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We apologize in advance if anyone provided peer review to the JMPT in the year 2006 and was not acknowledged on this list. If this has occurred, please contact the journal editor and a correction will be printed with the next listing.
Measuring Posterior to Anterior Stiffness.

Owens et al (p 116) assess the reliability of a new hand-held posterior-to-anterior spinal stiffness measuring system. Stiffness values in patients with low back pain were comparable with those measured with mechanical systems. Statistics indicated very good intraexaminer reliability over the short term.

Warning Signs of Deep Vein Thrombosis.

Fernandez et al (p 144) present a case report of deep vein thrombosis. Easily mistaken for a musculoskeletal injury, deep vein thrombosis may not present with symptoms of swelling, warmth, discoloration, and pain. This article describes how practitioners can be more conscious of this type of vascular disorder.

Who Cares About Research?

Suter et al (p 109) investigate the perceptions of doctors of chiropractic and massage therapists toward research and find that both have an overall positive perception but limited application in practice. Differences in research skills and evidence-based practice between the 2 professional groups may be attributed to the chiropractic profession’s relatively more research-focused professional training.

Chiropractic Care Integrated Into an Orthopedic Department.

Orlin and Didriksen (p 135) present the results of 44 sciatic patients, without changes of clinical or neurological parameters, who were treated by a chiropractor for lumbopelvic fixation. Forty-two of these patients returned to work in less than one third of the time normally needed after medical treatment. The unusual nature of this case is that the chiropractic care was integrated into an orthopedic department.

What Mysteries Can a Magnetic Resonance Imaging Reveal?

Jensen et al (p 98) evaluated 154 patients with sciatic pain who underwent magnetic resonance imaging (MRI) examinations at baseline and at 14 months follow-up. They investigate the possible association of disk-related MRI findings in relation to definite recovery and find that gender is a factor with MRI findings and recovery rates.

Pregnancy and Musculoskeletal Pain.

Skaggs et al (p 130) identify the prevalence of pregnancy-related musculoskeletal pain and its treatment in an underserved population of nearly 600 women. Sixty-seven percent had musculoskeletal pain, and 85% of them were not offered treatment of their pain. The authors suggest that this group of patients should receive more attention and care.

Precise Measurements of Posture.

Janik et al (p 124) used a set of 3 photographs of numerous positions of a mannequin head in a university biomechanics laboratory. The calculations of rotations and translations in 3D by a computer program, Posture-Print, were found to be accurate to 1.5° and 1.5 mm.

Differences in Trunk Motor Control.

Descarreaux et al (p 91) correlate changes in isometric force parameters and trunk muscle recruitment in a low back pain population. Patients with low back pain showed longer time to peak force value and longer electromyographic burst duration for abdominal and back muscles.

How to Recognize an Intracranial Aneurysm.

Larkin-Their et al (p 140) present a case study of a patient with headache symptoms that necessitated immediate referral for additional evaluation and surgical intervention. This article reviews the “red flags” that should be considered when evaluating patients with headache and possible intracranial aneurysm.

A Reliable System for Detecting Degenerative Marrow Changes.

Peterson et al (p 85) investigate the reliability of using the Modic classification system for diagnosing degenerative marrow changes in the lumbar spine on magnetic resonance imaging. The methods used simulated the diagnostic methods used in the clinical practice setting and thus could be considered for practice in addition to future research.

Traction Therapy and Synovial Cysts.

Taylor (p 152) presents of a case in which synovial cysts seemed to cause compromise of the neural foramina and the thecal sac, leading to initial improper attribution of neurological signs. Subsequent correlation with spondylolisthesis and conservative treatment of the instability resulted in a positive clinical outcome.
ORIGINAL ARTICLES

INTER- AND INTRAEXAMINER RELIABILITY IN IDENTIFYING AND CLASSIFYING DEGENERATIVE MARROW (MODIC) CHANGES ON LUMBAR SPINE MAGNETIC RESONANCE SCANS

Cynthia K. Peterson, RN, DC, MMedEd,a Brian Gatterman, DC,b J.C. Carter, DC,b B. Kim Humphreys, DC, PhD,c and Alexandra Weibel, DCd

ABSTRACT

Objective: Signal intensity changes noted on magnetic resonance imaging scans in degenerated disks and adjacent bone marrow have been described and labeled “Modic” changes. Three types are identified, with type 1 being linked to low back pain. This study reports on the reliability of identifying and categorizing Modic marrow changes as would be done in the normal course of clinical practice.

Methods: Fifty-one lumbar spine sagittal magnetic resonance imaging scans of adult male patients older than 40 years were used. Two radiologists independently read each case at 2 different periods; scans were reordered for the second reading. The radiologists recorded the presence or absence of Modic changes anywhere in the lumbar spine for each case and classified each one as type 1, type 2, or type 3, and the level or levels where they were noted. The $\kappa$ statistic was used to evaluate inter- and intraexaminer agreement overall and by disk level. Percent agreement was also calculated.

Results: The overall $\kappa$ value for the interexaminer agreement of diagnosing the presence/absence of Modic changes for the entire lumbar spine as well as classifying them when present was $\kappa = 0.52$ (moderate) with 71% agreement. At the L4 through 5 level, the $\kappa$ value was 0.81 (substantial) with 92% agreement, and at the L5 through S1 level, the $\kappa$ value was 0.58 (upper moderate) with 76% agreement. The L3 through L4 level had a $\kappa$ value of 0.66 (strong) but was considered “unstable” because of the lack of variability within the cells of the contingency table. The intraexaminer reliability gave a $\kappa$ value of 0.71 (strong) (82% agreement) for examiner 1 and a $\kappa$ value of 0.87 (almost perfect) (92%) for examiner 2.

Conclusions: The Modic classification system shows moderate to almost perfect inter- and intraexaminer reliability in this study, simulating the methods of diagnosis used in clinical/radiological practice. The results of studies using the Modic system before investigations of its reliability can be viewed with more confidence, and future studies can continue to evaluate the link with patient symptoms and treatment outcomes.

(J Manipulative Physiol Ther 2007;30:85-90)

Key Indexing Terms: Reproducibility of Results; Magnetic Resonance Imaging; Intervertebral Disk; Bone Marrow

Degenerative disk and joint disease of the lumbar spine is a frequent finding on plain film imaging, particularly with advancing age.¹ However, the correlation between the quantity and severity of lumbar degeneration, as determined from plain films, with reported pain levels, is weak, and there is no correlation between the

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plain film findings and reported disability levels.\textsuperscript{2} It has been suggested that degenerative disk disease and facet arthrosis are most symptomatic when they are in the early phases, often before any significant plain film findings,\textsuperscript{3} thus explaining the poor correlation between radiographs and patient symptoms.

Magnetic resonance imaging (MRI) has the ability to show degenerative disk disease at a much earlier phase than plain film radiography\textsuperscript{3}, and therefore, abnormal magnetic resonance (MR) findings of degeneration may have a stronger correlation to patient symptoms. In addition to signal intensity changes in the degenerated disks, changes in the adjacent bone marrow signal have been described,\textsuperscript{4,5} which cannot be seen on plain films. Originally, these marrow changes appeared similar to those described with spinal infections or tumors, and several authors emphasized the importance of distinguishing degenerative marrow changes from more sinister pathology.\textsuperscript{4,5,6} Dr Michael Modic\textsuperscript{5} was among the first to identify and classify degenerative marrow changes surrounding a dehydrated lumbar disk, and thus, his name has been attached to these abnormal MRI characteristics. Modic type 1 changes show decreased signal intensity on T1-weighted spin echo images and increased signal intensity on T2-weighted spin echo images (Figs 1 and 2). Type 2 changes show increased signal intensity on T1-weighted spin echo images with isointense or slightly increased signal intensity on T2-weighted images\textsuperscript{5,7,8} (Figs 1 and 2). There is also a category called Modic type 3, representing decreased signal intensity on both T1- and T2-weighted images, corresponding to the subchondral sclerosis seen on plain film radiographs.

Histologic studies determined that Modic type 1 changes are associated with disruption and fissuring of the vertebral end plates and vascularized fibrous tissue (inflammatory stage).\textsuperscript{5,8,10} Type 2 changes, which are more common, show yellow or fatty marrow replacement.\textsuperscript{7} Modic type 1 changes have been shown to enhance with gadolinium, reflecting the vascularity of the fibrous tissue, whereas there is no enhancement in type 2 marrow changes.\textsuperscript{6} Furthermore, longitudinal studies have shown that Modic type 1 changes eventually convert to the fatty marrow type 2 changes, usually within 14 to 36 months,\textsuperscript{8,10} and that it is extremely rare for type 2 changes to convert to type 1. Thus, there is a continuum of degenerative Modic changes, starting with type 1 early on and progressing to type 2 (and, in some cases, eventually to type 3) over time. In addition, Modic
type 1 marrow changes can be induced quickly, within 6 to 12 weeks, after the injection of chymopapain into the disk and are associated with further loss of disk height.9

A few studies have attempted to link these degenerative marrow changes to patient symptoms. A recent article by Kjaer et al11 looked for linkages between MRI findings and low back pain in 40-year-old men and women. Only Modic changes and antero–retrolisthesis were associated with patient symptoms. Because of the relatively young age of their population, most of the Modic changes were type 1, and the researchers stated that they grouped all types of Modic changes together for data analysis.11 Indeed, type 1 marrow changes appear to be at least weakly associated with increased levels of low back pain, with symptoms diminishing when the signal intensity converts to type 2 fatty marrow.8,12 In addition, it has been suggested that one reason for increased low back pain in patients with type 1 changes is that there is transient instability at the motion segment demonstrating type 1 changes.10,13 However, Modic changes are noted on the MRI scans of asymptomatic people as well7 but, predominantly, the fatty marrow changes seen in type 2.

Although a few studies have suggested that type 1 marrow changes are linked with low back pain and that type 1 changes convert to type 2 over time with a lessening of symptoms, no study also looked at disability levels in patients with Modic changes. Furthermore, studies need to first establish the reliability of identifying and categorizing Modic marrow changes. It appears from the literature that the accuracy of diagnosis and classification has been assumed, with only 1 recent study evaluating the reliability of the classification system at a single lumbar spinal level.14 This current study expands on that work by examining the inter and intraexaminer reliability of detecting Modic changes on lumbar spine MRI scans at all lumbar spinal levels, as well as categorizing these changes into types 1, 2, and 3 when present. This replicates the diagnostic procedure that is done in clinical and radiological practices. Future studies on these degenerative marrow changes can continue to focus on the link with patient symptoms using larger sample sizes as well as the effect that these marrow changes may have on patient outcomes from various treatments.15

These future studies will only be strengthened by establishing the inter- and intraexaminer reliability of the diagnosis of Modic changes in the clinical practice setting.

### Methods

A convenience sample of 51 lumbar spine sagittal T1- and T2-weighted MRI scans, already obtained in adult male patients older than 40 years as part of their clinical workup, were used.10 The images were done on a 0.6-T MRI unit, with patient identification removed. The principal investigator ensured that several patients without Modic changes, as well as those with Modic types 1 and 2 marrow changes, were included in the 51 cases selected. Two radiologists (examiners 1 and 2), already well versed in the Modic classification system, independently read each case at 2 different periods, approximately 3 months apart. After the first assessment, the scans were reordered for the second reading. The radiologists recorded the presence or absence of degenerative marrow changes (Modic changes) for each case. If Modic changes were present (any evidence of marrow signal intensity change adjacent to a degenerated disk), the radiologists classified each one identified as type 1, 2, or 3 and the level or levels where they were noted on each patient. Modic type 1 changes showed low signal intensity on T1-weighted images and high-signal intensity on T2-weighted images. Type 2 marrow changes are of high-signal intensity on T1- and either high-signal or isointense to normal bone marrow on T2-weighted images. Modic type 3 marrow changes are consistently low-signal intensity on both T1- and T2-weighted MRI scans. These data were recorded and transferred to contingency tables. No clinical information was given to the radiologists. The study received approval from the appropriate research ethics boards before commencement.

The κ statistic was used to evaluate inter- and intraexaminer agreement overall and by disk level because the data were categorical. The Landis and Koch17 system of κ interpretation was used, where 0 to 0.2 is slight agreement, 0.21 to 0.40 indicates fair agreement, 0.41 to 0.60 is moderate agreement, 0.61 to 0.80 is strong or substantial agreement, and 0.81 to 1.00 indicates very strong or almost perfect agreement (a value of 1.0 being perfect agreement).

