CHISG diagnostic criteria [Sjaastad, et al 1998] [94]	*Fastrak*[a]*:* 3 planes	n=73 patients with single classifiable intermittent headache of >1 year duration, mean age 40 years, 63% female, 25% prevalence of target diagnosis; n= 57 asymptomatic controls, mean age 38 years, 67% female	Restricted extension identified as one discriminating variable of CG vs non-CGH and controls; headache classification from physical assessment items had 100% sensitivity and 94% specificity
Ogince et al [2007]	CGH	Symptomatic criteria of the CHISG diagnostic criteria [Sjaastad, et al., 1998] [94] and symptomatic C1/2 dysfunction [Maitland et al 2001] [95]	*Visual estimation:* ≥ 10° limitation of expected rotation ROM on flexion-rotation test	n=58 patients (23 CGH, 12 migraine with aura, 23 asymptomatic controls), mean age 42 years, 66% female	Positive test had +LR = 10.7 (95%CI 4.1-24.4) & -LR = 0.1 (95%CI 0.02-0.29); calculated from data reported for therapist 1
Stiell et al [2003]	Acute cervical spine injury	Cervical fracture, dislocation or ligamentous instability demonstrated by imaging	*Visual estimation:* restricted active cervical rotation (< 45° in either direction) as item in Canadian C-Spine Rule	n=8283, alert and stable adults with acute head/neck trauma presenting to ER, mean age 38 years, 48% female, 2% prevalence of target diagnosis	Restricted rotation had +LR = 2.1 (95%CI 2-2.2) and -LR = 0.14 (95%CI 0.08-0.23); Canadian C-Spine Rule had +LR = 1.8 (95%CI 1.7-1.8) and -LR = 0.01 (95%CI 0.001-0.09).
Wainner et al [2003]	Cervical radiculopathy	Needle electromyography and nerve conduction study	*Goniometer:* 3 planes	n=82 patients with suspected cervical radiculopathy or carpal tunnel syndrome, mean age 45 years, 50% female, 23% prevalence of target diagnosis	Flexion < 55° had +LR = 1.5 (95%CI 1.2-2) & -LR = 0.27 (95%CI 0.07-1); rotation to the symptomatic side < 60° had +LR = 1.8 (95%CI 1.3-2.4) & -LR = 0.23

					(95%CI 0.06-0.85)
Stiell et al [2001]	Acute cervical spine injury	Cervical fracture, dislocation or ligamentous instability demonstrated by imaging	*Visual estimation:* restricted active cervical rotation (< 45° in either direction) as item in Canadian C-Spine Rule	n=8924, alert and stable adults with acute head/neck trauma presenting to ER, mean age 37 years, 48% female, 1.7% prevalence of target diagnosis	Restricted rotation had +LR = 2.2 (95%CI 2.1-2.3) and -LR = 0.07 (95%CI 0.03-0.16). Derived Canadian C-Spine Rule had +LR = 1.7 (95%CI 1.7-1.7) & -LR = 0.0 (95%CI 0.0-0.07).

Abbreviations: ROM, range of motion; CGH, cervicogenic headache; +LR, positive likelihood ratio; -LR, negative likelihood ratio; CHISG, Cervicogenic Headache International Study Group (CHISG); ER, emergency room.

[a]Polhemus, Colchester, VT, USA

Table 3. Studies investigating the utility of cervical range of motion in prognosis (n=14).

