



## First rib dysfunction in patients with neck and shoulder pain: a Delphi investigation

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### ABSTRACT

**Background:** First rib dysfunction is a possible cause of symptoms in patients with neck and/or shoulder pain.

**Objectives:** To explore therapists' perceptions of useful diagnostic criteria to identify first rib dysfunction.

**Methods:** A Delphi survey over four rounds involving international manual therapy experts who were asked to agree on which items were most useful in identifying first rib dysfunction.

**Results:** Consensus (>70% agreement) was reached on key aspects of first rib dysfunction being first rib mobility restriction, upper limb symptom distribution, and a subclassification into two subgroups was suggested. The main clinical findings suggested were: painful and restricted neck movements and shoulder girdle loading activities; positive Upper Limb Neural Test 1; direct palpation of first rib, neural structures, and scalene muscles; pain and hypomobility of first rib accessory movements with improvement after mobilization. The cervical rotation lateral-flexion test was considered a useful, although not widely used test among the experts. Its diagnostic accuracy and interpretation in isolation was questioned.

**Conclusions:** This Delphi study produced a cluster of clinical tests aimed to identify first rib dysfunction in patients with neck and/or shoulder conditions. However, these need to be tested out in further research to establish reliability and validity.

### KEYWORDS

Delphi study; first rib dysfunction; diagnostic criteria; tests

### Background

Neck pain is a common cause of symptoms, with point prevalence of at least 30% in the general adult population worldwide [1]. In an Australian population, 25% of the sample reported shoulder pain and dysfunction [2]. There are multiple potential anatomical causes for these symptoms. However, imaging studies and clinical tests have dilemmas with validity and reliability regarding the source of symptoms [3,4].

First rib dysfunction is considered one condition that can cause neck and shoulder pain, upper limb paresthesia, and neurological symptoms [5–8]. However, its prevalence is unknown; for instance, one investigation of shoulder disorders, did not list first rib dysfunction as a contributing factor [9].

Valid and reliable clinical features to diagnose first rib dysfunction are limited. Bookhout [10] proposed four criteria based on palpation: elevation of the superior aspect of the rib at a width of one finger higher in relation to the contralateral one, marked respiratory restrictions of motion, hypertonicity of the scalene muscles and marked tenderness of the superior aspect of the first rib. However, these diagnostic criteria have

not been tested for validity or reliability and are highly subjective.

Lindgren et al. [11] proposed the Cervical Rotation Lateral Flexion test (CRLF) to detect elevated first rib dysfunction in patients with thoracic outlet syndrome. Interexaminer reliability of this test proved to be moderate to perfect in two different studies [6,11], with reported kappa values of 0.5 and 1.0, respectively. In a single study, 'intermethod reliability' or validity between the clinical test and cineradiography was excellent (kappa = 0.84) [11]. However, the study suffered from a number of limitations, including: the small number of subjects (<25), problems with reproducibility of the measure, lack of blinding amongst the raters, lack of consensus prior to the ratings (pilot study), minimal number of raters (two), and lack of intra-examiner reliability. A more recent study [6] overcame some of these limitations, and recorded only moderate kappa values. Furthermore, additional studies interpreted the outcome of the test differently; for instance, focusing on pain or restricted range of movement, or both [5,12,13].

First rib dysfunction is treated in patients with thoracic outlet syndrome (TOS) either conservatively [14,15] or surgically [16]. Mobilizations of costotransverse and costovertebral joints can restore first rib

mobility and reduce TOS related symptoms [15], neck pain and upper extremity paresthesia [5]. Manipulative therapy directed at the first ribs and upper thoracic spine can improve shoulder pain [17,18]. A full picture of the role of first rib dysfunction in neck and/or shoulder problems is missing. The aim of this study was to explore the topic of first rib dysfunction amongst experienced manual therapists using a Delphi investigation.

## Methods

### Study design

A Delphi investigation was conducted to explore the ideas of a panel of experts to propose, rate, and reach consensus on issues relevant to first rib dysfunction over several rounds of in-put [19].