### Results

The T1- and T2-weighted sagittal MRI scans of 51 patients were evaluated by the 2 experienced radiologists, with interexaminer agreement on the total absence of Modic

### Table 1. κ and Weighted κ values for inter and intraexaminer reliability

<table>
<thead>
<tr>
<th></th>
<th>κ</th>
<th>Weighted κ</th>
<th>95% Confidence interval</th>
<th>Percent agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interexaminer reliability for entire lumbar spine</td>
<td>0.52</td>
<td>0.49</td>
<td>0.29-0.68</td>
<td>71%</td>
</tr>
<tr>
<td>Interexaminer reliability, L3 through L4</td>
<td>0.66 (unstable)</td>
<td>0.64</td>
<td>0.19-1.11</td>
<td>94%</td>
</tr>
<tr>
<td>Interexaminer reliability, L4 through L5</td>
<td>0.81</td>
<td>0.78</td>
<td>0.57-0.98</td>
<td>92%</td>
</tr>
<tr>
<td>Interexaminer reliability, L5 through S1</td>
<td>0.58</td>
<td>0.54</td>
<td>0.31-0.77</td>
<td>76%</td>
</tr>
<tr>
<td>Intraexaminer reliability, radiologist 1</td>
<td>0.70</td>
<td>0.68</td>
<td>0.51-0.85</td>
<td>82%</td>
</tr>
<tr>
<td>Intraexaminer reliability, radiologist 2</td>
<td>0.86</td>
<td>0.85</td>
<td>0.72-0.98</td>
<td>92%</td>
</tr>
</tbody>
</table>
changes in 16 patients (31%). The examiners also agreed that Modic type 1 degenerative changes were noted at 7 intersegmental levels, with 25 levels showing Modic type 2 changes. No Modic type 3 changes were identified by both examiners. Of the 51 patients evaluated, 12 were diagnosed, by at least 1 of the 2 examiners, with Modic changes at more than 1 spinal level. The most common level to show Modic changes was L5 through S1, with 4 cases of type 1 and 12 cases of type 2, detected by both examiners. The L4 through 5 level was the second most common level to show Modic changes, with 3 cases of type 1 and 8 cases of type 2. The other lumbar spinal levels were rarely identified as having Modic changes.

The overall $\kappa$ value for the interexaminer agreement of diagnosing the presence/absence of Modic changes as well as classifying them when present for the lumbar spine as a whole was 0.52 (weighted $\kappa = 0.49$) (moderate) with 71% agreement (Table 1). At the L4 through 5 level only, the $\kappa$ value was 0.81 (weighted $\kappa = 0.78$) (substantial to almost perfect) with 92% agreement, and at the L5 through S1 level, the $\kappa$ value was 0.58 (weighted $\kappa = 0.54$) (upper moderate), with 76% agreement. Although the L3 through L4 level had a $\kappa$ value of 0.64 (weighted $\kappa = 0.64$) (strong); this was considered “unstable” because of the lack of variability within the cells of the contingency table. Of the 51 patients, 45 were diagnosed with no Modic changes at this level with 94% agreement overall. No $\kappa$ values were calculated for other spinal levels because of their rare occurrence.

The intraexaminer reliability for the detection and classification of Modic changes throughout the lumbar spine as a whole on 2 separate occasions was $\kappa = 0.70$ (weighted $\kappa = 0.68$) (strong), with 82% agreement for examiner 1, and $\kappa = 0.86$ (weighted $\kappa = 0.85$) (almost perfect) with 92% agreement for examiner 2. All results are presented in Table 1.

**Discussion**

This study was purposely designed to replicate the conditions of MRI interpretation, as used in the clinical practice setting. Thus, all lumbar spinal levels were evaluated in the data collection, and a substantial number of healthy subjects (ie, no Modic changes present) were included. In this way, not only the classification system but also the detection of Modic changes were evaluated. Although a recent study found a high level of reliability of the Modic classification system, the researchers only evaluated 1 disk level per patient in which 96% of subjects were predetermined to have Modic changes.4 Although that was an important initial study, it did not provide a clear indication of the reliability of the identification process (presence or absence of Modic changes) or the classification system throughout the lumbar spine as used in the normal course of clinical practice. This information is imperative before further research studies attempt to link these MRI findings with patient symptoms and therapeutic outcomes.

The overall $\kappa$ value in this current study for the interexaminer agreement of determining the presence or absence of Modic changes throughout the lumbar spine, as well as classifying them when present, was moderate ($\kappa = 0.52$). However, at the L4 through L5 and L5 through S1 levels, where most of the Modic changes occurred, the $\kappa$ values were 0.81 (substantial to almost perfect) and 0.58 (high moderate), respectively. These values appear, at first glance, to be lower than those obtained by Jones et al14 who obtained an interexaminer $\kappa$ value of 0.85. However, in the Jones et al study, only 1 disk with adjacent Modic change was chosen for evaluation in each patient and only 2 of their patients had no Modic changes at all. Furthermore, the examiners in their study all had an example of each Modic type available for viewing during the data collection process. Twelve of the patients in this current study showed Modic changes at more than 1 spinal level, and 16 patients had no Modic changes at all. In addition, the examiners in this current study were told to evaluate all disk levels in the lumbar spine, and no examples of the various Modic changes were available for reference during the data collection. Thus, when comparing the Jones et al values with those obtained in this study, the reliability of using this classification system, even under more challenging research conditions, is good. One of the most likely reasons for the “moderate” agreement overall in this study, rather than the “almost perfect” agreement noted at the L4 through L5 level alone, is requiring the examiners to evaluate the entire lumbar spine, rather than a single, predetermined level. This would decrease the level of reliability expected. The inclusion of a substantial number of healthy subjects in the present study also may have reduced the reliability by challenging the confidence levels of the examiners. Thus, the overall $\kappa$ value obtained in this current study is probably more reflective of the actual reliability of using the Modic system in routine clinical practice. Radiologists are often more confident when definite abnormalities are detected. One of the most common disagreements between examiners was when 1 examiner determined that a spinal level was “normal,” whereas the other examiner recorded type 2 changes.

Most of the Modic changes in this present study were not at the L4 through L5 level, as found in the study of Jones et al,14 but at L5 through S1. In addition, all of the subjects in this current project were men, whereas both sexes appeared to have been used in the previous study. Whether there is a sex difference in the prevalence or location of Modic changes in the lumbar spine needs further investigation. Both studies, however, found a preponderance of Modic type 2 marrow changes, as compared to type 1, with type 3 changes being very rarely encountered in either study.

Interestingly, examiner 1 in this study recorded both type 1 and type 2 Modic changes at the same spinal level in 3 of the 51 patients on both reading sessions done 3 months apart.
This certainly decreased the interexaminer reliability. The reasons for this can only be speculated. At first glance, this may seem to be an error on the part of the examiner. However, the literature is quite clear that Modic type 1 changes eventually convert to type 2.8,9,10 This change would not occur instantaneously and would logically be on a continuum. Therefore, examiner 1 may have actually identified those patients in the process of converting from Modic type 1 to type 2, and therefore, applying a single classification to these 3 patients at that particular time was challenging. The literature has not adequately addressed the issue of the “converting Modic change” in terms of using the classification system or linking these changes with patient symptoms. Before the data collection, the 2 radiologists were not specifically instructed to only select 1 of the classification types per spinal level. In fact, the 2 radiologists did not meet together at all before data collection in an attempt to “standardize” how they would identify and classify the Modic changes. This adds further weight to the reliability of using the Modic system in clinical practice. They applied it according to the published criteria, and therefore, any knowledgeable clinician should be able to do the same.

The intraexaminer reliability results were higher than the interexaminer results, as expected. Examiner 1 obtained a $\kappa$ score of 0.70 (strong), and examiner 2 received an almost perfect score of 0.86. Examiner 1 was the radiologist more likely to diagnose either Modic type 1 or 2 changes on his first interpretation and normal on his second interpretation, whereas this rarely occurred with examiner 2. This difference in $\kappa$ values is not related to the experience level of the radiologists because both have many years of experience in image interpretation. Of the 2, examiner 1 is the more experienced in terms of years in practice.

One of the weaknesses of this study may be the absence of any Modic type 3 changes detected by the 2 examiners. However, this is similar to the results in the study of Jones et al14 in which only 1 Modic type 3 change was found in the 50 patients they evaluated. This study adds further support to the reliability of not only the use of the classification system, but the actual detection of Modic changes throughout the lumbar spine, as shown on MRI sagittal images. This system can be used with confidence in research projects linking these marrow changes with patient symptoms and treatment outcomes in the future. More work needs to be done on identifying those Modic changes in the process of converting from type 1 to type 2.

**CONCLUSIONS**

The Modic system for detecting and classifying degenerative marrow changes on lumbar spine MRI scans showed moderate to very substantial inter and intraexaminer reliability in this study, which simulated diagnostic methods used in the clinical practice setting. The results of studies using the Modic system before investigations of its reliability can be viewed with more confidence, and future studies can continue to evaluate the link with patient symptoms and treatment outcomes.

**Practical Applications**

- The Modic classification system shows moderate to substantial interexaminer agreement.
- The Modic classification system shows strong interexaminer reliability.
- Modic type 2 was the most common of the 3 types present.
- The most common level to show Modic changes was L5 through S1.

**ACKNOWLEDGMENT**

The authors thank the TRUEMRI Center for providing the images and Mark Fillery for his most valuable help in formatting the final manuscript.

**REFERENCES**

ISOMETRIC FORCE PARAMETERS AND TRUNK MUSCLE RECRUITMENT STRATEGIES IN A POPULATION WITH LOW BACK PAIN

Martin Descarreaux, DC, PhD,a Catherine Lalonde, BSc,b and Martin C. Normand, DC, PhDc

ABSTRACT

Objective: This study correlates changes in trunk isometric force parameters and trunk muscle recruitment strategies in subjects with low back pain (LBP) and healthy participants.

Methods: A control group study with repeated measures was performed. Study participants included 15 control subjects and 14 patients with LBP. Participants were required to exert 50% and 75% of their maximal trunk flexion and extension. In a learning phase, feedback was provided, after which study participants were asked to perform 10 trials without any feedback. Spatiotemporal parameters of muscular activity and force production were recorded. Dependent variables included time to peak force, peak force variability, absolute error in peak force, electromyogram (EMG) burst duration for agonist muscles, and normalized integrated EMG.

Results: Average time to peak force was significantly longer for subjects with LBP than for healthy subjects. Subjects with LBP showed longer burst duration for all 4 muscles recorded. No group difference was noted in normalized integrated EMG.

Conclusions: We suggest that the observed changes in trunk motor control and trunk muscle recruitment strategies are not only mediated by a neurophysiologic adaptation to chronic pain but also by cognitive adaptations modulated by fear of movement and fear of reinjury. (J Manipulative Physiol Ther 2007;30:91-97)

Key Indexing Terms: Low Back Pain; Motor Activity; Isometric Contraction; Muscle Contraction

Low back pain (LBP) is a major health and socioeconomic problem. It is one of the most common musculoskeletal injuries in Western industrialized societies. Epidemiologic studies have shown that lifetime prevalence of LBP is as high as 79.2% in Australian adults.1 This prevalence rate is very close to those reported in North America and Western Europe.2-6 Moreover, the prevalence of LBP seems to steadily increase with age.7,8 This condition also generates enormous costs. In the United States alone, the total annual costs of treating back pain are estimated to be $20 to $50 billion.7,9

There is strong evidence that approximately 10% of LBP cases account for more than 80% of the cost for LBP because of their chronicity.10-14 Frequently, LBP presents as a chronic condition characterized by a fluctuating pattern rather than a self-limiting course.15-18 As reported by Croft et al,18 most patients with LBP are still symptomatic after 1 year, with only 21% of patients being pain-free and 25% completely recovering from disabilities associated with their low back problems. One study demonstrated that individual, psychosocial, and workplace factors are all associated with the transition from acute to chronic occupational back pain.10 Psychosocial distress/depressive mood and somatization are also considered risk factors for the transition from acute to chronic LBP (cLBP).19

Hestbaek et al15 reported that chronicity should not solely be characterized by the duration of symptoms. Neurophysiologic, anatomical, psychosocial, and sensorimotor control modifications have also been reported in patients with LBP and should then be incorporated in the definition of chronic pain conditions. Impairments in sensorimotor control seem to be an integral part of cLBP and many authors have investigated these changes. Brumagne and colleagues20,21 reported that in a pelvic tilt task the repositioning accuracy of subjects with LBP was significantly lower than that of healthy subjects. Patients with cLBP also showed greater absolute errors in repositioning accuracy for 2 different tasks1: trunk repositioning in flexion and2 lumbar repositioning in a
4-point kneeling position. Moreover, subjects with LBP exhibited changes in postural control, delayed muscle responses to sudden trunk loading, and increased trunk movement detection threshold. Finally, recent data suggest that the higher activation of global abdominal musculature and altered synergist patterns observed in subjects with LBP may represent a motor control adaptation that would perpetuate dysfunction and chronic pain. Descarreaux et al investigated the motor control strategies and the variability of isometric trunk force production in subjects with LBP. They observed that subjects with LBP used 2 different control strategies to produce accurate trunk isometric forces. Their conclusion was that some subjects with LBP, to perform a task as accurately as healthy subjects, changed their motor strategy by adopting a more close-loop control.

