

**A centralization and directional preference : a systematic review**

MAY, Stephen and AINA, A

Available from Sheffield Hallam University Research Archive (SHURA) at:

<https://shura.shu.ac.uk/6975/>

---

This document is the

**Citation:**

MAY, Stephen and AINA, A (2012). A centralization and directional preference : a systematic review. *Manual Therapy*, 17 (6), 497-506. [Article]

---

**Copyright and re-use policy**

See <http://shura.shu.ac.uk/information.html>

## **Centralization and directional preference: a systematic review**

**Stephen May PhD<sup>1</sup>**

**Alessandro Aina PT, Dip MDT<sup>2</sup>**

**<sup>1</sup> Sheffield Hallam University, Sheffield, UK**

**Studio di Riabilitazione MDTC, Milano, Italy**

**<sup>1</sup> Corresponding author:**

**Faculty of Health and Wellbeing, Collegiate Crescent Campus, Sheffield Hallam**

**University, Sheffield, UK, S10 2BP. E-mail: [s.may@shu.ac.uk](mailto:s.may@shu.ac.uk)**

**Word count: 3,985 (excluding abstract, references and tables)**

**Key words: centralization, directional preference, McKenzie assessment, back pain**

## **Abstract**

Centralization is a symptom response to repeated movements that can be used to classify patients into sub-groups, determine appropriate management strategies, and prognosis. The aim of this study was to systematically review the literature relating to centralization and directional preference, and specifically report on prevalence, prognostic validity, reliability, loading strategies, and diagnostic implications. Search was conducted to June 2011; multiple study designs were considered. 62 studies were included in the review; 54 related to centralization and 8 to directional preference. The prevalence of centralization was 44.4% (range 11% to 89%) in 4745 patients with back and neck pain in 29 studies; it was more prevalent in acute (74%) than sub-acute or chronic (42%) of symptoms. The prevalence of directional preference was 70% (range 60% to 78%) in 2368 patients with back or neck pain in 5 studies. Twenty-one of 23 studies supported the prognostic validity of centralization, including 3 high quality studies and 4 of moderate quality; whereas 2 moderate quality studies showed evidence that did not support the prognostic validity of centralisation. Data on the prognostic validity of directional preference was limited to one study. Centralization and directional preference appear to be useful treatment effect modifiers in 7 out of 8 studies. Levels of reliability were very variable (kappa 0.15 to 0.9) in 5 studies. Findings of centralization or directional preference at baseline would appear to be useful indicators of management strategies and prognosis, and therefore warrant further investigation.

Words: 241

## **Centralization and directional preference: a systematic review**

### **1. INTRODUCTION**

The treatment of back and neck pain remains controversial. Recent research has highlighted the value of reliable examination findings that can be used to predict response to different treatments (Long et al., 2004; Childs et al., 2004; Hicks et al., 2005; Long et al., 2008). Clinically induced symptom responses have been used to determine treatment; with spinal loads being used to induce lasting changes in the site or intensity of symptoms to determine prognosis and management. Such responses are intrinsic to a number of spinal classification or management systems (Fritz et al., 2003; McKenzie and May, 2003; Petersen et al., 2003; Murphy and Hurwitz, 2007; Tuttle, 2009). Probably the most researched clinically induced symptom response is centralization, which has been defined as the abolition of distal and spinal pain in response to repeated movements or sustained postures (McKenzie and May, 2003). Centralization has been the subject of 2 systematic reviews within the last decade, both of which were positive about its usefulness as a prognostic indicator (Aina et al., 2004; Chorti et al., 2009). The first of these reviews is no longer contemporary, and the second was on the prognostic value of symptom responses in general; only half of the 18 studies dealt specifically with centralization.

An associated, but separate phenomenon is that of directional preference, which has been defined as the repeated movement which induces centralization or abolition of symptoms, but also a decrease in symptom severity, and/or a positive mechanical response, such as an increase in range of movement (McKenzie and May, 2003).

Movements in the opposite direction may cause these symptoms and signs to

worsen. A finding of directional preference at baseline has been shown to predict a significantly better response to directional preference exercises than non-specific exercises (Long et al., 2004, 2008). A number of classification systems use this phenomenon, though not always termed as such, as a part of their assessment and management process (Fritz et al., 2003; McKenzie and May, 2003; Petersen et al., 2003; van Dillen et al., 2003; Murphy and Hurwitz, 2007; Tuttle, 2009; Hall et al., 2009).

Thus given the apparent usefulness of the centralization phenomenon in predicting outcomes, and the value of directional preference in directing management strategy, it seemed appropriate to conduct a new systematic review. The aim of the present study was to systematically review the literature relating to all aspects of centralization and directional preference.

## **2. METHODS**

### **2.1 Study selection**

Any full-text study that reported some aspect of centralization or directional preference, in adults reporting spinal pain (low back or neck pain) with or without radiating symptoms. As we knew different types of study design were to be included we restricted qualitative evaluation of study methods to the prognostic studies, for which clear cut quality criteria exist (Hudak et al., 1996). To the authors knowledge the first paper on centralisation was published in 1990.