### Participants

All contacts were done by e-mail. A solicitation e-mail sent to prospective participants stated that each round of the Delphi process was voluntary and that their response to participate would serve as consent. The initial survey e-mail gathered both demographic data and initial responses to the research question. Local university ethics committee approval was gained prior to any data collection. Responses remained anonymous to all participants throughout each round, except to the primary researcher who sent and received e-mails. All identifying data were kept on a password-protected computer. Inclusion criteria for the definition of experts used in this study were as follows:

- At least 10 years of clinical practice in musculoskeletal manual therapy
- Orthopaedic Manipulative Physical Therapist (OMPT) trained according to the standards of International Federation of Orthopaedic Manipulative Physical Therapy (IFOMPT)
- And/or author of relevant publication in peer reviewed journals regarding first rib dysfunction.

### Data collection

In round one, responders answered open-ended questions, which allowed expression of their initial ideas independently of the other participants [20]. The responses were content analyzed by meaning. The most common term was used to group synonymous terms, no item was ignored, so that a complete list was developed of the main clinical aspects of this dysfunction as listed by the participants. In round two, each participant rated the importance of all the items that

emerged from round one according to a five-point Likert scale as follows:

1 = Strongly Agree: this item is very relevant to define and diagnose first rib dysfunction;

2 = Agree: this item is relevant to define and diagnose first rib dysfunction;

3 = Neither Agree or Disagree: this item is not very relevant to define and diagnose first rib dysfunction;

4 = Disagree: this item is not relevant to define and diagnose first rib dysfunction;

5 = Strongly Disagree: this item is not relevant at all to define and diagnose first rib dysfunction.

In subsequent rounds, each responder received a unique survey where they re-scored each item after viewing *their* previous response and the group responses. The rounds were continued until it was determined that a consensus had been reached, with the majority of participants responding either strongly agree or agree (1 and 2); neither agree or disagree (3); or disagree or strongly disagree (4 and 5).

### Data analysis

When questionnaires had been returned, frequency, and percentages of responses were analyzed. Results were divided into two categories. 'Related' category included items where the total amount of 'strongly agree' and 'agree' reached more than 50% of the totals: meaning that those items were relevant in the diagnosis of first rib dysfunction. 'Not Related' category included items where the total amount of 'strongly disagree,' 'disagree,' and 'neither agree or disagree' reached more than 50% of the scorings: meaning that those items were not relevant in the diagnosis of first rib dysfunction.

When at least 70% [20] of expert ratings were in the same category consensus was reached; and was named 'Consensus Related' (CR), or 'Consensus Not Related' (CNR). If consensus (>70%) had not been reached, but more than 50% of experts agreed, the item was labeled as "near Consensus Related (nearCR), or "near Consensus Not Related (nearCNR) [21]. All other statements were defined as 'undecided' (U). The composite score was then used to determine a numerical ranking for each statement that reached consensus, thus defining the items about which there was most agreement, and was determined with the formula [21]:

$$\text{Composite score} = (n1 \times 5) + (n2 \times 4) + (n3 \times 3) + (n4 \times 2) + (n5 \times 1)$$

Where: n1 = frequency of 'Strongly Agree,' n2 = frequency of 'Agree,' n3 = frequency of 'Neither Agree or Disagree,' n4 = frequency of 'Disagree,' n5 = frequency of 'Strongly Disagree.'

## Results

### Participant characteristics

Forty-five international experts from 11 countries were identified, and invited by e-mail to participate in this study. Five of them declined the invitation and twenty-four never responded. Sixteen experts accepted the invitation to participate (35% response rate). Twelve out of sixteen (75%) experts completed round one questions and the demographic sheet; all twelve (100%) returned round two; eleven out of twelve (92%) returned round three; ten out of twelve (83%) returned round four.

Table 1 provides demographic details of the participants from round one, their qualifications and the suggested frequency of medical diagnoses from referring physicians given by the experts for their patients with neck and/or shoulder complaints.