Because it is known that subjects with LBP are able to modulate their control strategy to increase their performance in an isometric force reproduction task, the aim of the present study was to evaluate if trunk muscle recruitment strategies are modified concurrently with isometric force control adaptations. Assuming that subjects with LBP, if given sufficient time, can change their motor strategy to perform as accurately as healthy subjects, we hypothesize that subjects with cLBP presenting an adaptation in their isometric control strategies should also demonstrate an adaptation in their trunk muscle recruitment strategies, such as increased duration of electromyogram (EMG) burst and modulation of EMG activity.

Therefore, the main objective of this study is to determine whether subjects with cLBP increase their time to peak force only by modifying the duration or amplitude of trunk muscle bursts. Identification of muscle recruitment and isometric force control strategies modifications will eventually help in the development of appropriate rehabilitation protocols and effective return to work procedures.

**Methods**

**Subjects**

Force production parameters were measured in 14 subjects with chronic nonspecific LBP and in 15 control subjects. Every participant gave informed written consent and the study was approved by the Université du Québec à Trois-Rivières (Trois-Rivières, Quebec, Canada) ethics committee. All subjects were recruited through local advertising. The experimental group (LBP) included 14 subjects (11 men, 3 women; average age, 36.6 years) who had a history of chronic recurrent LBP that lasted for at least 6 months. Exclusion criteria for both groups were spondylolisthesis or spondylolysis, ankylosing spondylitis, spinal osteoarthritis or inflammatory arthritis, nerve root compression, trunk neuromuscular disease, scoliosis (15° or more), previous spinal surgery, malignant tumor, hypertension, pregnancy, and breast-feeding. Lateral and anteroposterior radiographs of the lumbar spine (including pelvis) were taken to rule out the possibility of congenital, degenerative, or inflammatory diseases of the lumbar spine. Pain levels at the beginning and the end of the experiment were assessed by using a standard 100-mm visual analog pain scale (VAS). Each subject with LBP completed the modified Oswestry questionnaire before the experiment. The control group consisted of 15 healthy subjects (10 men, 5 women; average age, 34.5 years). Table 1 shows the details of both experimental and control groups.

**Force Data Recording and Analysis**

Subjects were asked to exert 50% and 75% of the maximal flexion and extension forces of trunk muscles against a harness connected to an isometric testing apparatus (Loredan Biomedical, West Sacramento, Calif). During the maximal voluntary contractions, subjects were verbally encouraged to give their maximum effort in both flexion and extension. The higher force value obtained in 3 consecutive 4-second trials was used as the reference for maximal voluntary contraction. Testing was done in a neutral standing posture (Fig 1).

Subjects had to learn to produce each of the 4 experimental conditions (50% and 75% of the maximal isometric force in extension and flexion), with their eyes closed, within an error margin of ±10%. For each trial, subjects were instructed to produce a rapid isometric force as soon as they hear the start signal given by the experimenter. They were encouraged to produce a single impulse (“shoot and release”) and to make no attempt at correcting the force once the contraction was initiated. After each learning trial, subjects opened their eyes and looked at their result on an oscilloscope (visual accuracy feedback) located in front of them. They could then evaluate their performance and correct it for the next trial, if necessary. The learning sequence stopped when 5 consecutive trials were successfully made (within the 10% margin). Immediately after these learning trials, subjects were asked to perform 10 consecutive trials without any visual feedback. All conditions were performed by block.

For every trial (3 seconds), torque data were recorded at a sampling rate of 500 Hz. Torque data were digitally filtered with a seventh-order Butterworth filter (7-Hz low-pass cutoff frequency). Onset of force and peak force were then determined in every trial for each subject. Using this information, we calculated time to peak force, time to peak

| Table 1. Basic data on LBP and healthy study participants |
|-----------------------------|-------------|
| **Controls (mean [SD])**    | **LBP (mean [SD])** |
| Subjects                  | n = 15      | n = 14      |
| Age (y)                    | 34.5 (12.9) | 36.6 (12.8) |
| Height (cm)                | 173.9 (6.3) | 171.6 (8.9) |
| Weight (kg)                | 70.6 (13.1) | 76.8 (10.8) |
| Oswestry index (%)         | –           | 22.6 (11.3) |
| Before testing             | –           | 2.0 (1.4)   |
| After testing              | –           | 2.7 (2.1)   |

<table>
<thead>
<tr>
<th>( V_A S ) (mm)</th>
<th>–</th>
<th>–</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>70.6 (13.1)</td>
<td>76.8 (10.8)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.9 (6.3)</td>
<td>171.6 (8.9)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>34.5 (12.9)</td>
<td>36.6 (12.8)</td>
</tr>
<tr>
<td>Subjects</td>
<td>n = 15</td>
<td>n = 14</td>
</tr>
<tr>
<td>Before testing</td>
<td>–</td>
<td>2.0 (1.4)</td>
</tr>
<tr>
<td>After testing</td>
<td>–</td>
<td>2.7 (2.1)</td>
</tr>
</tbody>
</table>

\( F_10 \) shot and release and to make no attempt at correcting the force once the contraction was initiated. After each learning trial, subjects opened their eyes and looked at their result on an oscilloscope (visual accuracy feedback) located in front of them. They could then evaluate their performance and correct it for the next trial, if necessary. The learning sequence stopped when 5 consecutive trials were successfully made (within the 10% margin). Immediately after these learning trials, subjects were asked to perform 10 consecutive trials without any visual feedback. All conditions were performed by block.
force variability, peak force variability as well as absolute error in peak force for each condition. Absolute error in peak force represents the positive difference between the reached peak force on each trial and the goal peak force, whereas time to peak represents the period between the beginning of rising force and the maximal force obtained in the trial.

Electromyographic Recording and Analysis

During each trial, spatiotemporal parameters of muscular activity (EMG) were recorded at a sampling rate of 1000 Hz. Bipolar disposable surface Ag-AgCl electrodes (Bortec Biomedical, Calgary, Alberta, Canada) were applied unilaterally over the surface of the right erector spinae L2 through L3, right lumbar multifidus L5 through S1, right rectus abdominis, and right external oblique. The reference electrode was placed over the acromion. The signals were preamplified at the source (gain = 500) before a second-level amplification (bandpass of 10 Hz-1 kHz; Bortec Amt-8, Bortec Biomedical). The EMG signals were bandpass filtered (100-1000 Hz) and full-wave rectified to determine the onset and duration of each muscle EMG burst during isometric contraction. The EMGs were integrated (iEMG) and expressed as a percentage of baseline muscle activity at rest because of the poor quality of EMG signal during maximal contractions in some subjects to determine the level of muscular activity during each condition. Integrated EMG allows for observation of the accumulated EMG activity over a predetermined period. Electromyogram-dependent variables included EMG burst duration for agonist muscles and amplitude of EMG using numerical integrated techniques. All burst onsets and endings were first determined visually by inspecting the EMG signals of the agonist muscles (rectus abdominis and external oblique during flexion and erector spinae and multifidus during extension) to identify the relevant EMG burst. Onsets and endings were objectively confirmed when the activity exceeded (±2 SD) or returned (endings) to normal baseline variability level for more than 10 consecutive samples (20 milliseconds) by using an EMG analysis software developed at Universite Laval (Analyse, Quebec, Canada). Integrated EMG activity was calculated during the buildup of isometric force production and iEMG levels were obtained for the time interval between the onset of EMG burst and the peak force identified on the force signal.

Statistical Analysis

All force and EMG-dependent variables were found to be normally distributed. Force data were submitted to a group × position × force analysis of variance with repeated measures on the last 2 factors, and EMG data were submitted to a group × force analysis of variance with repeated measures on the last factor. When a main effect of group or an interaction of group × trunk position was observed, post hoc comparisons were performed with Tukey tests. For all analyses, statistical significance was set at \( P < .05 \).

RESULTS

Subjects from the control and cLBP groups demonstrated similar maximal flexion and extension forces. On average, the peak flexion was 133.94 vs 139.5 N m for healthy subjects
and those with LBP, respectively ($P > .05$), whereas peak extension was significantly higher for the control group compared with the LBP group (242.52 vs 160.52 N m, respectively; $P = .018$). As reported in Table 1, pain levels of subjects with LBP, measured with the VAS, did not vary significantly during the course of the experiment ($P > .05$).

**Force Data**

The average time to peak force was significantly longer for subjects with LBP than for healthy subjects (420 vs 299 milliseconds, respectively; $F_{1,24} = 5.43$, $P = .028$ for the main effect of group). This observation is illustrated in Figure 2. For all groups, the time to peak force was longer when producing extension than when producing flexion forces (406 vs 313 milliseconds, respectively; $F_{1,24} = 17.21$, $P = .0004$). All interactions for force variables were not significant ($P > .05$). No group difference was observed for peak force variability (9.46 and 10.22 N m for subjects with LBP and healthy participants, respectively; $P > .05$) and absolute errors (16.74 and 17.2 N m for patients with LBP and healthy participants, respectively; $P > .05$). All interactions for these variables were not significant ($P > .05$).

**Electromyographic Data**

The EMG data of 1 healthy subject were removed from all analyses because of the poor quality of the signal. Across all experimental conditions, no group difference was noted in iEMG for all muscle groups ($P > .05$). However, subjects with LBP showed longer burst duration for all 4 muscles recorded (erector spinae, $P = .008$; rectus abdominis, $P = .008$; external oblique, $P = .026$; and multifidus muscles, $P = .014$). Figure 3 illustrates the burst duration for each muscle group.

![Figure 3](image)

**Table 2. Burst duration**

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Controls (mean [SD])</th>
<th>LBP (mean [SD])</th>
<th>$F_{1,23}$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus abdominis</td>
<td>646 (47)</td>
<td>844 (49)</td>
<td>8.48</td>
<td>.008</td>
</tr>
<tr>
<td>External oblique</td>
<td>662 (50)</td>
<td>836 (52)</td>
<td>5.70</td>
<td>.026</td>
</tr>
<tr>
<td>Erector spinae</td>
<td>645 (47)</td>
<td>843 (49)</td>
<td>8.45</td>
<td>.008</td>
</tr>
<tr>
<td>Multifidus</td>
<td>601 (47)</td>
<td>783 (49)</td>
<td>7.04</td>
<td>.014</td>
</tr>
</tbody>
</table>

**Table 3. Integrated EMG values for each group**

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Controls (mean [SD])</th>
<th>LBP (mean [SD])</th>
<th>$F_{1,23}$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus abdominis</td>
<td>445.34 (74.70)</td>
<td>474.36 (77.75)</td>
<td>0.07</td>
<td>.79</td>
</tr>
<tr>
<td>External oblique</td>
<td>390.4 (51.24)</td>
<td>341.99 (53.34)</td>
<td>0.43</td>
<td>.519</td>
</tr>
<tr>
<td>Erector spinae</td>
<td>307.72 (62.16)</td>
<td>205.8 (64.69)</td>
<td>1.29</td>
<td>.268</td>
</tr>
<tr>
<td>Multifidus</td>
<td>315.6 (66.62)</td>
<td>250.7 (69.34)</td>
<td>0.46</td>
<td>.506</td>
</tr>
</tbody>
</table>
muscle in both groups. Tables 2 and 3 present the mean (SD) burst duration and iEMG for healthy subjects and those with LBP, respectively.

**DISCUSSION**

Results of the present study indicate that subjects with cLBP, when attempting to reproduce isometric force, have longer time to peak force than healthy subjects. However, their spatial precision and variability are similar to those of healthy subjects. These results are similar to those previously reported in a similar task. It is proposed that the longer time to peak force observed in subjects with LBP is part of a modified control strategy developed under chronic exposure to pain. This strategy is characterized by a shift from feedforward control toward feedback control. The objective of this study was to document the changes in trunk muscle recruitment strategies that are associated with isometric force control strategies modification in a population with cLBP. Electromyographic data were obtained from 4 different trunk muscles to determine if trunk muscle recruitment strategies are modified along with isometric force production parameters. This study indicates that the increased time to peak force, observed in the population with LBP, is accompanied by an increase in EMG burst duration of superficial trunk muscles.

In 1991, Lund et al proposed a neurophysiologic model based on the phasic modulation of excitatory and inhibitory interneurons supplied by high-threshold sensory afferents. The “pain adaptation model” describes neurophysiologic adaptations to pain characterized by a decrease in the activity of agonist muscles associated with an increase in antagonist muscles activity. In patients with cLBP, increased antagonist activity is well illustrated by the absence of the flexion-relaxation phenomenon (persistence of paraspinal muscle activity) in full flexion. Lund et al suggested that such adaptations are designed to limit the range and velocity of motion and protect the injured anatomical structures. As previously reported, subjects with cLBP in our study exhibited decreased maximal voluntary contractions in trunk extension. These results could very well illustrate the consequence of chronic pain as suggested by Lund, but our results failed to show any significant changes in agonist and antagonist EMG activity. In fact, results of the present study indicate that there was no difference in agonist activity or antagonist activity, and the IEAG of all muscles were similar in both groups across all conditions. The longer time to peak observed in the LBP group cannot be explained by an increase in superficial antagonist muscle activity or by a decrease in superficial agonist muscle activity. Because only superficial trunk muscle activity was recorded during the experiment, it is however possible that the longer time to peak force observed can result from increased co-contraction of deeper trunk muscles. Future studies using intramuscular EMG are needed to explore this hypothesis.