Publication	Target outcome(s)	Measurement of cervical ROM	Intervention(s)	Sample	Findings
Castien et al [2012]	≥ 50% reduction in headache days and self-rated ≥ 'much improved' at 8 and 26 weeks	*CROM[a]:* sum of all directions	Thrust and non-thrust manipulation, exercise and postural education (maximum of 9 sessions)	n=145, chronic tension-type headache patients receiving manual therapy, 77% and 73% prevalence of target outcome at 8 and 26 weeks respectively	Greater baseline ROM positively associated with target outcome at 8 weeks (OR per ° = 1.01, 95%CI 1-1.02) and 26 weeks (OR per ° = 1.01, 95%CI 1-1.01)
Puentedura et al [2012]	≥ 'quite a bit better' on GROC by 3rd visit	*Goniometer:* 3 planes	Cervical thrust manipulation, gentle active ROM exercises and education (3 sessions)	n=82, patients with mechanical neck pain, mean age 38 years, 59% female, 39% prevalence of target outcome	Side-to-side difference in rotation ≥ 10° independently predictive of target outcome (+LR 6.8, 98%CI 3.1-14.6)
Salo et al [2012]	> 7 days of neck pain over 1 year reported 6 years post-baseline	*CMS[b]:* passive in 3 planes	None	n=192 (87% follow-up rate), asymptomatic volunteers, 100% female, 19% prevalence of target outcome	Baseline ROM (any plane) not associated with target outcome (AUC sagittal = 0.54 (95%CI 0.44-0.65); horizontal = 0.55 (95%CI 0.46-0.65); frontal = 0.56 (95%CI 0.45-0.76))
Borenstein et al [2010]	Sick leave of any length and sick leave ≥ 30 days at 2.5-3 years post WAD	*CMS:* 3 planes	(1) Exercise +/- MDT (2) Education	n=71, acute WAD grades 0-2, 20% prevalence of sick leave of any length and 15% prevalence of sick leave ≥ 30 days	Greater baseline ROM independently associated with reduced likelihood of target outcome
Cleland et al [2010]	Pain and NDI at 1 week, 4 weeks and 6 months	*Inclinometer:* extension < 30° as variable in 5-item CPR	(1) Thoracic thrust manipulation (1st 2 sessions only) + Exercise; (2) Exercise (5 sessions over 4 weeks)	n=140, patients with neck pain, mean age 40 years, 69% female	No significant 2-way interaction between rule status and time for pain (p = .3) or NDI (p = .7)
Mintken et al [2010]	≥ 'moderately better' on GROC by 3rd visit	*Goniometer & inclinometer:* 3 planes	Cervical non-thrust manipulation, thoracic thrust manipulation, exercise and education (3 sessions)	n=80, patients with shoulder pain, mean age 41 years, 60% female, 61% prevalence of target outcome	Baseline ROM not associated with target outcome in any direction (p>.3)
Hush et al [2009]	Development of an episode of neck pain lasting >24 hours over 1 year	*CROM:* 3 planes	None	n=53, asymptomatic office workers, mean age 42 years, 64% female, incidence of target outcome 49% / year	Greater baseline flexion-extension independently associated with reduced likelihood of target outcome (HR = 0.97, 95%CI 0.94-0.99, p=0.03); no other associations between baseline ROM variables and target outcome

Raney et al [2009]	≥ 'a great deal better' on GROC at 3 weeks post baseline	*Measurement not specified:* 3 planes	Intermittent cervical traction and exercises (6 sessions over 3 weeks)	n=68, patients with neck pain, mean age 48 years, 56% female, 44% prevalence of target outcome	No significant bivariate relationship between baseline ROM variables and target outcome (95% CI of corresponding +LR and -LR all cross 1)
Kasch et al [2008]	Continued significant neck pain or disability at 1 year post whiplash injury	*CROM:* 3 planes	(1) Verbal information; (2) Booklet; (3) MDT; (4) Neck collar	n= 688, acute WAD grades 1-3, 64% female	Reduced baseline ROM independently associated with increased risk of target outcome (RR=4.6, CI not reported)
Cleland et al [2007]	≥ 'quite a bit better' on GROC by 3rd visit	*Goniometer & inclinometer:* 3 planes	1. Thoracic thrust manipulation, cervical ROM exercises and patient education.	n=78, primary complaint of neck pain, mean age 42 years, 68% female, 54% prevalence of target outcome	Restricted extension ROM (< 30°) predictive of target outcome (+LR = 2.5, 95%CI 1.3-4.6)
Tuttle et al [2006]	Change in most limited direction between 1st and final session (maximum 6 sessions)	*3-axis orientation sensor[c]:* change in most limited direction between 1st and 2nd session	1. Manual therapy (maximum 6 sessions)	n=29, patients with neck pain, mean age 55 years, 72% female	Significant positive association between change in most limited direction between 1st and 2nd session and target outcome (R^2=0.57, p<0.001)
Keating et al [2005]	≥ 14/100 NDI improvement at discharge (median duration 6 weeks)	*Multi-cervical Unit[d]:* 3 planes	1. Neck strengthening exercises (median duration 6 weeks)	n=122, patients with chronic neck pain, mean age 41 years, 65% female, 56% prevalence of target outcome	No baseline ROM variable was predictive of the target outcome
Tuttle [2005]	Between-session improvement of most limited direction by ≥ 5°	*3-axis orientation sensor[c]: w*ithin-session improvement in most limited direction by ≥ 5°	1. Manual therapy (maximum 6 sessions)	n=29, patients with neck pain, mean age 55 years, 72% female	Within-session improvement (≥ 5°) in most limited direction predictive of target outcome for flexion-extension (OR = 8, 95%CI 2.4-26.8) and rotation (OR = 21.3, 95%CI 4.3-96.1), but not lateral flexion (OR = 2.5, 95%CI 0.6-10.1)
Kasch et al [2001]	Failure to return to usual level of activity or work 1 year post WAD	*CROM:* 3 planes	None	n=141, patients with acute WAD, mean age 34 years, 52% female, 8% prevalence of target outcome	Restricted baseline total ROM ≥ 2 SD below mean of asymptomatic sample predictive of target outcome (73% sensitivity, 91% specificity)