### First round

Round one collected 180 items, which were condensed into 134 items once synonyms were removed. These 134 items were organized into the following ten themes: Definitions, Prevalence of first rib dysfunction as primary dysfunction, Prevalence of first rib dysfunction as contributing to altered neurodynamics, Prevalence of first rib dysfunction in the form of scalene muscle tightness and first rib caudad glide restriction, History taking, Physical examination, Use of CRLF test, Interpretation of CRLF test, Validity/reliability of CRLF test, and Further comments.

### Subsequent rounds

Round three included only items that reached consensus and failed to reach consensus in round two. Round four included only the items close to an agreement in round three.

### Final result

There were 65 Consensus Related (53) and nearCR (12) items in seventeen themes, which covered five broad

domains regarding definitions, prevalence, history items, physical examination, and the cervical rotation lateral flexion test. Thirty-four items were Undecided, and three were Consensus Non-Related. See Table 2 for the full results with composite scores; only a summary of the key Consensus Related items are present in the text. It is important to note that some items demonstrated CR with a low composite score; this is due to a low response rate or 'n.' Thus, based on the calculation, the score is lower. An example is provided after Table 2.

### Definitions

At the end of the process, the definitions that reached a Consensus Related score included those that interpreted first rib dysfunction as being associated with mobility restriction, thoracic outlet syndrome (TOS), painful palpation or accessory movements of the first rib, local pain, and nonspecific upper limb referred pain. Definitions that implied a structural displacement of first rib failed to reach a consensus.

### Prevalence

The experts reached a consensus estimation of a prevalence below 10% considering first rib dysfunction as a primary dysfunction, and between 20% and 30% considering it as a contributing factor in neurodynamic/vascular problems in their patients with neck and/or shoulder complaints.

### History taking

The items that reached a Consensus Related score were neck and vague ipsilateral upper limb distribution of symptoms (pain and paresthesia), but also with particular mention of ulnar nerve distribution, and neck, shoulder girdle and respiratory activities as aggravating factors. Onset was associated with direct traumas, whiplash, shoulder girdle efforts, such as carrying heavy bags or pulling on ipsilateral arm, and shoulder surgery.

**Table 1.** Demographics of participants (N= 12).

Age (years), mean ( $\pm$ SD)	53 (7.1)
Years in practice ( $\pm$ SD)	29 (6.9)
Proportion neck and/or shoulder patients ( $\pm$ SD)	33% (15.6)
Medical diagnoses provided by referring physician: cervical	pain dysfunction (42%); cervicobrachial (42%); thoracic outlet syndrome (33%); disc (25%); whiplash (17%); instability (8%); headache (8%)
Medical diagnoses provided by referring physician: shoulder	frozen shoulder (33%); impingement (33%); instability (25%); pain dysfunction (25%); rotator cuff (25%); post-operative (17%)
Professional qualifications	Orthopedic Manual PT (10) + International Maitland Teaching Association (8); Fellow American Academy Orthopedic Manual PT (1); Doctor Osteopathy + Society Orthopedic Musculoskeletal medicine (1).

**Table 2.** Results of findings – Consensus Related (CR), near Consensus Related (nearCR), and Consensus Not Related (CNR) with composite scores.