### **2.2 Data sources and searches**

A search was made of Medline, Cinahl and AMed from 1990 to June 2011. We also used the website [www.mckenziemdt.org](http://www.mckenziemdt.org) which has a repository of references, which includes a section on centralization. The reference lists of all included articles were also searched. Search terms were as follows: centralization, directional preference, spine pain, back pain, neck pain; which were used individually and then in combinations. Titles and abstracts were reviewed by one reviewer (SM) to see if they appeared relevant; all potential articles were reviewed by both reviewers to determine their final relevance, with any disagreements resolved by discussion.

### **2.3 Data extraction and quality assessment**

Data was independently extracted and the prognostic studies were scored against existing quality criteria (Hudak et al., 1996). If studies came near to these set criteria half a point was given. Hudak et al. (1996) also provided levels of evidence: *strong* evidence partially or fully meeting all criteria; *moderate* evidence partially fulfilling most criteria; *weaker* evidence when studies failed to fulfil multiple criteria. Any disagreements were resolved with discussion. Assessing methodological quality in the other studies or conducting a meta-analysis was not possible due to the range of study designs that were retrieved.

## **3. RESULTS**

### **3.1 Study selection and characteristics of studies**

1416 titles and abstracts were screened, 131 full articles were reviewed, and 62 articles were finally included (see figure 1). The majority of studies related to centralization; only 8 related to directional preference (Delitto et al., 1993; Erhard et al., 1994; Snook et al., 1998; Fritz et al., 2003; Hefford, 2008; Long et al., 2004; May,

2006; Long et al., 2008; Werneke et al., 2011). The majority involved patients with back pain, only 5 involved patients with neck pain (Tuttle, 2005; Tuttle et al., 2006; Dionne et al., 2006; Piva et al., 2006; Fritz and Brennan, 2007), or a mixed population (Werneke et al., 1999, 2008; May, 2006; May et al., 2008; Hefford, 2008). Nine studies involved patients with disc herniation or sciatica (Mitchell et al., 2001; Lisi, 2001; Broetz et al., 2003; Skytte et al., 2005; Abdulwahab and Beatti, 2006; Rapala et al., 2006; Broetz et al., 2008; Murphy et al., 2009b; Broetz et al., 2010) or pregnancy-related back pain (Murphy et al., 2009a), the rest being non-specific acute to chronic spine pain with or without referred symptoms (see table 1 for study details).

There were 23 cohort studies, and 7 secondary analysis of cohort studies. The cohort studies looked at the prognostic validity of centralization, at associations between centralization and other variables, or were simply observational studies. There were 9 randomised controlled trials (RCT) and 7 secondary analysis of RCTs. There were 7 criterion validity studies against discography, or MRI investigations. There were 6 reliability studies, 2 surveys, and one mini case series.

Some studies offered little additional material, and so have not been included in further discussion though these are listed in table 1. These included a mini case series (Lisi, 2001), a pilot study of slump stretching that used centralization as one of its outcome measures (Cleland et al., 2006), and a study that used centralization as part of a treatment algorithm, but did not give prevalence figures (Murphy et al., 2009). The other study looked at the effect of prone lying and the addition of interferential therapy on patients with lumbar radiculopathy, but the study design

could not distinguish between the effect of prone lying and the addition of the modality (Abdulwahab and Beattie, 2006). One study involving patients with neck pain referred to centralization in the abstract and methods, but did not specifically report on this in the results (Piva et al., 2006). In addition three studies did not clearly use repeated movements in determining centralization, which is a key component of inducing this symptom response, so these results have been discounted (Cleland et al., 2006; Piva et al., 2006; Fritz and Brennan 2007). The latter reported use of active range of movement (retraction exercises) or use of traction (at least 50% of sessions).

### **3.2 Definitions of centralization**

Most studies were consistent in the operational definition they used for centralization, which was the abolition of the most distal symptoms in response to repeated movements or sustained posture. If back pain only was present then this was centralised and abolished. This is mostly in line with McKenzie's original description. Fritz et al. (2000) included a change in neurological signs and symptoms as well; and some studies included a reduction in intensity of symptoms in the definition (Delitto et al., 1993; Erhard et al., 1994; Laslett et al., 2006; Karas et al., 1997). Werneke et al. (1999) applied a stricter definition in which centralization occurred only in the clinic, progressed sequentially on each clinic visit, until complete abolition of all symptoms. They also described a partial centralization group, in which changes occurred, but less completely and not on each visit. An overlay body template was used to measure the occurrence of centralization (Werneke et al., 1999). Tuttle (2005; Tuttle et al., 2006) monitored centralization, but in response to manual



therapy rather than repeated movements, but we have included this study in the results.

### **3.3 Prevalence of centralization and directional preference**

The occurrence of centralization as a proportion of the total study population could be calculated in 29 studies (table 2). Among 4745 patients centralization occurred in 2109 (44.4%); ranging from 11% to 89%. This included 168 patients with neck pain of whom 62 (36.9%) demonstrated centralization.