Abbreviations: ROM, range of motion; OR, odds ratio; GROC, Global Rating of Change scale; +LR, positive likelihood ratio; AUC, area under the curve (denotes percentage of randomly drawn pairs of subjects correctly classified by their status on the predictor variable); WAD, whiplash associated disorder; MDT, McKenzie's Mechanical Diagnosis and Therapy; NDI, Neck Disability Index; CPR, clinical prediction rule; HR, hazard ratio; -LR, negative likelihood ratio; RR, relative risk.
[a]Cervical Range of Motion Instrument, Performance Attainment Associates, Minnesota, IL, USA
[b]Cervical Measurement System, Kuntoväline Ltd, Helsinki, Finland
[c]MicroStrain Inc, Williston, VT, USA
[d]BTE, Hanover, MD, USA

Table 4. Studies investigating the effects of thrust manipulation and non-thrust mobilisation on cervical ROM (n=15).

Publication	Study design	Measurement of cervical ROM	Interventions	Sample	Findings
Dunning et al [2012]	RCT	*CROM[a]:* Rotation in end range flexion at baseline and 48 hours post-intervention	(1) Upper cervical/thoracic thrust manipulation; (2) upper cervical/thoracic non-thrust mobilisation (1 session)	n=107, mechanical neck pain, any duration	Significant between group difference (favoring thrust manipulation)
Lau et al [2011]	RCT	*Multi-Cervical Unit[b]:* 3 planes at baseline, 4 weeks, 3 months and 6 months	(1) Thoracic thrust manipulation, infrared, education; (2) infrared, education (8 sessions over 4 weeks)	n=120, chronic neck pain	Significant between group difference (favoring thrust manipulation) in flexion, RLF, LLF and RRot at each time point
Kanlayanaphotporn et al [2010]	RCT	*CROM:* 3 planes at baseline and 5 minutes post intervention	(1) Cervical central non-thrust mobilisation; (2) cervical random (central, left or right unilateral) non-thrust mobilisation (1 session)	n=60, central or bilateral mechanical neck pain, any duration	No significant between group difference in ROM change in any direction
Fernandez-de-las-Penas et al [2009]	RCT, secondary analysis	Goniometer: 3 planes pre-and post-treatment within 1st, 3rd and 5th sessions	(1) Thoracic thrust manipulation, TENS, heat, massage; (2) TENS, heat, massage (5 sessions)	n=45, acute mechanical neck pain	Significant between-group differences (favoring manipulation) in the magnitude of within-session ROM change in all directions
Gonzalez-Iglesias et al [2009a]	RCT	*Goniometer:* 3 planes at baseline and 5 weeks (2 weeks post discharge)	(1) Thoracic thrust manipulation, TENS, heat, massage; (2) TENS, heat, massage (5 sessions)	n=45, acute mechanical neck pain	Significantly greater improvement in all directions in manipulation group
Gonzalez-Iglesias et al [2009b]	RCT	*Goniometer:* 3 planes at baseline and 4 weeks (1 week post discharge)	(1) Thoracic thrust manipulation, TENS, heat, massage; (2) TENS, heat, massage (6 sessions)	n=45, acute mechanical neck pain	Significantly greater improvement in all directions in manipulation group
Kanlayanaphotporn et al [2009]	RCT	*CROM:* 3 planes at baseline and 5 minutes post intervention	(1) Preferred non-thrust cervical mobilisation on symptomatic side; (2) random non-thrust cervical mobilisation (1 session)	n=60, unilateral neck pain of > 1 week duration	No significant between group difference in ROM change, except for increased flexion in the 'preferred mobilisation' group
Krauss et al [2008]	RCT	*CROM:* Bilateral rotation at baseline and immediately post intervention.	(1) Thoracic thrust translatoric spinal manipulation (1 session); (2) No treatment	n=32, mechanical neck pain aggravated by cervical rotation	Significant between-group difference (favouring manipulation) in the magnitude of change in