Themes (17)/items (102)	Composite Score*	Consensus
<b>Definitions– primary</b>		
Mobility restriction of first rib	53	CR
Dysfunction characterized by painful palpation/accessory movements of first rib	47	CR
Dysfunction that can be associated with the presence of cervical rib or local trauma such as first rib fracture	44	CR
<b>Definitions– secondary</b>		
Dysfunction related to thoracic outlet syndrome/compression of brachial plexus and/or arteries and veins	52	CR
Usually first rib dysfunction is not isolated; cervical and thoracic spine or shoulder might be involved as well. It is difficult to state whether the first rib 'dysfunction' is the chicken or the egg	50	CR
It is often effective to treat the first rib area in cervicobrachial symptoms	49	CR
Soft tissues alteration could be relevant in first rib dysfunction, especially scalene muscles	43	CR
Dysfunction producing local pain over first rib/scalene muscles/trapezius area/neck	43	CR
Dysfunction producing nonspecific arm pain/upper limb referred pain	43	CR
Symptomatic condition related to thoracic spine and rib articulation	41	CR
Dysfunction often associated to tightness of anterior and medius scalene muscles	41	nearCR
<b>Prevalence</b>		
Contributing factor in 20–30% of patients with neck and/or shoulder problems	50	CR
Primary problem < 10% of patients with neck and/or shoulder problems	45	CR
Contributing factor in 20%–30% of patients with neck and/or shoulder problems with altered neurodynamics <sup>1</sup>	29	CR
Contributing factor in 40–60% of patients with neck and/or shoulder problems	21	nearCR
Primary problem 40–100% of patients with neck and/or shoulder problems	11	CNR
<b>History– pain distribution</b>		
Pain in cervicothoracic area/neck base/deep in the trapezius	53	CR
Vague ipsilateral upper limb paresthesia/anesthesia	52	CR
Pain irradiation into the ipsilateral arm	47	CR
Pain irradiated into the ipsilateral medial arm and hand	45	CR
Neurogenic ulnar nerve related symptoms	43	CR
Ipsilateral hand paresthesia/anesthesia in a peripheral nerve territory	40	CR
<b>History– aggravating factors</b>		
Neck rotation and lateral-flexion	50	CR
Ipsilateral neck movements	47	CR
Carry heavy bags on ipsilateral the shoulder	45	CR
Play musical instruments (e.g. Trumpet)	34	CR
Ipsilateral neck rotation and contralateral neck lateral-flexion <sup>2</sup>	33	nearCR
Deep inspiration and exhalation/coughing/sneezing	32	nearCR
<b>History– onset activity</b>		
Onset after direct trauma on first rib	47	CR
Onset after heavy pulling on the hanging arm	45	CR
Onset after carrying heavy load	41	CR
Onset after a whiplash	40	CR
Onset after shoulder surgery	42	nearCR
<b>Physical examination– observation</b>		
Shoulder girdle elevation alleviates symptoms	48	CR
<b>Physical examination– active movements</b>		
Cervical spine lower quadrant (combination of extension, lateral flexion and ipsilateral rotation) painful and restricted	48	CR
Cervical spine ipsilateral rotation movement painful and restricted	40	CR
Cervical spine contralateral rotation movement painful and restricted	36	CR
Cervical spine contralateral lateral-flexion movement painful and restricted	44	nearCR
Cervical spine ipsilateral lateral-flexion movement painful and restricted	41	nearCR
Cervical spine contralateral rotation movement painful and restricted	36	CR
All cervical spine movements painful and restricted	27	CNR
<b>Physical examination– neurological</b>		
Positive upper limb neural test 1 (ULNT 1)	46	CR
First rib plays a major role in assessment and treatment of patients with positive upper limb neural test 1	43	CR
<b>Physical examination– palpation</b>		
Palpation of first rib painful	55	CR
Palpation with inhalation and exhalation	49	CR
Tight scalene muscles	48	CR
Nerves and brachial plexus palpation	37	CR
<b>Physical examination– first rib accessory movements</b>		
Longitudinal caudad accessory movements of first rib painful and restricted	56	CR
First rib spring test (caudal glide in sitting) painful and restricted	52	CR
Assessment of first rib accessory movements (restriction and pain) is a very helpful diagnostic tool	51	CR
Antero-posterior accessory movements of first rib painful and restricted	51	CR
Postero-anterior accessory movement of first rib painful and restricted	47	CR
<b>Physical examination– cervical spine accessory movements</b>		
Antero-posterior lower cervical spine segments painful and restricted	38	CR
<b>Physical examination– muscle length tests</b>		
Positive muscle length test for scalene muscles	48	CR
<b>Physical examination– first rib response to treatment</b>		
Improvement after mobilization of first rib	51	CR
<b>Cervical Rotation Lateral Flexion test– usefulness</b>		
I don't use it	39	CR
This test has no diagnostic potential as a standalone test but could be part of a cluster of findings	32	nearCR
It could be a good comparable sign, sensitive but not specific	32	nearCR
Useful tool to identify first rib dysfunction	26	CR
<b>Cervical Rotation Lateral Flexion test– positive if. . . . .</b>		

(Continued)

Table 2. (Continued).