Centralization occurred in 74%, 50%, and 40% of 317 acute, 123 sub-acute, and 567 chronic spine problems. In 3738 patients with mixed duration pain or not stated duration centralization occurred in 1584 (42%). Among 2368 patients in 5 studies (table 2) directional preference or derangement was reported by 1661 (70%); with a much smaller range 60% to 78%. The studies that included mechanical classification of derangement (May, 2006; Hefford, 2008) were included in this summation, as directional preference is one of the main characteristics of derangement (McKenzie & May 2003).

Centralization has been documented as being more common in those with acute, rather than chronic problems; and in those who are younger, rather than older (Werneke et al., 2008, 2011). For instance in acute and chronic back pain 54% and 35%, and in those aged 18-44 years 61% compared to 15% in those aged over 65 years (Werneke et al., 2011). Classification with centralization (43%) or derangement (67%) was far more common than patients who met the manipulation (13%) or stabilisation (7%) clinical prediction rules (Werneke et al., 2010).

### **3.4 Prognosis of centralization**

Twenty-three studies considered the prognostic value of centralization; 4 of these (Werneke and Hart, 2003, 2004; Tuttle et al., 2006; Broetz et al., 2010) were long-term follow-ups or secondary analyses of earlier studies so are not included in the quality review table (table 3). Two other studies were also secondary analyses (George et al., 2005; May et al., 2008), but the original studies were not included in this review. The mean quality score was 3.4. Three studies showed *strong* evidence for the prognostic validity of centralization (Long, 1995; Skytte et al., 2005; Werneke and Hart, 2001); 2 studies showed *moderate* evidence (Werneke et al., 1999; Tuttle, 2005; May et al., 2008), and one showed *moderate* evidence for non-centralization as a negative prognostic factor (Niemesto et al., 2004). Two studies showed *moderate* evidence unsupportive of centralization (Schmidt et al., 2008; Christiansen et al., 2010). The remaining 15 studies, representing *weaker* evidence, supported the prognostic validity of centralization.

Non-centralization was generally a negative predictor of outcome and also more likely to be associated with psychosocial issues. Specifically non-centralization had odds ratio of 9, 13, 2, and 3 for non-organic signs, pain behaviours, somatisation, and fear of work respectively (Werneke and Hart, 2005). When centralization was present fear beliefs did not need to be addressed, whereas if non-centralization was present fear beliefs should be addressed (Werneke et al., 2009). The presence of centralization also confounded the association between depression and somatisation and had an impact on chronic pain and disability (Edmond et al., 2010).

Centralization was a more significant predictor than fear avoidance (George et al., 2005), bothersomeness and depression (Long et al., 2008), work satisfaction,

Waddell signs, pain behaviours, depression, somatisation, and fear avoidance (Werneke et al., 1999), and referral of symptoms (Werneke and Hart, 2004).

Patients with sciatica who centralized at baseline had significant improvements in pain and disability both short and long-term (Broetz et al. 2003; Skytte et al., 2005; Murphy et al., 2009b; Broetz et al., 2010); and were significantly less likely to undergo surgery in the following year - odds ratio for surgery in the non-centralization group was 6.2 (Skytte et al., 2005). Centralization detected over several treatment sessions was more likely to predict pain and function outcomes than centralization at the first session (Werneke and Hart, 2003). Relative precision to discriminate changes in pain intensity and function were respectively 5.5 and 6.6 (Werneke and Hart, 2003).

Patients with neck pain who demonstrated centralization in one session were more likely to show overall improvement across sessions (Tuttle, 2005). Odds ratio for improvement were 9.2, compared to 21.3 for a change in rotation movement, and 4.5 for a change in pain intensity. However a re-analysis found that centralization in one session, and other changes, only predicted overall change in that particular outcome, and not in other impairments (Tuttle et al., 2006).

Two studies showed a lack of association between centralization and outcomes, which included return to work, back and leg pain, disability, and back surgery (Schmidt et al., 2008; Christiansen et al., 2010). Higher Waddell scores were a better predictor of return to work in another study (Karas et al., 1997). Back pain, rather than neck pain, and chronic rather than acute symptoms were stronger predictors of

improvement in the secondary analysis of a RCT (*moderate* evidence) (May et al., 2008).

### **3.5 Prognosis of directional preference**

Whereas directional preference accompanied by centralization predicted a good outcome in terms of pain and function, directional preference by itself was not a useful predictor of function (Werneke et al., 2011).

### **3.6 Using centralization as a treatment effect modifier**

In 2 studies patients with centralization responded significantly better to treatment when randomised to appropriate centralizing exercises than other treatments (Browder et al., 2007; Kilpikoski et al., 2009). However differences were not dramatically better than treatment with orthopaedic manual therapy (Kilpikoski et al., 2009).