Another hypothesis was put forward to explain the results of this experimentation. Many authors have shown that there is only a minimal relation between pain intensity and fear of movement or fear of reinjury. In many subjects, changes in daily activities and probably in motor behavior are dictated by a specific fear that physical activity will cause reinjury.

The effect of experimental and chronic LBP on neuro-muscular control has been well documented in the past. However, pain can be defined as a sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage, and it is possible that our results reflect cognitive behavior associated with chronic pain observed changes. Numerous studies have shown the relationship between psychologic factors such as fear of pain and fear avoidance behavior and physical impairments. In a recent article, Moseley et al exposed the effects of LBP anticipation on postural adjustment. Healthy subjects anticipating painful electrical stimulation of their back demonstrated a delayed postural activation and a decrease in EMG amplitude of deep trunk muscles compared to control trials (without anticipation of back pain). Concurrently, an increase in superficial trunk muscle activity was noted. The authors proposed that the anticipation of pain, solely, is sufficient to induce a change in postural control. Several other studies indicate that when subjects with chronic pain demonstrate a fear of pain or reinjury, the motor output is modified and these changes are anatomically specific to the area of changes. Moreover, Al-Obaidi et al demonstrated that for subjects with LBP, fear avoidance behavior, such as fear of pain during physical activity, is correlated to isometric trunk forces measured at different angles. In the present study, the pain level of subjects with LBP was minimal at the time of testing (2.0 and 2.7 before and after the experimental session), and one could argue that the observed changes are more likely due to fear avoidance behavior than true neurophysiologic adaptations to chronic pain. Subjects with cLBP usually present with a high level of fear avoidance beliefs and concomitant disability. It is possible that subjects with LBP involved in this study increased their time to peak force (and concurrently prolonged their muscular activation) to avoid pain or further injuries. As proposed by many authors, fear avoidance beliefs and distress should be identified, measured, and considered when studying chronic pain populations.

**CONCLUSION**

In summary, our data show that subjects with cLBP demonstrating an adaptation in their motor control strategies increased their time to peak force by modifying the duration
of trunk muscle bursts, and not by modulating agonist and antagonist activity. We suggest that the observed changes in trunk muscle recruitment strategies are not only mediated by a neurophysiologic adaptation to chronic pain, but also by cognitive adaptations modulated by fear of movement and fear of reinjury. We suggest that functional screening, including simple motor control tasks, and a fear avoidance belief questionnaire should be included in clinical evaluation of patients with cLBP.

**Practical Applications**

- Low back pain may impair sensorimotor control of the trunk.
- Subjects with LBP in this study exhibited longer time to peak force in a trunk flexion and extension.
- Longer time to peak are coupled with longer EMG burst in trunk muscles.

**ACKNOWLEDGMENT**

This study was funded by the Fondation Chiropratique du Québec and the Université du Québec à Trois-Rivières.

**REFERENCES**

MAGNETIC RESONANCE IMAGING FINDINGS AS PREDICTORS OF CLINICAL OUTCOME IN PATIENTS WITH SCIATICA RECEIVING ACTIVE CONSERVATIVE TREATMENT

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ABSTRACT

Objective: The aims of this study were to investigate the possible prognostic value of disk-related magnetic resonance imaging (MRI) findings in relation to recovery at 14 months in patients with severe sciatica, and whether improvement of disk herniation and/or nerve root compromise is concurrent with recovery.

Methods: All patients included in this prospective observational study of patients with sciatica receiving active conservative treatment were scanned at baseline and at 14 months’ follow-up. Definite recovery at follow-up was defined as an absence of sciatic leg pain and a Roland Morris disability score of 3 or less. Potential predictors of interest were disk-related MRI findings in the lumbar spine. Bi- and multivariate logistic regression analyses were used to identify any predictors of recovery. Age, sex, and treatment were included in the analyses as possible confounding/modifying factors.

Results: According to the definitions used, 53% of 154 patients recovered; 63% of men (n = 84) and 40% of women (n = 70). In the multivariate analyses, broad-based protrusions, extrusions, and male sex were found to be predictive of a positive outcome. Sex was identified as a true confounder in that the prevalence of disk-related MRI findings was different for men and women, and they had different recovery rates. Improvement of disk herniations and nerve root compromise over time did not coincide with definite recovery.

Conclusions: In patients with sciatica receiving active conservative treatment, broad-based protrusions and extrusions at baseline were positive predictors of definite recovery at 14 months. However, at 14 months the MRI-defined improvement of disk herniations and nerve root compromise was not correlated with definite recovery. (J Manipulative Physiol Ther 2007;30:98-108)

Key Indexing Terms: Magnetic Resonance Imaging; Sciatica; Herniated Disk; Lumbar Vertebrae; Prognosis

Sciatica is a relatively uncommon ailment in the general European population with a prevalence of 4% to 12%.1,2 However, it is an important condition because it results in severe pain and disability for the individual patient and significant costs in terms of treatment, sick leave, and pensions for the society.

In patients with sciatica, magnetic resonance imaging (MRI) is often used as part of the diagnostic evaluation, where large size of disk herniations and nerve root compromise is the anatomical aspect most often considered to be pathognomonic of sciatica. This association has been confirmed in previous cross-sectional studies.3,5

The prognostic value of MRI findings in relation to relief of sciatic pain in patients treated nonsurgically has been investigated in previous prospective studies.6–9 According to these studies, a small herniation in a large spinal canal,6 annular rupture,9 nerve root compression,9 and disk extrusion7,8 correlated with a positive outcome, whereas a foraminal location of the herniation correlated with a negative outcome.9
Three studies have related the clinical outcome to a second MRI of the herniations seen in selected groups of patients.\textsuperscript{7,10,11} In these studies, recovery from symptoms was associated with the degree of reduction seen on MRI. However, these studies were all carried out on selected nonconsecutive groups of patients with identified herniations and, thus, may not reflect daily clinical practice in primary care.

The prognostic values of other degenerative disk changes in relation to recovery have also been investigated. In one report based on a study of 30 patients, low degree of degeneration of the presumed symptomatic disk was associated with symptom recovery.\textsuperscript{12} In contrast, in a study of 73 patients, T2-signal intensity in the disk at the symptomatic level did not correlate with the clinical course.\textsuperscript{8}

According to a recent prospective study by the research team of this paper, it was possible to identify the symptomatic disk level in 90% of cases from MRI findings when studying 154 consecutive patients with sciatica who were receiving active conservative treatment; the classification recommendations from the combined task forces of the North American Spine Society, the American Society of Spine Radiology, and the American Society of Neuroradiology were used for that study.\textsuperscript{13} In concordance with previous studies,\textsuperscript{10,14-20} over a period of 14 months, the largest herniations, namely, broad-based protrusions, extrusions, and sequestrations, improved considerably as compared to mere bulges and focal protrusions \((P < .0001)\). Nerve root compromise improved in 21\% to 80\% of cases, depending on the disk contour observed at baseline. A new finding was a significant difference between men and women in relation to baseline findings in that men were twice as likely to have extrusions and nerve root compromise as women. In relation to development over time, men were also more likely to experience an improvement of nerve root compromise.\textsuperscript{21}

The previous report dealt only with imaging information and not with clinical findings, and it was therefore necessary to investigate the possible predictive value of MRI findings in relation to definite recovery of leg pain and disability at 14 months in these patients. The specific objectives of this study were:

1. To investigate the prognostic value of disk-related MRI findings at the symptomatic disk level at baseline
(ie, type and location of disk pathology, and nerve root compromise).

2. To investigate the prognostic value of degenerative changes at all 5 lumbar levels at baseline (ie, disk contour, location of herniation, nerve root compromise, disk signal, disk height, high-intensity zones [HIZ], and stenosis).

3. To investigate whether improvement of disk herniation and/or nerve root compromise is concurrent with definite recovery.

MATERIALS AND METHODS

Study Design

In this prospective observational study, patient symptoms and disk-related MRI findings were described at baseline and after 14 months in patients with sciatica who participated in a randomized controlled clinical trial of active conservative treatment. Detailed information of the clinical study has been reported elsewhere and is summarized in Figure 1.21,22 The study was approved by the local research ethics committee (ref. no. VF-2001/0134).

Study Sample

For the purpose of the present study, patients who participated in the clinical study were classified into 3 groups: (1) those who did not have identifiable symptomatic disk lesions (n = 15); (2) those with identifiable symptomatic disk lesions who did not have surgery during follow-up (n = 139); (3) those with identifiable symptomatic disk lesions who had lumbar disk surgery during follow-up (n = 12). Of these, group 3 was excluded from the present study.

Variables of Interest

Sciatic leg pain, defined as radicular symptoms with a dermatomal distribution, was assessed from averaged values of three 11-box scales (present pain, worst pain in the last 2 weeks, and average pain during the last 2 weeks) with 0 being no pain and 10 being worst imaginable pain. Disability was assessed with the Roland Morris Questionnaire (RMQ-23).23 Our definition of the clinical outcome at the time of follow-up was designed with the purpose of identifying clear and definite recovery. Some degree of disability was accepted as to allow for patients with nonsciatic disability, such as low back pain (LBP), to be included in the definition of recovered. Therefore, the definition of “definite recovery” was defined as absence of sciatic leg pain (<1 on box scale) and low disability score (≤3 on RMQ-23).

The predictor variables were obtained from the baseline MRI and are listed in Table 1. Examples of magnetic

### Table 1. Frequency of MRI findings in 154 patients with sciatica who received active conservative treatment

<table>
<thead>
<tr>
<th>MRI finding</th>
<th>Grading (previously described by Kjaer26)</th>
<th>Symptomatic disk levels (n = 154)</th>
<th>All disks (n = 770)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk contour</td>
<td>Normal</td>
<td>15 (10)</td>
<td>487 (63)</td>
</tr>
<tr>
<td></td>
<td>Bulge</td>
<td>33 (21)</td>
<td>149 (19)</td>
</tr>
<tr>
<td></td>
<td>Focal protrusion</td>
<td>52 (34)</td>
<td>72 (9)</td>
</tr>
<tr>
<td></td>
<td>Broad-based protrusion</td>
<td>10 (6)</td>
<td>14 (2)</td>
</tr>
<tr>
<td></td>
<td>Extrusion</td>
<td>36 (23)</td>
<td>40 (5)</td>
</tr>
<tr>
<td></td>
<td>Sequestration</td>
<td>8 (5)</td>
<td>8 (1)</td>
</tr>
<tr>
<td>Location of herniationa</td>
<td>No herniation (normal and bulge)</td>
<td>48 (31)</td>
<td>636 (83)</td>
</tr>
<tr>
<td></td>
<td>Right extraforaminal</td>
<td>0 (0)</td>
<td>1 (0)</td>
</tr>
<tr>
<td></td>
<td>Right foraminal</td>
<td>3 (2)</td>
<td>6 (1)</td>
</tr>
<tr>
<td></td>
<td>Right subarticular (lateral recess)</td>
<td>42 (27)</td>
<td>46 (6)</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>17 (11)</td>
<td>27 (4)</td>
</tr>
<tr>
<td></td>
<td>Left subarticular (lateral recess)</td>
<td>38 (25)</td>
<td>44 (6)</td>
</tr>
<tr>
<td></td>
<td>Left foraminal</td>
<td>6 (4)</td>
<td>9 (1)</td>
</tr>
<tr>
<td></td>
<td>Left extraforaminal</td>
<td>0 (0)</td>
<td>1 (0)</td>
</tr>
<tr>
<td>Nerve root</td>
<td>No contact</td>
<td>39 (25)</td>
<td>613 (80)</td>
</tr>
<tr>
<td></td>
<td>Contact between disk and nerve root</td>
<td>37 (24)</td>
<td>64 (8)</td>
</tr>
<tr>
<td></td>
<td>Dislocation of nerve root</td>
<td>53 (34)b</td>
<td>66 (8)b</td>
</tr>
<tr>
<td>Disk signal</td>
<td>Homogeneously hyperintense</td>
<td>0 (0)</td>
<td>4 (1)</td>
</tr>
<tr>
<td></td>
<td>Hyperintense with visible intranuclear cleft</td>
<td>13 (8)</td>
<td>348 (45)</td>
</tr>
<tr>
<td></td>
<td>Intermediate signal intensity</td>
<td>69 (45)</td>
<td>250 (32)</td>
</tr>
<tr>
<td></td>
<td>Hypointense</td>
<td>72 (47)</td>
<td>168 (22)</td>
</tr>
<tr>
<td>Disk height</td>
<td>Disk narrower than the disk above</td>
<td>55 (36)</td>
<td>142 (18)</td>
</tr>
<tr>
<td></td>
<td>Disk as high as the disk above (if normal)</td>
<td>38 (25)</td>
<td>100 (13)</td>
</tr>
<tr>
<td></td>
<td>HIZ not present</td>
<td>116 (75)</td>
<td>682 (89)</td>
</tr>
<tr>
<td></td>
<td>HIZ present</td>
<td>38 (25)</td>
<td>88 (11)</td>
</tr>
<tr>
<td>Central stenosis</td>
<td>Relative stenosis</td>
<td>14 (9)</td>
<td>26 (3)</td>
</tr>
<tr>
<td></td>
<td>Stenosis</td>
<td>2 (1)</td>
<td>2 (0)</td>
</tr>
<tr>
<td>Lateral stenosis</td>
<td>Relative stenosis</td>
<td>2 (1)</td>
<td>4 (1)</td>
</tr>
<tr>
<td></td>
<td>Stenosis</td>
<td>0 (0)</td>
<td>1 (0)</td>
</tr>
<tr>
<td>Foraminal stenosis</td>
<td>Relative stenosis</td>
<td>22 (14)</td>
<td>35 (5)</td>
</tr>
<tr>
<td></td>
<td>Stenosis</td>
<td>3 (2)</td>
<td>3 (0)</td>
</tr>
</tbody>
</table>

Values are shown as n (%).

a For multivariate analysis, location of herniation was simplified (see Data Analysis section).

b Gradings in bold indicate predefined cut-points for variables used in the regression analyses.
Fig 2. Examples of magnetic resonance images. Sagittal (A and B) and axial (C and D) T1- and T2-weighted magnetic resonance images of a 44-year-old man. Right subarticular extrusion is seen at the L4-L5 level with compromise of the right L5 nerve root.