Themes (17)/items (102)	Composite Score*	Consensus
If it reproduces patient's symptoms	38	CR
If it reproduces local pain	32	CR
If the amount of lateral-flexion is significantly decreased when testing the affected side compared to the contralateral side but always in a cluster of clinical tests showing clinical evidence of potential upper rib problem	32	nearCR
<b>Cervical Rotation Lateral Flexion test– reliability/validity</b>		
There are no normative data on asymptomatic subjects and on differences between dominant and nondominant arm	39	CR
No evidences for diagnostic accuracy	37	CR
Reliability seems good, but on a too small population	37	CR
No reports of validity; reliability one report [11]	31	CR
Good interrater reliability	25	nearCR
Specificity could be low since the test involves cervical spine movements; therefore, motion restriction of cervical spine must be ruled out	24	nearCR

\* From potential of 60

Example of apparently illogical composite score values:

<sup>1</sup>Contributing factor in 20%–30% of patients with neck and/or shoulder problems with altered neurodynamics – consensus >70% with composite score 29, CR; whereas <sup>2</sup>ipsilateral neck rotation and contralateral neck lateral-flexion – consensus >50% with composite score 33, nearCR.

Scores: <sup>1</sup> = 7 agree (X4), 1 strongly disagree (X1), 2 no choice (X0) = 29, and 7 out of 10 agreed = 70% positive consensus.

Scores: <sup>2</sup> = 2 strongly agree (X5), 3 agree (X4), 3 neither agree nor disagree (X3), 1 disagree (X2), 1 no choice = 33, and 5 out of 10 agreed = 50% of positive consensus.

### Physical examination

On physical examination, active contralateral and ipsilateral neck rotations, lateral-flexions, and combined movements with extension were the main aggravating activities with restricted range of movement. Key clinical features were positive Upper Limb Neural Test, pain on direct palpation of first rib (with or without simultaneous deep breathing), pain on palpation of tight scalene muscles and neural structures, and restricted painful anterior pressure on lower cervical segments. There was pain and hypomobility of first rib accessory movements in frontal and caudal planes, which improved after mobilization. The only other alleviating factor identified was active shoulder girdle elevation.

### Rotation-lateral flexion test

The items that reached CR about the use of CRLF were 'I don't use it' and 'useful tool.' The consensus was that pain reproduction the patient recognized as 'their complaint' and the lateral flexion component restriction were the most useful criteria to establish positivity, but only in the context of a cluster of clinical features suggesting first rib dysfunction. Consensus was also reached regarding its lack of validity and reliability due to the absence of normative data and validity studies, and the limited sample size of the few reliability studies that had been conducted.

### Discussion

This study aimed to establish a consensus amongst manual therapy experts, defined by their training, experience, and authorship, about diagnosis and prevalence of patients with first rib dysfunction

among patients with neck and/or shoulder complaints. The panel felt that while key aspects existed to identify this problem, such as mobility restriction of the neck, upper limb, and TOS-like symptom distribution, ultimate classification depended on a cluster of clinical features, rather than one specific test. The value of the CRLF test is ambiguous based on the results of the study; some participants found it useful while others did not. Problematic issues with the test remained, regarding lack of normative data, and limited validity and reliability studies. These results suggested a sub-classification of first rib dysfunction into two groups (1) primary first rib dysfunction, (2) contributing factor in upper limb neurodynamic dysfunction or painful scalene muscle tightness.

### Diagnosis

The panel agreed that primary neck aggravating movements were contralateral or ipsilateral rotation and lateral flexion, which has been suggested before with contralateral movements [11,22,23], but not ipsilateral ones [22]. Among the panel there was disagreement that all cervical spine movements would have been altered; although this seems possible [24].