### **3.7 Using directional preference as a treatment effect modifier**

In 3 studies patients with a directional preference responded significantly better to treatment when randomised to appropriate directional preference exercises than other treatments (Delitto et al., 1993; Long et al., 2004, 2008), but not in another study (Erhard et al., 1994). These were all trials with very short follow-up. In a trial of classification-based treatment, which included directional preference exercises, versus guideline-based treatment, there were significantly better outcomes in the former group at 4 weeks (Fritz et al., 2003). Snook et al. (1998) found that restricting early morning flexion, which would apply with a directional preference for extension, resulted in significant differences in pain severity and days in pain and levels of

medication compared to a control group. When the control group then received the same intervention they also had significant improvements in these outcomes.

### **3.8 Reliability of assessment for centralization**

For judgements about centralization in the assessment of patients with neck pain kappa was 0.46 (Dionne et al., 2006). For judgements about centralization in patients with back pain kappa values were 0.79 (Fritz et al., 2000); 0.15 during flexion, 0.28 during extension, 0.46 during sustained extension (Fritz et al., 2006); 0.51 (Kilby et al., 1990); 0.7 (Kilpikoski et al., 2002); and judgements about DP had a kappa value of 0.9 (Kilpikoski et al., 2002). Studies used video recordings of patient assessment, and direct observation by 2 therapists to collect data on agreement.

### **3.9 Variables associated with centralization**

A number of variables were associated with the presence of centralization, or non-centralization. Centralization has been shown to have a significant association with pain during movement, more improvement in extension range of movement over time, and confound the association between depression, somatisation and fear-avoidance beliefs and chronic disability (Bybee et al., 2005, 2009; Werneke et al., 2009; Edmond et al., 2010). Non-centralization has been shown to have a significant association with mental distress and depression (Christiansen et al., 2009), and non-organic signs, pain behaviours, somatisation and fear of work (Werneke and Hart, 2005).

### **3.10 Loading strategies associated with centralization**

Only a few studies reported the loading strategy that was associated with centralization or directional preference. Just using sagittal plane repeated movements Donelson et al. (1991) found that 40% centralized with extension, and 7% centralized with flexion. Hefford (2008) listed treatment principles for derangement syndromes and described loading strategies associated with directional preference. These were as follows for lumbar, cervical, and thoracic spine: extension: 70%, 72%, 85%; flexion: 6%, 9%, 0%; and lateral movement: 24%, 19%, 15% respectively. Of 30 of 49 patients with back pain who centralized this was with extension 77%, flexion 3%, and with lateral movements 20% (Murphy et al., 2009b). Williams et al. (1991) found different sitting postures assumed over a 24-hour period associated with very different symptom responses. Of those encouraged to main a lordotic sitting posture 56% experienced centralisation and 4% experienced peripheralization; whereas those encouraged to maintain a kyphotic sitting posture 10% experienced centralization and 24% experienced peripheralization.

### **3.11 Diagnostic implications of centralization**

A number of studies have linked centralization to discogenic problems, or non-centralization to non-discogenic problems (Donelson et al., 1997; Young et al., 2003; Laslett et al., 2005, 2006a, 2006b). These studies compared response to discography to symptomatic responses. Donelson et al. (1997) found a sensitivity and specificity of 92% and 52% to discogenic pain (Bogduk and Lord, 1997); whereas others found a sensitivity and specificity of 40% and 94% (Laslett et al., 2005). However diagnostic implications are affected by the presence of disability and distress, especially regarding specificity, which was 80% and 89% in those with severe distress, but 100% in those with moderate, minimal or no distress (Laslett et

al., 2005). Centralization is not associated at all with positive responses to lumbar zygapophyseal joint blocks (Laslett et al., 2006b), but is associated with discogenic pain and pain when rising from sitting (Young et al., 2003).

There was a significant association between a positive discography and the occurrence of centralization ( $p < 0.007$ ) or peripheralization ( $< 0.004$ ), and centralization was significantly associated with an intact annulus ( $p < 0.001$ ), whereas peripheralization was not (Donelson et al., 1997). If there were no symptom changes there was highly unlikely to be a positive discography ( $p < 0.001$ ). However in studies comparing MRI or CT findings to pain response, centralization commonly occurred in patients with extrusions and sequestrations (Broetz et al., 2003, 2008; Rapala et al., 2006).

#### **4. DISCUSSION**

This is the largest review to date on centralization, and the first to attempt to review data on directional preference. The literature on centralization has expanded considerably since the first review (Aina et al., 2004). This current review found that the occurrence of centralization was less than reported previously, but still represented a substantial proportion of the neck and back pain populations that were included. There was an indication that centralization was more common in acute spine problems and patients under 44-years old. Centralization was associated with a good prognosis in 21 of 23 studies; and non-centralization was associated with a poor prognosis, but also greater psychosocial issues. Centralization appeared to be a positive prognostic indicator for non-specific low back pain and for sciatica;

whereas there was less evidence for centralization as a treatment effect modifier.

Directional preference had limited evidence as a prognostic indicator, but there was some evidence for it as a treatment effect modifier.