Table 2. Potential predictors of definite recovery at 14 months in 154 patients with sciatica receiving active conservative treatment

<table>
<thead>
<tr>
<th>Multivariate analysis</th>
<th>MRI finding</th>
<th>Odds ratio (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted</td>
<td>Disk contour (Ref.: no protrusion)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bulge</td>
<td>1.0 (0.3-3.5)</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Focal protrusion</td>
<td>4.0 (0.7-22.8)</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>Broad-based protrusion</td>
<td>15.6 (1.8-131.5)b</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>Extrusion</td>
<td>8.0 (1.4-47.2)</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Sequestrationa</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Location of herniation (Ref.: central location)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No herniation (normal or bulge)</td>
<td>3.0 (0.3-28)</td>
<td>.34</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.5 (0.1-2.1)</td>
<td>.32</td>
</tr>
<tr>
<td></td>
<td>Root compromise (yes/no)</td>
<td>0.3 (0.1-1.1)</td>
<td>.06</td>
</tr>
<tr>
<td>Adjusted for age, sex, and treatments groups</td>
<td>Disk contour (Ref.: no protrusion)</td>
<td>0.9 (0.2-3.4)</td>
<td>.91</td>
</tr>
<tr>
<td></td>
<td>Bulge</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Focal protrusion</td>
<td>4.6 (0.8-25.6)</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>Broad-based protrusion</td>
<td>22.9 (2.5-209.1)b</td>
<td>.006</td>
</tr>
<tr>
<td></td>
<td>Extrusion</td>
<td>8.7 (1.5-49.5)</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Sequestrationa</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Location of herniation (Ref.: central location)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No herniation (normal or bulge)</td>
<td>4.4 (0.5-42.1)</td>
<td>.20</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.6 (0.1-2.7)</td>
<td>.53</td>
</tr>
<tr>
<td></td>
<td>Root compromise (yes/no)</td>
<td>0.4 (0.1-1.3)</td>
<td>.14</td>
</tr>
<tr>
<td></td>
<td>Age group (45+/&lt;45)</td>
<td>1.3 (0.6-2.6)</td>
<td>.51</td>
</tr>
<tr>
<td></td>
<td>Sex (female/male)</td>
<td>2.3 (1.1-4.7)</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Treatment (sham exercise/spine exercise)</td>
<td>0.8 (0.4-1.7)</td>
<td>.61</td>
</tr>
</tbody>
</table>

Multivariate analyses of MRI findings at the symptomatic disk level (n = 154).

a Sequestrations (n = 8) were dropped in the analyses due to collinearity.
b Estimates in bold indicate significant values (P < .05).

resonance images are shown in Figure 2. For the symptomatic disk level (objective 1), disk contour, location of disk herniation, and nerve root compromise were used as predictors. In addition, for the analysis of all levels (objective 2), disk signal, disk height, HIZ, and stenosis were chosen as predictor variables. Age, sex, and treatment group were also included in the analyses as potential confounding/modifying variables.
Validity of Variables

Leg pain was obtained from the LBP rating scale, which has been shown to be valid and reliable in the assessment of patients with LBP and sciatica. Information on disability was obtained from the RMQ-23 which has been validated in Danish and found to be acceptable in assessing functional disability in patients with LBP and previous lumbar disk herniations. The intraobserver and interobserver agreements of evaluation of disk-related MRI findings (disk contour, location of herniation, disk signal, disk height, and HIZ) had \( \kappa \) values in the range of 0.59 to 0.97. \( \kappa \) values for the intraobserver agreement of evaluations of nerve root and stenosis were 0.82 and 0.90, respectively. All MRI evaluations were performed by the same radiologist (JSS) who was blinded to all clinical data.

Data Analysis

Data from the questionnaires and MRI evaluation forms were entered into 2 separate databases using EpiData 3.02 (EpiData Association, Odense, Denmark). These databases were then cross checked and errors corrected before
transferring data to STATA 8.2 (StataCorp LLC, College Station, Tex) for statistical analysis.

Descriptive data were obtained for the baseline variables. Differences in estimates of continuous data (pain and disability) in relation to age, sex, and treatment groups were tested using the unpaired *t* test. Prediction of definite recovery was analyzed using a forward stepwise logistic analysis model separately for symptomatic disk levels and all lumbar disk levels on the basis of predictor variables with a prevalence of at least 10% among symptomatic levels and with *P* values < .20. For the regression analyses, predictor variables were simplified at predefined and relevant cut-points (Table 1). The multivariate analyses were performed twice: 1 analysis was unadjusted and the second was adjusted for age, sex, and treatment groups. To account for dependency within individuals, the cluster-option in STATA was used in the regression analyses of all disk levels (objective 2). In the regression analyses, the variable “location of herniation” was reduced to “no herniation” (normal or bulging disks), “central herniation,” and “lateral herniation” to reflect the focal location of disk herniations in relation to definite recovery. Therefore, in the analyses, the resulting odds ratio of “no herniation” is meaningless and what is of interest is the odds ratio for “lateral herniation” vs “central herniation.”

### Table 4. Potential predictors of definite recovery at 14 months in 154 patients with sciatica who received active conservative treatment. Multivariate analyses of MRI findings at the 5 lowest lumbar disk levels stratified by sex (n = 770)

<table>
<thead>
<tr>
<th>MRI finding</th>
<th>Odds ratio (95% CI)</th>
<th><em>P</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females (n = 70)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk contour (Ref.: no protrusion)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulge</td>
<td>0.9 (0.5-1.8)</td>
<td>.77</td>
</tr>
<tr>
<td>Focal protrusion</td>
<td>0.3 (0.05-1.3)</td>
<td>.11</td>
</tr>
<tr>
<td>Broad-based protrusion</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Extrusion</td>
<td>0.7 (0.1-4.6)</td>
<td>.69</td>
</tr>
<tr>
<td>Sequestrationa</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Location of herniation (Ref.: central location)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No herniation (normal or bulge)</td>
<td>0.4 (0.1-3.0)</td>
<td>.37</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.4 (0.1-3.1)</td>
<td>.39</td>
</tr>
<tr>
<td>Root compromise (yes/no)</td>
<td>0.3 (0.1-1.4)</td>
<td>.13</td>
</tr>
<tr>
<td>Central stenosis (yes/no)</td>
<td>1.2 (0.4-4.0)</td>
<td>.72</td>
</tr>
<tr>
<td>Age group (45+/&lt;45)</td>
<td>0.9 (0.3-2.3)</td>
<td>.80</td>
</tr>
<tr>
<td>Treatment (sham exercise/spine exercise)</td>
<td>1.0 (0.4-2.6)</td>
<td>.96</td>
</tr>
<tr>
<td><strong>Males (n = 84)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk contour (Ref.: no protrusion)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulge</td>
<td>0.6 (0.4-0.9)</td>
<td>.04</td>
</tr>
<tr>
<td>Focal protrusion</td>
<td>4.1 (0.7-25.5)</td>
<td>.13</td>
</tr>
<tr>
<td>Broad-based protrusion</td>
<td>12.4 (0.9-157.8)</td>
<td>.053</td>
</tr>
<tr>
<td>Extrusion</td>
<td>10.1 (1.4-74.2)</td>
<td>.02</td>
</tr>
<tr>
<td>Sequestrationa</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Location of herniation (Ref.: central location)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No herniation (normal or bulge)</td>
<td>4.7 (0.6-38.9)</td>
<td>.15</td>
</tr>
<tr>
<td>Lateral</td>
<td>1.8 (0.4-8.4)</td>
<td>.42</td>
</tr>
<tr>
<td>Root compromise (yes/no)</td>
<td>1.3 (0.4-4.1)</td>
<td>.70</td>
</tr>
<tr>
<td>Central stenosis (yes/no)</td>
<td>4.2 (1.2-14.7)</td>
<td>.03</td>
</tr>
<tr>
<td>Age group (45+/&lt;45)</td>
<td>1.5 (0.6-3.7)</td>
<td>.39</td>
</tr>
<tr>
<td>Treatment (sham exercise/spine exercise)</td>
<td>1.0 (0.4-2.4)</td>
<td>.96</td>
</tr>
</tbody>
</table>

*a* Dropped in the analyses due to collinearity.

*b* Estimates in bold indicate significant values (*P* < .05).
Associations between definite recovery and improvement of disk herniation and nerve root compromise were analyzed using Fisher exact test for the group of 139 patients with an identifiable symptomatic disk. \( P \) values less than the 5% level were considered significant.

RESULTS

Study Sample

In all, 181 individuals entered the initial clinical study. These were MRI scanned at baseline and 172 completed the 2-month treatment period. Fourteen months after baseline, that is, 12 months after the end of treatment, 166 patients had a second MRI. Of these, 12 had lumbar disk surgery during the follow-up period; 5 of whom received active treatment and 7 were from the control group.

This report deals with the 154 nonsurgically treated patients from the clinical study (84 males and 70 females) who were MRI scanned at baseline and after 14 months. Age ranged between 18 and 65 years (median and mean, 45). The most common duration interval of sciatic symptoms was 1 to 3 months. The baseline median leg pain intensity was 6 (q25, 5; q75, 7) and the mean intensity on the 0 to 10 scale was 5.6 (SD, 1.9). The median disability was 15 (q25, 12; q75, 18) and the mean disability on the 0 to 23 scale was 14.6 (SD, 4.6). There were no statistical differences between age, sex, or treatment groups in relation to leg pain or disability. For a summary of MRI findings, please see Table 1.

Definite Recovery

According to our definition, 53% of the 154 patients with sciatica recovered from their sciatic leg pain and disability; 52% of the 82 actively treated patients and 53% of 72 patients in the control group. Sixty-three percent of the men recovered as compared to 40% of women \( (P < .003) \).

Can MRI Findings at the Symptomatic Level Predict Definite Recovery?

Results from the multivariate analyses for MRI findings at the symptomatic disk level predicting definite recovery at 14 months are summarized in Table 2. In the unadjusted and adjusted multivariate analysis, the presence of broad-based protrusions and extrusions was a strong predictor of positive outcome. In the adjusted analysis, male sex was also predictive of a positive outcome after 14 months. In spite of sex being a true confounder, that is, affecting outcome as well as the MRI predictors,\(^21\) stratification by sex yielded no significant predictors (data not shown).

Can MRI Findings at All Lumbar Levels Predict Definite Recovery?

Results from the multivariate analyses for MRI findings at all disk levels predicting definite recovery from leg pain at 14 months are summarized in Table 3. In the unadjusted analyses, the presence of broad-based protrusions and extrusions, as well as the absence of central stenosis, were identified as positive predictors in relation to recovery. As was seen in the analysis for symptomatic levels, male sex was found to be predictive of a positive outcome in the adjusted analysis together with broad-based protrusions and extrusions. In the multivariate analysis, stratified by sex, no significant predictors were found for women. For men, the presence of disk extrusions and absence of central stenosis were found to be predictive of a positive outcome, whereas the presence of disk bulging was identified as a negative predictor (Table 4).

Is There an Association Between Improvement of Disk and Nerve and Definite Recovery?

Whether or not disk herniations improved or nerve root compromise had diminished, there was no association with recovery at the 14-month follow-up among the 139 patients who at baseline had abnormal disk contour and/or nerve root compromise, as seen in Tables 5 and 6.