In this study, the physical examinations that received the highest level of agreement were the cervical spine lower quadrant combined movement, accessory movements on the first rib, and the CRLF test. The combined movement consists of lower cervical spine extension with ipsilateral lateral flexion and rotation [25]. Lee [22], speculated that cervical spine extension and ipsilateral rotation and lateral flexion may be limited by anterior rotation restriction of first rib. Cineradiography was used in a single, early study [11] as the 'gold standard' to evaluate validity. Still, it is

unknown if this remains the most valid standard against which to judge clinical tests.

In this study, palpation of first rib and assessment of accessory movements reached a strong consensus of being key aspects to identify the first rib dysfunction. The longitudinal caudad accessory movement claims to assess first rib passive mobility [26]; however, its reliability has been questioned when used for detecting passive stiffness of the first rib [27]. Loyd et al. [26] suggested a method to locate the first rib that was valid, but only on a cadaver. More research is indicated to support the use of this procedure.

### **Prevalence**

According to the expert panel, first rib dysfunction could represent a contributing factor in 20–30% of patients with upper limb neurodynamic dysfunctions. To our knowledge, only a case report has shown the presence of first rib dysfunction, assessed with the CRLF test, in a subject with positive neurodynamic assessment [5]. A positive neurodynamic assessment, especially upper limb nerve tension test 1 (ULNT1), reached strong consensus by the expert panel. This test is valid and reliable to determine if a patient has increased peripheral median nerve mechanosensitivity [28,29]. A similar test, a modified version of Elvey's upper limb tension test, was found to be very frequently positive in TOS patients [23]. First rib dysfunction was detected in carpal tunnel syndrome patients [13] and these subjects frequently have a positive ULNT1 [30].

A test in this study with consensus agreement was shoulder girdle elevation for the alleviation of neurological symptoms. Watson et al. [31] suggested the use of this test as a diagnostic tool for TOS in patients with depressed shoulder girdle to increase the thoracic outlet and the subcoracoid tunnel. There is a consensus for this treatment; however, research for the mechanism of improvement is lacking.

### **Cervical rotation lateral flexion test**

In the literature, the interpretation of the CRLF test results was often different from the original description [11]. The original interpretation [11] was unequivocal, referring to a 'total blockage.' This statement did not reach a consensus in this study. However, consensus was reached on positivity if patient symptoms were reproduced, and if the amount of lateral flexion was decreased compared to the contralateral side, but only in a cluster of other clinical tests. Like other studies [5,12], the experts agreed on the need to place the test in the context of a cluster of sound clinical findings.

The expert panel added two more suggestions to aid the diagnostic process: location of patient's symptoms and local pain reproduction, and both these

statements reached a consensus. These statements are typical of a clinical reasoning based on the signs and symptoms model in which the therapist attempts to identify movements and tests that reproduce the patient symptoms or 'comparable signs' [32]. The strong component of Maitland concept teachers (67%) in this expert panel could have introduced a bias in this direction. However, there is no data suggesting that the CRLF test should evoke symptoms, which further raises issues about the lack of standardization around interpretation. Further testing is indicated to determine the efficacy of the CRLF test.

### **Remaining uncertainties**

From the limited existing literature, there appears to be considerable uncertainty about major issues relating to first rib dysfunction, such as, prevalence, diagnosis and management. The expert panel in this study reflected this lack of consensus or confusion, but the point of the Delphi approach is to explore areas in which evidence is lacking. In this study, the aim was to explore agreement amongst a group of manual therapy experts on this topic. Despite lack of consensus in many areas, there was agreement about the presentations of this condition, and the need for a cluster of signs and symptoms for diagnosis. Regarding prevalence, there was much variability, but some agreement; about management, there was the suggestion that mobilizing the first rib with accessory movements improved signs and symptoms. The latter was not the focus of the study, and such a suggestion would require further research to confirm.

### **Limitations**

There are numerous limitations to this study that might impact on its generalizability. A Delphi study aims to obtain experts' opinions on a topic from their personal experience and cannot verify these opinions against clinical evidence [33]. The definition of experts in this study was explicit but selective; other 'experts' could have been recruited, so there was an element of exclusion bias. A third of the prospective 45 experts agreed to participate in the study; however, that third did not contribute to each round. About two thirds of participants were International Maitland Teachers Association members, and therefore may have shared a very similar training and perspective. Despite these limitations, this Delphi survey defined classifications of first rib dysfunction and provided a cluster of clinical features that might help clinicians identify the condition. Further evaluation of these suggestions is needed.