Although some good levels of reliability were reported for centralization and directional preference, some studies also reported poor levels of reliability between clinicians. This degree of uncertainty about whether clinicians can agree or not about the existence of centralization is clearly a limitation to centralization. More training in the McKenzie approach appeared to be associated with better levels of reliability. Centralization and directional preference appear to be most commonly associated with extension repeated movements in all spinal areas (70-80%), a minority with lateral movements (about 20%), and a minority with flexion movements (<10%).

There appears to be some relationship between centralization and discogenic pathology, but it is somewhat unclear at this time what this relationship is. Differing levels of sensitivity and specificity have been recorded, and also that disability and distress can be a confounding factor. Exactly what type of discogenic pathology this might represent is also unclear; whereas one study has clearly linked the response to an intact annular wall; other studies have suggested that centralization can occur with extrusions and sequestrations.

There have been two previous systematic reviews that considered centralization (Aina et al., 2004; Chorti et al., 2009). The first of these considered various aspects of centralization as this review has done; it included 14 studies and made positive



conclusions about the high prevalence, reliability of assessment, and prognostic validity of centralization (Aina et al. 2004). Chorti et al. (2009) considered the prognostic value of symptom responses in general, and concluded that only changes in pain location / centralization and/or intensity with repeated spinal movements could be considered as useful responses to inform management. This current review does not seriously challenge these conclusions, but it does draw attention to the fact that the prevalence rate, the reliability, and the prognostic validity may be less than previously reported or contradictory between studies.

This review also included data about directional preference, which no previous review has done. There was some evidence that it may be a possible treatment effect modifier, but possibly less important as a prognostic indicator. However data is very limited on the differential prognostic validity of these 2 variables and the prognostic validity of centralization is much more clearly established.

One of the strengths of the review is that our search strategy allowed us to access substantially more data than any previous review. However a weakness has to be noted that we did not gain this comprehensiveness from the initial search, but depended substantially on searches of the reference lists of included articles and the mckenziemdt.org website. We did not need to restrict our search to English language only. Because of the heterogeneity of study design it was clearly inappropriate to attempt to summarise all data, and also not possible to make any overall summary of study quality. In deed as we make clear in the results, and is clear from table 1 there is a large degree of heterogeneity across studies. The sample sizes range from very small to substantial, there is variety in the outcomes, and variety in study designs.

This could be deemed a major flaw, and certainly would in most standard systematic reviews. However we have attempted to summarise *all* the literature on this topic, rather than address a single research question, such as what is the prognostic value on centralization? This review did however relate the prognostic validity of centralization to a definite quality review criteria, and found that high and weak quality studies provided strong evidence in favour of the prognostic validity of centralization; whereas moderate quality evidence was contradictory.

Although the evidence does not appear to be as overwhelming as in the first review of centralization (Aina et al., 2004); the majority of the evidence is still supportive of this clinical symptom response as being common, mostly reliably assessed, and generally associated with a good prognosis. Thus the clinical implications still remain about the importance of assessing with the use of repeated movements for the presence of directional preference or centralization.

Clearly more research is needed, especially given the contradictory or limited nature of some of the evidence reviewed. There is the suggestion, especially from more recent literature that the prognostic value of centralization declines with increasing chronicity of symptoms, and with older patients, and also that centralization is a more useful prognostic indicator than directional preference. There is limited evidence relating to the topic in patients with neck pain, and there is an urgent need for a long-term cohort study to determine the prognostic value of these phenomena in these patients. More evidence is needed about their role as treatment effect modifiers.

## **Conclusion**

Centralization and directional preference appear to be well accepted concepts commonly encountered by clinicians examining patients with back and neck pain, of a specific or non-specific nature, and have been reported in at least 62 studies, most of which deal with centralization. This review attempted to summarise the data from these studies. Centralization is generally, but not universally associated with a good prognosis, but this effect declines in certain sub-groups. The evidence for directional preference and prognosis is more limited, though it is better for directional preference as a treatment effect modifier. Studies into the reliability of determination of centralization and directional preference have been contradictory. The review also summarised evidence about the relevant loading strategies, and the diagnostic implication of centralization.

## **References**

- Abdulwahab SSA, Beatti MA. The effect of prone position and interferential therapy on lumbosacral radiculopathy. *Advances in Physiotherapy* 2006;8:82-7.
- Aina A, May S, Clare H. Centralization of spinal symptoms – a systematic review of a clinical phenomenon. *Manual Therapy* 2004;9:134-43.
- Bogduk N, Lord S. A prospective study of centralization of lumbar and referred pain: a predictor of symptomatic disc and annular competence: commentary. *Pain Medicine Journal Club* 1997;3:246-8.
- Broetz D, Kuker W, Maschke E, Wick J, Dichgans J, Weller M. A prospective trial of mechanical physiotherapy for lumbar disk prolapse. *Journal of Neurology* 2003;250:746-9.

Broetz D, Hahn U, Maschke E, Wick W, Kueker W, Weller M. Lumbar disk prolapse: response to mechanical physiotherapy in the absence of changes in magnetic resonance imaging. Report of 11 cases. *NeuroRehab* 2008;23:289-94.