DISCUSSION

To the best of our knowledge, this is the largest study on the association between MRI findings and recovery from sciatica in a consecutive patient population receiving active
conservative treatment. Also, this is the first report in which all 5 lumbar disk levels were included.

Predicting Definite Recovery in Sciatica Patients

In the present study, we have investigated the association of MRI findings at the symptomatic disk level and at all lumbar levels in relation to definite recovery and came to the same result, namely, that broad-based protrusions and extrusions at baseline are strongly associated with a positive outcome. This is an important finding as it confirms that the disk level presumed to be symptomatic is also one of importance in relation to recovery from sciatica, which is in agreement with previous studies.10,14,21 A likely explanation for this is that these types of disk herniations have a high degree of resorption over time, thought to be related to inflammatory response, neovascularization, and macrophage infiltration that seem to be initiated when the nucleus pulposus material comes into contact with the epidural tissue.10,14,21

Nerve root compromise and location of disk herniation were not associated with definite recovery. This is surprising, as it has been previously reported in a study of 133 patients with sciatica that these MRI findings predict recovery from sciatica at 12 weeks.9 We believe that this discrepancy can be explained in that only bivariate analyses were performed in the previous study. Also, in the present study, the bivariate analysis identified nerve root compromise as a positive predictor of definite recovery (data not shown). However, in the multivariate analysis, nerve root compromise did not produce significant estimates. This is in line with another study of 196 patients with LBP or radiculopathy.27

In men, the presence of disk extrusion and absence of central stenosis were identified as positive predictors, whereas disk bulge was predictive of a negative outcome. An explanation for extrusion as a predictor has been described above in detail. The explanation for disk bulge as a negative predictor is similar, as it has been previously reported that bulges do not resorb as well over time.21 The prognostic value of central stenosis is supported by a previous retrospective study of 1092 patients with sciatica, in which it was reported that recovery from leg pain was less common in patients with spinal stenosis.28 This is understandable, as additional tissue occupying the spinal canal may induce or worsen central stenosis which in turn may cause irreversible damage on the nerve roots.29,31

Sex as a Confounder

We were surprised to note that sex was a true confounder in that men had a higher prevalence of herniations and were more likely to recover from sciatica than women. This is supported by the fact that in 5 of 6 previous prospective MRI and CT studies, with predominantly male participants,7,10,11,14,32,33 a higher recovery rate was reported as compared to those studies with an equal sex distribution6,9,34 and a study that included predominantly female participants.12 This may have important consequences for research and clinical practice.

Obviously, analyses should be stratified by sex. It is possible that in past studies, in which findings from both men and women were reported as 1 group, important information may be hidden.

Also, in relation to clinical practice, men and women who have sciatica, should not be considered as being identical, although their symptoms may be. It is possible that the cause of sciatic pain is different in men and women. At an anatomical level, previous studies have reported men to be more likely to have sciatica or herniations,28,35-37 to have more massive herniations,21,27 and to have proportionally larger herniations in relation to the cross-sectional area of the spinal canal than women.6 At a physiologic level, sex differences in pain mechanisms and pain perception have also been described.38-41 In our previous report on the development over time of disk-related MRI findings, we noted a difference between sexes in relation to baseline prevalences of MRI findings and their development over time.21 We speculated that spinal stenosis could be a likely cause of sciatica in women, as it has also been reported that women are more likely to have stenosis than men.37 However, central stenosis was found not to have a prognostic value for women.

No Association Between Improvement and Definite Recovery

We found, in general, no association between the improvement of disk herniations and nerve root compromise at follow-up in relation to definite recovery.

In relation to the MRI development of disk herniations, this may appear to be in contrast to previous studies.7,10,11,14 However, study samples in previous studies consisted predominantly of selected groups of male patients with extrusions as compared to our study, in which a consecutive group of both male and female patients was included irrespective of disk contour. As our results show, male sex and extrusions are predictors of definite recovery. Therefore, it is obvious that studies including only such cases have a different result than our study in which all types of patients were included. In fact, a post hoc look at our raw data revealed that 69% of the 32 men with extrusion and sequestration recovered as compared to the 53% in the whole study sample. Also, the definitions of recovery used in the previous studies were based on the improvement of symptoms over time as compared to the definition of definite recovery used in the present report. Finally, the development of disk herniations over time in the previous reports was classified as a change in size of the herniation in the spinal canal, rather than a change in type of disk contour (ie, from extrusion to bulge) as classified in the present report. Considering that three of the 4 previous
studies merely make a subjective judgment of whether the lesion is “smaller,” “larger,” or “the same,” the present method may in fact be more objective, because our subclassifications are clearly defined.

To our knowledge, this is the first study to report on the correlation between improvement of nerve root compromise and definite recovery in patients with sciatica treated conservatively. Furthermore, it is probably the first time that the development of all types of disk contours has been studied in relation to sciatica. Taking into account that neither improvement of disk herniation nor of nerve root compromise is associated with definite recovery, one must assume that the mechanical pressure of the nerve root alone has limited effect in relation to sciatic pain. This confirms the previous works of others, which have shown that a combination of inflammation and compression of the nerve root is more likely to produce sciatic symptoms than inflammation or compression alone, at least in animals.42-44

Strengths and Weaknesses

Our study has some potential weaknesses that should be taken into consideration. First, this should not be considered as the “true” prognostic model in relation to recovery in patients with sciatica receiving active conservative treatment as it includes only data from the MRI. The reason for this is that the focus of our study was to investigate whether MRI findings alone could predict recovery. Therefore, to make a more complete prognostic model, one must include other clinically relevant data, such as physical examination findings. Second, evaluation of images obtained with low-field MRI scanners, as was used in this study, has been reported to have lower interobserver reproducibility when compared to that obtained with high-field scanners in one study of poor quality.35 However, because our study was conducted in a research department, enough scan time was provided to obtain optimal images and acceptable reproducibility comparable to other studies using high-field systems.46-50

The high quality of our images can be seen in Figure 2. A third potential weakness is that as the study subjects were patients, the base-line images were available at follow-up for the radiologist. This may in some way have influenced the final judgment, if the radiologist was in some way partial to the expected development over time in this type of patient. Also, the radiologist could have altered the interpretation criteria over time.

The strengths of this study were that we had a large, relatively homogeneous study sample, consisting of consecutive patients of both sexes with well-defined inclusion criteria, known duration of the symptoms, and that these patients were submitted to 1 of 2 well-described treatment arms, one of which was likely to be very close to no treatment at all. In addition, all patients had follow-up examinations at the same time in relation to the start of treatment, whereas most past studies used follow-up periods of varying lengths.10,11,14 In relation to our MRI data, all images were described by the same observer, who has previously shown consistency in interpreting disk pathology.36

Conclusion

We suggest that there are several research consequences for this study. First, in relation to the clinical picture, it is now possible to say that the type of disk contour as seen on MRI can predict definite recovery, at least for men. Second, men and women should not be thought of as 2 identical groups in relation to sciatica and its prognosis. In relation to future research in this area, this means that men and women should not be analyzed as 1 group, but stratification by sex should always be performed in the statistical analyses. Obviously, there are 2 important research questions needing to be answered: why do men and women have a different MRI profile and why does their prognosis differ?

For the clinician, our study provides the following messages. It is possible to predict the clinical outcome, for male patients in particular, on the basis of the MRI findings. The prognosis for sciatica differs between men and women. Improvement of disk herniations and nerve root compromise is not associated with definite recovery.

Acknowledgment

TSJ was the recipient of grants from the Danish Foundation of Chiropractic Research and Postgraduate Education, the Danish Rheumatism Foundation, and the Medical Research Council of the County of Funen, Denmark. HBA was the recipient of a grant from the Regional Institute of Health Sciences Research, Denmark. The authors declare that they have no conflicts of interest.
REFERENCES


HOW IMPORTANT IS RESEARCH-BASED PRACTICE TO CHIROPRACTORS AND MASSAGE THERAPISTS?

Esther Suter, PhD,a,b Laura C. Vanderheyden,c Lana S. Trojan, BSc,d,e Marja J. Verhoef, PhD,f,g and Gail D. Armitage, MAh

ABSTRACT

Objective: This study evaluated the perceptions of research, frequency of use of research findings in practice, and the level of research skills of chiropractors and massage therapists in Canada. Predictors of application of research findings in clinical practice were also explored.

Methods: A survey was mailed to members of the College of Chiropractors of Alberta (n = 833) and the Massage Therapist Association of Alberta (n = 650). Univariate and logistic regression analysis were conducted with SPSS and Stata.

Results: A total of 483 questionnaires were returned (response rate, 32.6%). Chiropractors and massage therapists reported an overall positive perception toward research, acknowledging the importance of research to validate their practice. Although both groups felt comfortable using the library, they had little confidence in their research skills and overall application of research in practice was limited. Significant differences were found between the 2 professional groups, with chiropractors reporting more research skills and evidence-based practice. Primary discipline, frequent referral to peer-reviewed journals, and strong agreement with the statement that “research adds credibility to my discipline” were predictors of research application in practice.

Conclusion: It appears that in Canada neither chiropractors nor massage therapists consistently apply research in practice, which may result from a lack of research education and research skills. The differences between the 2 professional groups may be attributed to the chiropractic profession’s relatively more research-focused professional training. Strategies to encourage greater research uptake and evidence-based behavior by practitioners include professional association incentives, such as education credits or practitioner cooperatives that would provide time and support for research. (J Manipulative Physiol Ther 2007;30:109-115)

Key Indexing Terms: Evidence-Based Medicine; Research Activity; Massage; Chiropractic; Questionnaires

Motivated by the need to provide efficient, effective, and cost-effective care, there is an increasing expectation that health care practice should be driven by research.1-4 Although evidence-based practice is a well-supported concept in conventional medical care, pressure is mounting to apply the same standards to complementary/alternative health care.5 The traditional focus of evidence-based practice to rely primarily on randomized controlled trials is a source of concern for many complementary/alternative health care practitioners who believe that this type of standardized study design is inappropriate for testing the effectiveness of their individualized practice.6 More recently, it has been recognized that evidence to inform clinical decision making should be derived from different sources and that clinical expertise and patient preference have a place alongside quantitative and qualitative research.7,8

Despite the widespread support for the concept of evidence-based practice as a means to improve patient outcomes, there is a large body of literature suggesting that many professions fail to make use of available best evidence.2 Furthermore, uptake of evidence into practice is limited and occurs with considerable delays.2

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Many barriers to research uptake have been identified such as lack of research education and skills, difficulties accessing evidence-based resources or information, time, and a perceived or actual lack of impact on practice change.\textsuperscript{4,7-10} In addition, positive perceptions and presence of a receptive environment (organizational and professional culture) are often essential for effective research uptake.\textsuperscript{2,11}

Much of the research uptake literature comes from the nursing profession; however, there is some indication that different professional groups may experience different barriers to evidence-based practice and that educational strategies may need to be tailored to these groups if research uptake is the goal.\textsuperscript{4}

This study was part of a larger project aimed to assess research education needs of 2 groups of complementary and alternative medicine (CAM) practitioners: chiropractors and massage therapists. This article concentrates on the following topics:

1. perceived importance of research and use of research in practice,
2. perceived level of research literacy (the ability to understand research) and research capacity (the ability to conduct research), and
3. determinants of applying research findings in clinical practice.

\textbf{METHODS}

Data were collected through a self-administered questionnaire mailed to members of the College of Chiropractors of Alberta and members of the Massage Therapist Association of Alberta (MTAA). Survey packages were sent to the administrative office of the respective organizations, which distributed the surveys to their registered members (College of Chiropractors of Alberta, n = 833; MTAA, n = 650). Only 1 mail-out was completed; no reminders were sent. A stamped and addressed envelope was included for ease of return.

There was no standardized instrument appropriate for this study, necessitating the development of a new questionnaire. Survey questions were informed by in-depth interviews with 8 CAM practitioners, and focused on their perception of research, perceived value of research to enhance clinical practice, extent of evidence-based practice, self-reported research skills, and desire for research education. The questionnaire was pilot tested for content validity and question clarity by 5 (CAM and conventional) practitioners and was assessed for face validity by an expert in CAM research literacy. Based on the feedback, small changes were made to the questionnaire as appropriate. The final questionnaire consisted of 21 questions, including a brief demographic section. Most questions used either a 4-point Likert scale or check boxes.