## Conclusion

This Delphi study suggested that a cluster of clinical tests might be needed to identify first rib dysfunction in patients with neck and/or shoulder complaints, and that two subclassifications may exist. However, it did not establish whether such a clinical condition actually exists. Further studies are needed to explore this area, such as: prevalence of first rib dysfunction in patients with neck and/or shoulder problems, best tests for diagnosis and management, and the value of the CRLF test in this process. Potential studies in this area are indicated.

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## Notes on contributors

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**Stephen May** trained as a physiotherapist in Leeds, UK, and graduated in 1990; he then worked in the NHS, UK, in musculoskeletal care. In 2002 he became a senior lecturer and then Reader at Sheffield Hallam University teaching on research issues and musculoskeletal care, and supervising numerous MSc and PhD students. He has written a number of text books, especially with Robin McKenzie, chapters in text books, and numerous articles in scientific journals; with nearly 100 publications in total. He has served on a number of national and international committees relating to guideline development and the McKenzie institute, and has peer reviewed for numerous international physical therapy and musculoskeletal journals. In 2006 he was awarded a Fellowship by the Chartered Society of Physiotherapy for contributions to the profession.

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## References

[1] Cohen SP. Epidemiology, diagnosis, and treatment of neck pain. *Mayo Clinic Proc.* 2015;90(2):284–299.

- [2] Hill CL, Gill TK, Shanahan EM, et al. Prevalence and correlates of foot pain and stiffness in a population-based study: the North West Adelaide health study. *Int J Rheum Dis.* 2010;13(3):215–222.
- [3] Cohen SP, Hooten WM. Advances in the diagnosis and management of neck pain. *Br Med J.* 2017;j3221. DOI:10.1136/bmj.j3221
- [4] Lewis J. Rotator cuff related shoulder pain: assessment, management and uncertainties. *Man Ther.* 2015;23:57–68.
- [5] Brismée JM, Phelps V, Sizer P. Differential diagnosis and treatment of chronic neck and upper trapezius pain and upper extremity paresthesia: A case study involving the management of an elevated first rib and uncovertebral joint dysfunction. *J Man Manipul Ther.* 2005;13(2):79–90.
- [6] Burns SA, Cleland JA, Carpenter K, et al. Interrater reliability of the cervicothoracic and shoulder physical examination in patients with a primary complaint of shoulder pain. *Phys Ther Sport.* 2016;18:46–55.
- [7] Lindgren KA, Leino E, Manninen H. Cineradiography of the hypomobile first rib. *Arch Phys Med Rehab.* 1989;70(5):408–409.
- [8] Singer KP, Edmondston S. Introduction: the enigma of the thoracic spine. In: Giles LGF, Singer KP, editors. *The clinical anatomy and management of thoracic spine pain.* Oxford: Butterworth-Heinemann; 2000. p. 9.
- [9] Van der Windt DAWM, Koes BW, Boeke AJP, et al. Shoulder disorders in general practice: prognostic indicators of outcome. *Br J Gen Pract.* 1996;46:519–523.
- [10] Bookhout MR. Evaluation of the thoracic spine and rib cage. In: Flynn TW, editor. *The thoracic spine and rib cage: musculoskeletal evaluation and treatment.* Boston: Butterworth-Heinemann; 1996. p. 163.
- [11] Lindgren KA, Leino E, Manninen H. Cervical rotation lateral flexion test in brachialgia. *Arch Phys Med Rehab.* 1992;73(8):735–737.
- [12] Smith TM, Brismée JM, Dedrick GS, et al. The double crush syndrome: a common occurrence in cyclists with symptoms of ulnar nerve neuropathy. *J Man Manipul Ther.* 2006;14(3):182. Available from: <http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=106270944&site=ehost-live>
- [13] Vaught MS, Brismée JM, Dedrick GS, et al. Association of disturbances in the thoracic outlet in subjects with carpal tunnel syndrome: A case-control study. *J Hand Ther.* 2011;24(1):44–52.
- [14] Hooper TL, Denton J, McGalliard MK, et al. Thoracic outlet syndrome: a controversial clinical condition. Part 1: anatomy, and clinical examination/diagnosis. *J Man Manipul Ther.* 2010;18(2):74–83.
- [15] Lindgren KA. Conservative treatment of thoracic outlet syndrome: a 2-year follow-up. *Arch Phys Med Rehab.* 1997;78(4):373–378.
- [16] Barkhordarian S. First rib resection in thoracic outlet syndrome. *J Hand Surg.* 2007;32(4):565–570.
- [17] Bergman GJD, Winters JC, Groenier H, et al. Manipulative therapy in addition to usual medical care for patients with shoulder dysfunction and pain. *Am Coll Phys.* 2004;21(15):432–440.
- [18] Dunning J, Mourad F, Giovannico G, et al. Changes in shoulder pain and disability after thrust manipulation in subjects presenting with second and third rib syndrome. *J Manipul Physiol Thera.* 2015;38(6):382–394.