Broetz D, Burkard S, Weller M. A prospective study of mechanical physiotherapy for lumbar disk prolapse: five year follow-up and final report. *NeuroRehab* 2010;26:155-8.

Browder DA, Childs JD, Cleland JA, Fritz JM. Effectiveness of an extension-oriented treatment approach in a subgroup of subjects with low back pain: a randomized clinical trial. *Physical Therapy* 2007;87(12):1608-18.

Bybee R, Hipple L, McConnell R, Crossland P. The relationship between reported pain during movement and centralization of symptoms in low back pain patients. *Manuelle Therapie* 2005;9:122-7 (In German). English version *International Journal of Manual Diagnosis and Therapy* 1.2.8-13.

Bybee F, Olsen D, Cantu-Boncser G, Condie Allen H, and Byars A. Centralization of symptoms and lumbar range of motion in patients with low back pain. *Physiotherapy Theory and Practice* 2009;25(4):257-67.

Childs JD, Fritz JM, Flynn TW, Irrgang JJ, Johnson KK, Majkowski GR, Delitto A. A clinical prediction rule to identify patients with low back pain most likely to benefit from spinal manipulations: a validation study. *Annals of Internal Medicine* 2004;141(12):920-8.

Chorti AG, Chortis AG, Strimpakos N, McCarthy CJ, Lamb SE. The prognostic value of symptom responses in the conservative management of spinal pain. A systematic review. *Spine* 2009;34(24):2686-99.

Christiansen D, Larsen K, Jensen OK, Nielsen CV. Pain responses in repeated end-range spinal movements and psychological factors in sick-listed patients with low back pain: is there an association? *Journal of Rehabilitation Medicine* 2009;41:545-9.

Christiansen D, Larsen K, Jensen OK, Nielsen CV. Pain response classification does not predict long-term outcome in patients with low back pain who are sick listed. *Journal of Orthopedic Sports Physical Therapy* 2010;40(10):606-15.

Cleland JA, Childs JD, Palmer JA, Eberhart S. Slump stretching in the management of non-radicular low back pain: a pilot clinical trial. *Manual Therapy* 2006;11:279-86.

Delitto A, Cibulka MT, Erhard RE, Bowling RW, Tenhula JA. Evidence for use of an extension-mobilization category in acute low back syndrome: a prescriptive validation pilot study. 1993;73(4):216-22.

Dionne CP, Bybee RF, Tomaka J. Inter-reliability of McKenzie assessment in patients with neck pain. *Physiotherapy* 2006;92:75-82.

Donelson R, Murphy K, Silva G. Centralisation Phenomenon: Its usefulness in evaluating and treating referred pain. *Spine* 1990;15(3):211-3.

Donelson R, Grant W, Kamps C, Medcalf R. Pain response to sagittal end-range spinal motion: a prospective, randomized multicentered trial. *Spine* 1991;16(6S):S206-S212.

Donelson R, Aprill C, Medcalf R, Grant W. A prospective study of centralization of lumbar and referred pain. A predictor of symptomatic discs and annular competence. *Spine* 1997;22(10):1115-22.

Edmond SL, Werneke MW, Hart DL. Association between centralization, depression, somatisation, and disability among patients with nonspecific low back pain. *Journal of Orthopedic and Sports Physical Therapy* 2010;40(12):801-10.

Erhard RE, Delitto A, Cibulka MT. Relative effectiveness of an extension program and a combined program of manipulation and flexion and extension exercises in patients with acute low back syndrome. *Physical Therapy* 1994;74(12):1093-100.

Fritz JM, Delitto A, Vignovic M, Busse RG. Interrater reliability of judgements of the centralization phenomenon and status change during movement testing in patients with low back pain. *Archives Physical Medicine and Rehabilitation* 2000;81:57-61.

Fritz JM, Delitto A, Erhard RE. Comparison of classification-based physical therapy with therapy based on clinical practice guidelines for patients with acute low back pain: a randomized clinical trial. *Spine* 2003;28(13):1363-71.

Fritz JM, Brennan GP, Clifford SN, Hunter SJ, Thackeray A. An examination of the reliability of a classification algorithm for subgrouping patients with low back pain. *Spine* 2006;31(1):77-82.

Fritz JM, Brennan GP. Preliminary examination of a proposed treatment-based classification system for patients receiving physical therapy interventions for neck pain. *Physical Therapy* 2007; 87(5):513-24.

George SZ, Bialosky JE, Donald DA. The centralization phenomenon and fear-avoidance beliefs as prognostic factors for acute low back pain: a preliminary investigation involving patients classified for specific exercise. *Journal of Orthopedic and Sports Physical Therapy* 2005;35:580-8.

Hall H, McIntosh G, Boyle C. Effectiveness of a low back pain classification system. *Spine Journal* 2009;9:648-57.

Hefford C. McKenzie classification of mechanical spinal pain: profile of syndromes and directions of preference. *Manual Therapy* 2008;13:75-81.

Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a

stabilization exercise program. Archives Physical Medicine and Rehabilitation 2005;86:1753-62.

Hudak P, Cole D, Haines A. Understanding prognosis to improve rehabilitation: the example of lateral elbow pain. Archives Physical Medicine and Rehabilitation 1996;77:586-93.

Karas R, McIntosh G, Hall H, Wilson L, Melles T. The relationship between nonorganic signs and centralization of symptoms in the prediction of return to work for patients with low back pain. Physical Therapy 1997;77(4):354-60.

Kilby J, Stigant M, Roberts A. The reliability of back pain assessment by physiotherapists, using a 'McKenzie algorithm'. Physiotherapy 1990;76(9):579-83.

Kilpikoski S, Airaksinen O, Kankaanpaa M, Leminen P, Videman T, Alen M. Inter-tester reliability of low back pain assessment using the McKenzie method. Spine 2002;27(8):E207-E214.

Kilpikoski S, Alen M, Paatelma M, Simonen R, Heinonen A, Videman T. Outcome comparison among working adults with centralizing low back pain: secondary analysis of a randomized controlled trial with 1-year follow-up. Advances in Physiotherapy 2009;11(3):210-7.

Kilpikoski S, Alen M, Simonen R, Heinonen A, Videman T. Does centralizing pain on the initial visit predict outcome among adults with low back pain? A secondary analysis of a randomized controlled trial with 1-year follow-up. Manuelle Therapie 2010;14:136-41. (In German) English version: International Journal of Mechanical Diagnosis and Therapy 2010;5(3):18-24.

Laslett M, Oberg B, Aprill CN, McDonald B. Centralization as a predictor of provocation discography results in chronic low back pain, and the influence of disability and distress on diagnostic power. Spine Journal 2005;5:370-80.

Laslett M, Aprill CN, McDonald B, Oberg B. Clinical predictors of lumbar provocation discography: a study of clinical predictors of lumbar provocation discography.

European Spine Journal 2006a;15:1473-84.

Laslett M, McDonald B, Aprill CN, Tropp H, Oberg B. Clinical predictors of screening lumbar zygapophyseal joint blocks: development of clinical prediction rules. Spine Journal 2006b;6:370-9.

Lisi AJ: The centralization phenomenon in chiropractic spinal manipulation of discogenic low back pain and sciatica. Journal of Manipulative and Physiological Therapeutics 2001;24(9):596-602.

Long AL. The centralisation phenomenon. Its usefulness as a predictor of outcome in conservative treatment of chronic low back pain (a pilot study). Spine 1995;20(23):2513-21.

Long , Donelson R, Fung T. Does it matter which exercise? A randomized control trial of exercise for low back pain. Spine 2004;29(23):2593-602.

Long A, May S, Fung T. Specific directional exercises for patients with low back pain: a case series. Physio Canada 2008;60(4):307-17.

Long A, May S, Fung T. The comparative prognostic value of directional preference and centralization: a useful tool for front-line clinicians? Journal of Manual and Manipulative Therapy 2009;16(4):248-54.

May S. Classification by McKenzie's Mechanical Syndromes: A survey of McKenzie-trained faculty. Journal of Manipulative and Physiological Therapeutics 2006;29(8).637-42.

May S, Gardiner E, Young S, Klaber-Moffett J. Predictor variables for a positive long-term functional outcome in patients with acute and chronic neck and back pain



treated with a McKenzie approach: a secondary analysis. *Journal of Manual and Manipulative Therapy* 2008;16(3):155-60.

McKenzie R, May S. *The Lumbar Spine Mechanical Diagnosis and Therapy*. 2<sup>nd</sup> ed. Waikanae, New Zealand: Spinal Publications New Zealand Ltd; (2003).

Mitchell UH, Wooden MJ, McKeough DM. The short-term effect of lumbar positional distraction. *Journal of Manual and Manipulative Therapy* 2001;9(4):213-21.

Murphy DR, Hurwitz EL. A theoretical model for the development of a diagnosis-based clinical decision rule for the management of patients with spinal pain. *BMC Musculoskeletal Disorders* 2007;8:75.

Murphy DR, Hurwitz EL, McGovern EE. Outcome of pregnancy-related lumbopelvic pain treated according to a diagnosis-based decision rule: a prospective observational cohort study. *Journal of Manipulative and Physiological Therapeutics* 2009a;32(8):616-24.

Murphy DR, Hurwitz EL, McGovern EE. A nonsurgical approach to the management of patients with lumbar radiculopathy secondary to herniated disk: a prospective observational cohort study with follow-up. *Journal of Manipulative and Physiological Therapeutics* 2009b.32(9):723-33.

Niemisto L, Sarna S, Lahtinen-Suopanki T, Lindgren KA, Hurri H. Predictive factors for 1-year outcome of chronic low back pain following manipulation, stabilizing exercises, and physician consultation or physician consultation alone. *Journal of Rehabilitation Medicine* 2004;36:104-9.