Descriptive statistics (mean values, frequency distributions, $\chi^2$, and confidence intervals [CI]) are reported to describe practitioners’ sociodemographic characteristics, perceptions of research, use of research findings in practice, use of information sources, and research literacy and capacity skills. Resampling with replacement (bootstrapping), is a nonparametric tool used to account for the relatively small sample size and potentially biased responses.\textsuperscript{12} Using a resampling approach increases the precision of the CI by better approximating the error term. Tables 2-5 report bias-corrected 95\% CI for the resampled statistics and $\chi^2$ tests of the reported frequencies. The associated $\chi^2$ values indicate whether chiropractors’ and massage therapists’ responses are significantly different at $P \leq 0.05$. Logistic regression analysis was used to explore what variables, if any, predict research-based practice as reflected by the statement “I sometimes/always apply research findings in my practice.” A forward stepwise conditional approach was used. Variables were added 1 at a time until the step at which the remaining variables had a significance level greater than .05, that is, they did not significantly enhance the model. The following independent variables were tested in the model: number of years in role, primary discipline, sex, experience with research, use of evidence-based resources (peer-reviewed journals, Cochrane database), and several statements regarding perceptions of research. These covariates were chosen based on statistically significant correlations ($P \leq 0.05$) with the respondents’ reported application of research findings in practice. Data were analyzed with SPSS Version 13.0 (SPSS Inc, Chicago, Ill) and Stata/SE Version 9.2 (Statacorp LLC, College Station, Tex).

\textbf{RESULTS}

A total of 483 questionnaires were returned, for a response rate of 32.6\%. Chiropractors had a higher response rate (n = 323; 38.8\%) compared to massage therapists (n = 160; 24.6\%). Most of the chiropractors surveyed were male (77.8\%), whereas massage therapists were predominantly female (87.1\%). Massage therapists tended to be slightly younger (Table 1A). Most respondents were practitioners (91.8\%) and few were students (3.2\%), administrators (0.6\%), or educators (2.2\%). Most members of both professional groups were active as practitioners for less than 10 years (Table 1B).

\textbf{Perceptions of Research}

Both chiropractors and massage therapists commented positively on the importance of research (Table 2). Both groups were equally likely to agree or strongly agree with the statements that research adds credibility to their discipline, leads to improved patient care, helps evaluate existing treatments in their discipline, and that clinical practice should be based on research. However, profession was a significant factor for the statement that research
education should be a mandatory component of clinical training in their discipline, with a smaller percentage of massage therapists agreeing with that statement.

Use of Research in Practice

Most chiropractors and massage therapists indicated that their practice was sometimes guided by research; however, chiropractors reported more consistent use of research in their practice. For example, although 65.9% of chiropractors and 65.8% of massage therapists indicated that they sometimes apply research findings in their practice, 30.6% of chiropractors stated that they always do so as compared to 13.3% of massage therapists. Differences between chiropractors and massage therapists were also found for consulting with colleagues, using research to develop clinical practice guidelines, and using research to change conditions, policies, or practices in their discipline (Table 3).

Use of Research Based Resources

Both practitioner groups indicated that they access resources for evidence-based information but different resources were used to varying extents. For example, the Cochrane Database of Reviews was used by neither chiropractors nor massage therapists on a frequent basis, with only 9% of chiropractors and 1% of massage therapists using it at least once a month. Web sites, peer-reviewed journals, and colleagues were the most common resources accessed by chiropractors, whereas massage therapists accessed handbooks most often, followed by colleagues, Web sites, and clinical practice guidelines. Overall, chiropractors accessed information sources more often compared to massage therapists (Table 4).

Research Literacy and Capacity Skills

Although all respondents had more confidence in their research literacy than their research capacity skills, massage therapists reported less confidence in both skills sets (Table 5). Most of chiropractors and massage therapists reported having experience, and not needing assistance, with using the library to find research information. Most chiropractors also reported having some or a lot of experience with conducting a literature search and reading and appraising research. However, only 21.7% of chiropractors and 13.4% of massage therapists indicated having experience in research design. This was consistent with reported research experience: 25.6% of chiropractors and 4.4% of massage therapists reported having participated in at least 1 CAM research project, mainly in-house audits, case series, or surveys.

Chiropractors and massage therapists showed similar level of interest in research education with 48.4% and 53.5%, respectively, wanting to receive further education.

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Table 1A. Age group by discipline (%)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Chiropractic</th>
<th>Massage Therapy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger than 30 y</td>
<td>58 (18.1)</td>
<td>49 (30.8)</td>
<td>107</td>
</tr>
<tr>
<td>31-40 y</td>
<td>161 (50.3)</td>
<td>52 (32.7)</td>
<td>213</td>
</tr>
<tr>
<td>41-50 y</td>
<td>54 (16.9)</td>
<td>37 (23.3)</td>
<td>91</td>
</tr>
<tr>
<td>51-60 y</td>
<td>37 (11.6)</td>
<td>17 (10.7)</td>
<td>54</td>
</tr>
<tr>
<td>Older than 60 y</td>
<td>10 (3.1)</td>
<td>4 (2.5)</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>320</td>
<td>159</td>
<td>479</td>
</tr>
</tbody>
</table>

Table 1B. Number of years in role by discipline (%)

<table>
<thead>
<tr>
<th>Years in Role</th>
<th>Chiropractic</th>
<th>Massage Therapy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5 y</td>
<td>86 (26.8)</td>
<td>55 (34.8)</td>
<td>141</td>
</tr>
<tr>
<td>5 to 10 y</td>
<td>117 (36.4)</td>
<td>60 (38.0)</td>
<td>177</td>
</tr>
<tr>
<td>More than 10 y</td>
<td>64 (19.9)</td>
<td>43 (27.2)</td>
<td>107</td>
</tr>
<tr>
<td>More than 20 y</td>
<td>54 (16.8)</td>
<td>0 (0.0)</td>
<td>54</td>
</tr>
<tr>
<td>Total</td>
<td>321</td>
<td>158</td>
<td>479</td>
</tr>
</tbody>
</table>

Table 2. Perceptions of research by discipline (% of practitioners who agreed or strongly agreed)

<table>
<thead>
<tr>
<th>Perception</th>
<th>Chiropractors (95% CI)</th>
<th>Massage therapists (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research adds credibility to my discipline</td>
<td>93.5 (90.7-96.0)</td>
<td>91.9 (87.5-95.6)</td>
<td>.524</td>
</tr>
<tr>
<td>Research leads to improved patient care in my discipline</td>
<td>81.4 (77.6-85.7)</td>
<td>78.8 (72.5-85.0)</td>
<td>.503</td>
</tr>
<tr>
<td>Research helps evaluate existing treatments in my discipline</td>
<td>79.6 (75.2-84.3)</td>
<td>73.8 (66.9-80.0)</td>
<td>.154</td>
</tr>
<tr>
<td>Clinical practice should be based on research</td>
<td>53.4 (48.8-59.1)</td>
<td>50.6 (43.0-59.6)</td>
<td>.560</td>
</tr>
<tr>
<td>Research education should be a mandatory component of clinical training in my discipline</td>
<td>66.6 (61.0-71.5)</td>
<td>52.8 (46.5-61.6)</td>
<td>.005*</td>
</tr>
</tbody>
</table>

Respondents were asked what best represents their perceptions of research by indicating strongly disagree to strongly agree on a 5-point Likert scale.

* Denotes statistically significant difference between chiropractors and massage therapists.
Main educational topics concerned how to appraise research studies, how to identify bias in research, or how to design research studies.

**Predicting the Likelihood of Applying Research Findings in Practice**

A logistic regression used to identify variables that predict application of research findings in clinical practice revealed 3 significant predictors. Chiropractic discipline was the strongest predictor with chiropractors being 3.4 times more likely than massage therapists to report the application of research findings in practice. The other statistically significant predictors were more frequent reference to peer-reviewed journals (odds ratio, 2.4) and strongly agreeing with the statement that “research adds credibility to my discipline” (odds ratio, 1.6). Predictors that were not statistically significant and hence did not enter the model included sex, number of years in practitioner role, reference to the Cochrane Database of Reviews, respondents’ research experience, and agreement with statements regarding perceptions of research ("research helps evaluate existing treatments in my discipline" and “clinical practice should be based on research”). The final model with the 3 predictors accounted for 23.1% of the variance (Table 6).

**DISCUSSION**

Overall, both professional groups reported a positive perception of research, acknowledged its relevance for clinical practice, and agreed that research helps to validate their treatment approaches. Other studies have also noted that practitioners generally have a positive perception of research and recognize its value.2,8,13,14 However, a positive perception does not necessarily translate into practice,13,15 which again was confirmed in the present study: although almost 80% of the respondents strongly agreed with the statement that research adds credibility to their practice, only about 25% reported that they apply research in their practice in a consistent manner.

Chiropractors and massage therapists in this study indicated minimal use of evidence-based information sources, such as peer-reviewed journals and electronic databases, and instead indicated a preference for handbooks and consulting with colleagues. Several previous studies have reported that colleagues and textbooks are the most popular information resources across different professional groups, whereas evidence-based electronic databases are infrequently used.4,7,15-17 Health professionals have been found to change their practice based on consensus rather than textual...
information, further highlighting the status of colleagues as an important information source. Although ease of access to colleagues and handbooks might help to explain these preferences, these sources are not necessarily evidence-based or current, and may have limited use for making evidence-based treatment decisions. These results further support the notion that research uptake in clinical practice is limited.

Some authors have suggested that producing a research mindedness is essential for increasing evidence-based practice. This includes greater awareness and better understanding of the value of research as well as appropriate development of research literacy and capacity skills. Previous research participation has also been linked to more positive attitudes toward research in chiropractic students or research use. A high proportion of chiropractors and massage therapists in the present study were not equipped with critical appraisal skills, and a lack of research experience may make it difficult to identify implications of research findings for practice.

Several differences were noted between the 2 professional groups in the present study. Chiropractors reported more evidence-based behavior than massage therapists as reflected by more frequent application of research in practice and more frequent use of peer-reviewed journals. Differences between other professional groups have been previously documented, and a potential link to education has been

### Table 5. Research literacy and capacity skills by discipline (% of practitioners who reported practical experience and some theoretical knowledge or who would not need assistance)

<table>
<thead>
<tr>
<th>Research literacy skills</th>
<th>Chiropractors (95% CI)</th>
<th>Massage therapists (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the library to find research information</td>
<td>79.6 (75.2-84.1)</td>
<td>66.7 (59.6-73.7)</td>
<td>.003*</td>
</tr>
<tr>
<td>Conducting a literature search</td>
<td>72.8 (68.0-77.6)</td>
<td>46.2 (39.1-55.1)</td>
<td>.000*</td>
</tr>
<tr>
<td>Reading and appraising research</td>
<td>65.6 (60.5-71.4)</td>
<td>42.7 (35.7-50.3)</td>
<td>.000*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Research capacity skills</th>
<th>Chiropractors (95% CI)</th>
<th>Massage therapists (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designing research studies</td>
<td>21.7 (17.9-27.2)</td>
<td>13.4 (8.9-19.8)</td>
<td>.018*</td>
</tr>
<tr>
<td>Identifying bias in research</td>
<td>37.4 (32.9-43.1)</td>
<td>20.4 (15.3-28.7)</td>
<td>.000*</td>
</tr>
</tbody>
</table>

Respondents were asked to select the statement that best described their knowledge and experience with research: (1) know nothing and have no practical experience; (2) know some theory but have no practical experience; (3) know some theory and have practical experience but have not mastered; or (4) know quite a bit and would not need assistance.

* Denotes statistically significant difference between chiropractors and massage therapists.

### Table 6. Logistic regression

<table>
<thead>
<tr>
<th>Step</th>
<th>−2 log likelihood</th>
<th>Cox and Snell R²</th>
<th>Nagelkerke R²</th>
<th>Variables in the equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>217.229</td>
<td>.066</td>
<td>.149</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>207.982</td>
<td>.086</td>
<td>.195</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>200.616</td>
<td>.102</td>
<td>.231</td>
<td></td>
</tr>
</tbody>
</table>

| Step 1 | Variable(s) entered on step 1: q9e (Use of peer-reviewed journals). |
| Step 2 | Variable(s) entered on step 2: q1 (Discipline).                   |
| Step 3 | Variable(s) entered on step 3: q7a (Research adds credibility to my discipline). |
suggested. Although the present study was not designed to investigate educational differences between chiropractors and massage therapists practicing in Alberta, a review of some educational curricula suggests that scientific research and the development of research skills are a much bigger focus in the training of chiropractors than massage therapists. The Canadian Memorial Chiropractic College in Toronto, where most chiropractors practicing in Canada are trained, has an accreditations statement underlining the importance of research. Furthermore, providing chiropractors with the fundamentals of scientific research is an explicit objective of the education program and it is structured accordingly. In contrast, although the importance of research to guide practice is promoted by the Canadian Massage Therapy Research Network, a subcommittee of the Canadian Massage Therapist Alliance, of which MTAA is a member, few formal opportunities for research exposure exist at this time.

A recent study on undergraduate chiropractic students found an increase in confidence to do research between the first and third year of the 4-year program. These students also showed increasing agreement over the course of their education that research was necessary and would promote the recognition and development of the chiropractic profession. Physiotherapist students’ self-reported knowledge and behavior toward research increased as a result of attending a research methods course. They also showed a greater level of confidence and ability to critically review literature and to apply knowledge and skills in practice. The authors of both studies strongly argue that mastery of research literacy and capacity skills is the critical link for incorporating results of research studies into clinical practice. It appears likely that the difference in research use between chiropractors and massage therapists is related to differences in research skills, which may in turn be a result of the different research education received during professional training. Developing education programs at the professional training level and offering continuing education opportunities to further those skills may be effective strategies to enhance evidence-based practice in these disciplines.