- [19] Powell C. The Delphi technique: myths and realities. *J Adv Nurs*. 2003;41(4):376–382.
- [20] Keeney S, Hasson F, McKenna H. The Delphi technique in nursing and health research. Oxford UK: John Wiley and Sons; 2011.
- [21] Cook C, Brismée JM, Fleming R, et al. Identifiers suggestive of clinical cervical spine instability: a Delphi study of physical therapists. *Phys Ther*. 2005;85(9):895–906.
- [22] Lee D. The thorax - an integrated approach. White Rock, British Columbia, Canada: Delta: Diane G. Lee Physiotherapist Corporation; 2003.
- [23] Sanders RJ, Hammond SL, Rao NM. Diagnosis of thoracic outlet syndrome. *J Vasc Surg*. 2007;46(3):601–604.
- [24] Dewitte V, Cagnie B, Barbe T, et al. Articular dysfunction patterns in patients with mechanical low back pain: A clinical algorithm to guide specific mobilization and manipulation techniques. *Man Ther*. 2015;20(3):499–502.
- [25] Maitland GD. Examination of the cervical spine. *Aus J Physio*. 1979;25(2):49–57.
- [26] Loyd BJ, Gilbert KK, Sizer PS, et al. The relationship between various anatomical landmarks used for localizing the first rib during surface palpation. *J Man Manipul Ther*. 2014;22(3):129–133.
- [27] Smedmark V, Wallin M, Arvidsson I. Inter-examiner reliability in assessing passive intervertebral motion of the cervical spine. *Man Ther*. 2000;5(2):97–101.
- [28] Nee RJ, Jull GA, Vicenzino B, et al. The validity of upper-limb neurodynamic tests for detecting peripheral neuropathic pain. *J Orth Sports Phys Ther*. 2012;42(5):413–424.
- [29] Schmid AB, Brunner F, Luomajoki H, et al. Reliability of clinical tests to evaluate nerve function and mechanosensitivity of the upper limb peripheral nervous system. *BMC Musculoskel Dis*. 2009;10(1):1–9.
- [30] Baselgia LT, Bennett DL, Silbiger RM, et al. Negative neurodynamic tests do not exclude neural dysfunction in patients with entrapment neuropathies. *Arch Phys Med Rehab*. 2017;98(3):480–486.
- [31] Watson LA, Pizzari T, Balster S. Thoracic outlet syndrome part 1: clinical manifestations, differentiation and treatment pathways. *Man Ther*. 2009;14(6):586–595.
- [32] Hengeveld E, Banks K. Maitland's peripheral manipulation. 5th ed. Edinburgh: Churchill Livingstone; 2013.
- [33] Keeney S, Hasson F, McKenna HP. A critical review of the Delphi technique as a research methodology for nursing. *Int J Nurs Stud*. 2001;38(2):195–200.