Petersen T, Laslett M, Thorsen H, Manniche C, Ekdahl C, Jacobsen S. Diagnostic classification of non-specific low back pain. A new system integrating patho-anatomic and clinical categories. *Physiotherapy Theory and Practice* 2003;19: 213-37.

Piva SR, Erhard RE, Childs JD, Browder DA. Inter-tester reliability of passive intervertebral and active movements of the cervical spine. *Manual Therapy* 2006;11:321-30.

Rapala A, Rapala K, Lukawski S. Correlation between centralization or peripheralization of symptoms in low back pain and the results of magnetic resonance imaging. *Ortopedia Traumatologia Rehabilitacja* 2006;8(5):531-6.

Schmidt I, Rechter L, Hansen VK, Andreasen J, Overvad K. Prognosis of subacute low back pain patients according to pain response. *European Spine Journal* 2008;17:57-63.

Skikic EM, Suad T. The effects of McKenzie exercises for patients with low back pain, our experience. *Bosnian Journal Basic Medicine Science* 2003;iii(4):70-75.

Skytte L, May S, Petersen P: Centralization: Its prognostic value in patients with referred symptoms and sciatica. *Spine* 2005;30(11):E293-E299.

Snook SH, Webster BS, McGorry RW, Fogleman MT, McCann KB. The reduction of chronic nonspecific low back pain through the control of early morning lumbar flexion. A randomized controlled trial. *Spine* 1998;23(23):2601-7.

Sufka A, Hauger B, Trenary M, Bishop B, Hagen A, Lozon R, Martens B. Centralisation of low back pain and perceived functional outcome. *Journal of Orthopedic and Sports Physical Therapy* 1998;27(3):205-12.

Tuttle N. Do changes within a manual therapy treatment session predict between-session changes for patients with cervical spine pain? *Australian Journal of Physiotherapy* 2005;51:43–48.

Tuttle N, Laakso L, Barrett R. Changes in impairments in the first two treatments predicts outcome in impairments, but not in activity limitations, in subacute neck pain: an observational study. *Australian Journal of Physiotherapy* 2006;52:281-5.

Tuttle N. Is it reasonable to use an individual patient's progress after treatment as a guide to ongoing clinical reasoning. *Journal of Manipulative and Physiological Therapeutics* 2009;32(5):396-403.

Van Dillen LR, Sahrman SA, Norton BJ, Caldwell CA, McDonnell MK, Bloom N. The effect of modifying patient-preferred spinal movement and alignment during symptom testing in patients with low back pain: a preliminary report. *Archives Physical Medicine and Rehabilitation* 2003;84:313-22.

Werneke M, Hart DL, Cook D. A descriptive study of the centralization phenomenon. *Spine* 1999;24(7):676-83

Werneke M, Hart DL. Centralization phenomenon as a prognostic factor for chronic pain or disability. *Spine* 2001;26(7):758-65.

Werneke M, Hart DL. Discriminant validity and relative precision for classifying patients with non-specific neck and back pain by anatomic pain patterns. *Spine* 2003;28(2):161-6.

Werneke MW, Hart DL. Categorizing patients with occupational low back pain by use of the Quebec Task Force Classification system versus pain pattern classification procedures: discriminant and predictive validity *Physical Therapy* 2004;84(3):243-54.

Werneke M, Hart DL. Centralization: association between repeated end-range pain responses and behavioural signs in patients with acute non-specific low back pain. *Journal of Rehabilitation Medicine* 2005;37:286-90.

Werneke M, Hart DL, Resnik L, Stratford PW, Reyes A. Centralization: prevalence and effect on treatment outcomes using a standardized operational definition and measurement method. *Journal of Orthopedic and Sports Physical Therapy* 2008;38(3):116-25.

Werneke MW, Hart DL, George SZ, Stratford PW, Matheson JW, Reyes A. Clinical outcomes for patients classified by fear-avoidance beliefs and centralization phenomenon. *Archives Physical Medicine and Rehabilitation* 2009;90:768-77.

Werneke MW, Hart DL, Oliver D, McGill T, Grigsby D, Ward J, Weinberg J, Oswald W, Cutrone G. Prevalence of classification methods for patients with lumbar impairments using the McKenzie syndromes, pain pattern, manipulation, and stabilization clinical prediction rules. *Journal of Manual and Manipulative Therapy* 2010;18(4):197-204.

Werneke MW, Hart DL, Cutrone G, Oliver D, McGill T, Weinberg J, Grigsby D, Oswald W, Ward J. Association between directional preference and centralization in patients with low back pain. *Journal of Orthopedic and Sports Physical Therapy* 2011;41(1):22-31.

Williams MM, Hawley JA, McKenzie RA, Van Wijmen PM. A comparison of the effects of two sitting postures on back and referred pain. *Spine* 1991;16(10):1185-91.

Young S, Aprill C, Laslett M. Correlation of clinical examination characteristics with three sources of chronic low back pain. *Spine J* 2003;3:460-5.