					RRot and LRot
Reid et al [2008]	RCT	*CROM:* 3 planes at baseline, 4 and 12 weeks	(1) Cervical SNAG in provocative direction; (2) detuned laser (4-6 sessions)	n=34, chronic cervicogenic dizziness	No significant between-group difference in ROM change across time
Martinez-Segura et al [2006]	RCT	*CROM:* 3 planes at baseline and 5 minutes post-intervention	(1) Cervical thrust manipulation; (2) cervical non-thrust manipulation (sustained hold) (1 session)	n=70, mechanical neck pain of > 1 month duration	Significant between-group difference (favouring thrust manipulation) in the magnitude of ROM change in all directions
Whittingham and Nilsson [2001]	RCT, cross-over (3 week phases)	*Inclinometer:* horizontal and frontal planes at baseline, 3,6,9 and 12 weeks	(1) Cervical thrust manipulation (toggle-recoil); (2) sham manipulation with deactivated instrument; (3) no treatment (3 sessions)	n=105, chronic cervicogenic headache	Significant favorable changes in RLF, LLF, RRot and LRot following the spinal manipulation phase
Nilsson et al [1996]	RCT	*Goniometer:* 3 planes (passive) at baseline and 1 week post-intervention	(1) Cervical thrust manipulation; (2) low-level laser therapy and massage (6 sessions)	n=39, cervicogenic headache	No significant between-group difference in any ROM direction
Yurkiw and Mior [1996]	RCT	*CROM:* Lateral flexion at baseline and 5 minutes post-intervention	(1) Cervical manipulation (diversified technique); (2) Activator adjusting instrument (1 session)	n=14, subacute unilateral neck pain	No significant between group difference in ROM change
Cassidy et al [1992]	RCT	*Goniometer:* 3 planes at baseline and 5 minutes post-intervention	(1) Cervical thrust manipulation; (2) muscle energy technique (single session)	n=100, mechanical unilateral neck pain	No significant between-group difference in ROM change post-intervention
Koes et al [1992]	RCT	*Inclinometer:* most limited spinal movement at baseline, 3, 6 and 12 weeks	(1) 'Physiotherapy' – exercises, massage and electro-thermotherapeutic modalities; (2) spinal thrust manipulation and non-thrust mobilisation; (3) GP management; (4) Placebo – detuned SWD/US (maximum 3 months)	n=256, pain or self-reported limited range of motion in the back or neck for > 6 weeks	Changes in spinal mobility among the 4 groups were small and showed no consistent pattern

Abbreviations: ROM, range of motion; RCT, randomized controlled trial; RLF, right lateral flexion; LLF, left lateral flexion; RRot, right rotation; TENS, transcutaneous electrical nerve stimulation; SNAG, sustained natural apophyseal glide; LRot, left rotation; SWD/US, shortwave diathermy/ultrasound.

[a]Cervical Range of Motion Instrument, Performance Attainment Associates, Minnesota, IL, USA

[b]BTE, Hanover, MD, USA

Table 5. Summary of results of review.

Construct	Conclusion
Measurement of cervical ROM as an outcome of mobilisation/manipulation in patients with neck pain	Commonly available instruments were used most often (e.g., such as goniometer, inclinometer or CROM[a]), with few studies utilizing sensors or other devices. All included studies reported measurements in two dimensions in the cardinal planes of movement, with no studies including three dimensional, coupled or functional movements.
Cervical ROM in diagnosis	There is limited evidence from seven studies that cervical ROM may have diagnostic utility as a component of assessments used to diagnose cervicogenic headache (4 studies), cervical radiculopathy (1 study) and clinically important cervical spine injuries[b] (2 studies).
Cervical ROM in prognosis	There is conflicting evidence from two prospective studies that restricted cervical ROM may or may not be associated with a future onset of neck pain in a population asymptomatic at baseline. There is limited evidence that restricted cervical ROM is associated with negative outcomes (3 studies) and greater cervical ROM is associated with positive outcomes (2 studies).
Effects of mobilisation/ manipulation on cervical ROM	There is limited evidence from nine studies that suggests mobilisation/manipulation may be beneficial in increasing cervical ROM in patients with mechanical neck pain, however, more than a single session is necessary. There were more studies reporting increased cervical ROM following thoracic thrust manipulation (5 studies) than cervical thrust manipulation (3 studies) or both (1 study). This evidence conflicted with studies reporting that cervical ROM does not change following cervical thrust manipulation (3 studies) or cervical non-thrust mobilisation (3 studies).

Abbreviation: ROM, range of motion.

[a]Cervical Range of Motion Instrument, Performance Attainment Associates, Minnesota, IL, USA
[b]Clinically important cervical spine injuries were defined as any fracture, dislocation, or ligamentous instability demonstrated by diagnostic imaging

Figure 1. Flow chart of search strategy and study selection