Furthermore, efforts should be made to increase accessibility of research results (cognitively and physically), for example, through user-friendly presentation or access to researchers/colleagues with research skills and up-to-date evidence-based knowledge. Practice-based research networks are important resources for promotion of, and assistance with, research. Furthermore, support of professional associations is important because lack of time and resources are frequently cited by practitioners as barriers to conducting research. Incentives could include education credits and financial assistance to allow time and support to do research. The main purpose of research is to render better patient care; therefore, the promotion of the value of research-based practice to clients of CAM practitioners would also be beneficial for providers and patients. These strategies may demystify research and make research more accessible, practical, and relevant for practitioners.

The study has several limitations that must be considered. First, only 38.8% of chiropractors and 24.6% of massage therapists returned the survey, which may have been a result of the study design that did not use follow-up or advance notices, both of which have been linked to higher response rates. These strategies were not used because of restricted access to association mailing lists. The relatively low overall response rate may have biased the findings as chiropractors and massage therapists with positive perceptions of research may have been more likely to respond. Thus, the results may not necessarily reflect the overall prevailing attitude of chiropractors and massage therapists toward research. If we assume that nonresponders have a less favorable perception of research, it may be argued that their practice is likely less evidence-based and that they may have less developed research skills due to a lack of interest compared to the survey responders. This would further support the findings that overall, evidence-based practice is limited and that chiropractors and massage therapists are not adequately equipped to appraise or conduct research. Also, it is likely that positive response bias was similar for both practitioner groups, lending support to the observed differences between chiropractors and massage therapists. In addition, the statistical resampling approach takes into account the small sample size and potential bias, and thus, the results reported are likely valid beyond the present study sample.

Future research could focus on perceptions and actual use of research by complementary/alternative practitioners in relation to educational requirements, as well as identifying how research participation could be facilitated for these groups.

CONCLUSION

In summary, the present study found overall positive perceptions of research in a sample of chiropractors and massage therapists practicing in Alberta with most of them acknowledging the importance of research to validate their practice. In contrast, self-reported research use was low, and differed significantly between the 2 professional groups. Based on the data and evidence in the literature, it appears that the more frequent research use reported by chiropractors may be related to the chiropractic profession’s relatively research-oriented culture, their more intense research education, and exposure to research during their professional training. As a result of their training, chiropractors may be more confident in their research skills and ability to apply evidence-based findings in their practice.

Despite their limited skills, chiropractors and massage therapists in the present study recognized the importance of research for clinical practice and were interested in and willing to improve their skills. Timely and appropriate strategies will help to reduce practitioners’ fears, assist them...
in developing adequate skills, and allow them to use their research knowledge in daily practice, all of which will render patient care better.

**Practical Applications**
- Chiropractors and massage therapists reported an overall positive perception toward research.
- Practitioners’ application of research in practice was limited.
- Differences were found between the 2 professional groups, with chiropractors reporting more research skills and evidence-based practice.
- The differences between the 2 professional groups may be attributed to the chiropractic profession’s relatively more research-focused professional training.
- Strategies are needed to foster research skills and encourage greater research uptake by chiropractors and massage therapists.

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**The Reliability of a Posterior-to-Anterior Spinal Stiffness Measuring System in a Population of Patients With Low Back Pain**

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**Abstract**

**Objective:** A system for measuring posterior-to-anterior spinal stiffness (PAS) was developed for use in clinical trials of manipulation for low back pain. The reliability of this device is under investigation in this study.

**Methods:** The PAS system uses electronic sensors to record displacement and force while a human operator provides the force of indentation. A test-retest design was used with measures repeated by the same operator within 5 minutes. Posterior-to-anterior loads were applied to each lumbar spinous process of patients lying prone on a hard flat bench. Force and displacement were recorded and used to calculate PAS.

**Results:** The subjects consisted of 22 males and 14 females; average age was 49.1 years (SD, 14.2). All subjects had low back pain of at least 4 weeks duration, with mean Roland-Morris scores of 7.6 (SD, 3.3). Spinal stiffness ranged from 4 to 26 N/mm (average, 11.2; SD, 3.5). Stiffness in the first and second tests varied on the average by 0.31 N/mm (P = .03). Standard error of the measurement was 1.62 N/mm. The single measures intraclass correlation coefficient (3,1) was 0.790 (95% confidence interval, 0.739-0.832).

**Conclusions:** The equipment and method produced repeatable results over the short-term. The system may be sensitive enough to detect changes in spinal stiffness that occur with care. (J Manipulative Physiol Ther 2007;30:116-123)

**Key Indexing Terms:** Chiropractic; Lumbar Vertebrae; Biomechanics; Low Back Pain; Reproducibility of Results

Measures of spinal stiffness are important indicators of patient status in manual therapies and may help indicate the spinal level on which to concentrate interventions. Chiropractors, physical therapists, and osteopaths use a manual assessment of posterior-to-anterior spinal stiffness (PAS) which involves pressing into the spine with the patient in a prone position and judging the relative rigidity of the spine at different segments. Similar maneuvers might be performed with the patient sitting or side-lying.

Recently, Childs et al found in a clinical trial that spinal stiffness was 1 of 5 predictors of which patients with low back pain (LBP) would respond favorably to a particular physical therapy manipulation. In their study, they used a manual assessment to grade the relative stiffness of the L4-L5 and L5-S1 joints. A palpable difference in the stiffness at these joints helped predict which patients were more likely to respond favorably to manipulative therapy.

Manual palpation methods have been notoriously difficult to quantify and suffer from a lack of objectivity. Interexaminer reliability of chiropractic palpation of segmental fixation is typically poor to slight. Intra-examiner reliability is usually rated somewhat better, in the moderate to substantial range, depending on the experience of the examiner. Similarly, stiffness measures commonly used by physical therapists show little interexaminer agreement. Childs et al were able to achieve acceptable reliability in the lumbar mobility test they used by reducing the assessment to 3 levels: hypomobile, normal, and hypermobile. A recent method of stiffness assessment where the examiner compares spinal stiffness to the stiffness of an external reference has shown promise in enhancing objectivity, but sensitivity or clinical utility of this new method is untested.

When interexaminer reliability is low, then objectivity of the measurement is in question. Several attempts have been made to quantify spinal stiffness using electronic devices to
provide more objective assessments. The technique most commonly reported in the literature is the use of a motor-driven stylus to press into the paraspinal tissues or onto the soft tissue overlying the spinous process (SP) while measuring the applied load and displacement of the stylus. These systems are designed to mimic the testing performed by manual therapists, including the use of comparable loads to those applied during spinal mobilization.

Whether performed manually or with a device, there are still questions regarding what is being measured with PAS testing. The system has been modeled as a beam under 3-point loading where the lumbar spine is supported at the cephalad end by the rib cage and at the caudal end by the pelvis. Imaging studies have shown both with radiographic and magnetic resonance imaging that extension occurs in the lumbar intervertebral joints when PA spinal loads are applied. Posterior-to-anterior (PA) loading was seen to produce extension not only at the spinal level at which it was applied, but also at adjacent segments. In some cases, flexion was seen distal to PA loading in the upper lumbar region. Lee and Evans applied static loads of 150 N to the SP of L4 and observed sagittal plane rotations between $1^\circ$ and $2^\circ$. Kulig et al. used dynamic manual loads and did not measure the applied force. They observed segmental rotations on average of $3.6^\circ$ at the segment where loading was applied. Recent work has found a correlation between PAS measured in cadavers and 3-dimensional flexibility measured at the same thoracic segments using a testing system that applied bending moments directly to the vertebrae.

Soft tissue components can also play a part in the displacements seen with PAS testing. The soft tissues through which loads are applied to the spine are compressible. In addition, there may be some support from below the lumbar spine by the contents of the abdominal cavity. Although respiration has been found to affect spinal stiffness measures in some patients, especially when effort is exerted, Lee and Evans concluded that the relaxed abdomen does not contribute significant support to the spine during PAS testing.

In the PAS analysis, stiffness of the spine is calculated from force and displacement data as the change of force with respect to displacement. Plots of force vs displacement are typically nonlinear, with a low-stiffness toe region at low forces (<30 N) and a steeper, linear region at higher forces of indentation. The toe region is considered either to be caused by soft tissue compression or spinal loading in the neutral zone. The steeper, more often linear region is thought to represent the bending stiffness of the spine and is the factor most often reported in the literature.

Computer-controlled devices for testing PAS have shown excellent reliability in short-term testing on patients, especially when compared to manual methods. Such devices are considered capable of accurately measuring spinal load displacement properties.

Furthermore, spinal stiffness has been found to be related to changes in LBP. Even though patients could not be discriminated from pain-free controls based on PAS, patients did show an average 8% decrease in PAS when they were retested at a time when their pain was decreased. Controls showed no change in PAS on repeat testing.

None of the devices developed to date have seen wide use in a clinical setting. Some limitations might be their large size and lack of portability, which perhaps contributes to patient anxiety. A motor-driven indentation device certainly confers benefits in terms of repeatability and control of the measuring head displacement. However, the safeguards and protections that are needed to guarantee patient safety and encourage confidence add complexity to the system.

A new PAS device was recently developed as part of a randomized controlled trial of chiropractic care for patients with LBP. We intended to create a portable, handheld device using newer position tracking technology to quantify spinal stiffness. The new device combines a computerized force and displacement monitoring system with manual force application. In the current study, we assessed the test-retest reliability of this device by measuring the PAS in patients with LBP already enrolled in a randomized controlled trial.

**METHODS**

The equipment for this study consisted of an electromagnetic tracking device and a force transducer and associated electronics (Fig 1). The PAS device itself consisted of a 66-cm-long plastic rod mounted firmly to a wooden block which served as a handle. The rod was...
circular in cross section with a 2-cm diameter (cross-sectional area of 3.14 cm²). An inline force transducer (LC201-50, Omegadyne, Inc, Sunbury, OH) was mounted 4 cm from the lower end of the rod. A position-tracking sensor was mounted at the upper end (Polhemus Liberty, Virtalis Group, Manchester, UK). The tracking system produced an electromagnetic field and measured the change in that field in the sensor to track location and orientation with reported resolution of 0.038 mm for location and 0.0012° for orientation. Motion Monitor software (Innovative Sports Training, Chicago, Ill) running on an Intel Pentium–based PC recorded data on both rod location and force at 240 samples per second.

It was necessary to mount the metallic force transducer far away from the position sensor to avoid interference with the Polhemus tracking field. The Motion Monitor software, however, enabled a calibration of the plastic rod so that data on the rod tip at the point of contact with the patient were recorded. Furthermore, as location of both ends of the rod was recorded in 3 dimensions, it was possible to calculate the component of the rod tip displacement along the axis of the rod giving displacement in the direction of the applied load.

The system differed from previously used computer-interfaced PAS testing devices in that the force for spinal indentation was produced by the examiner, rather than by a motor-driven device. Hence, this device was handheld and portable. The examiner was provided with audible feedback to indicate when the desired force was reached during the test.

**Patient Characteristics**

The reliability study was performed as part of an ongoing clinical trial of the effects of chiropractic manipulation on pain and spine biomechanics of patients with subacute or chronic LBP. This study was approved by the Palmer University institutional review board. Patients were recruited for the clinical trial from the local area using radio and print ads. The study coordinator described the procedures, screened for specific inclusion criteria (Fig 2), and administered informed consent. The study’s clinical team screened patients for exclusion criteria (Fig 2) including contraindications to spinal manipulation or biomechanical testing. Patients were also excluded if they had been under the care of a chiropractor within the previous 4 weeks. Intake forms included an assessment of back pain using the Roland-Morris Questionnaire.

**Examiners**

The 9 examiners in the study consisted of the faculty, student assistants, and technicians employed in the LBP trial for biomechanics testing. Four examiners were doctors of chiropractic with between 2 and 20 years of clinical experience and 1 was a student in the chiropractic program at the college. The other examiners were undergraduate students in a biomedical engineering program.

Before the study, examiners were trained by testing the stiffness of a steel bar that could be mounted to mimic the range of forces and displacements seen in patients. During training, the examiners were given visual feedback on the force and displacement plots they produced. They were trained until they could complete the test within 5 seconds,
apply a load of 80 N to within 2 N, and showed symmetrical load/unload profiles.

**Testing Protocol**

The PAS reliability testing was carried out by duplicating the spinal stiffness tests that were performed as part of the biomechanical assessments in the LBP trial on all patients for the first 10 weeks of the trial. The PAS test was performed with patients in the prone position on a hard flat bench. Padding was placed only under the face, knees, and ankles. The examiner palpated and marked the skin over the 5 lumbar SPs, using the posterior superior iliac spine as the landmark to locate the first sacral segment. The SP most tender to palpation was found by applying digital pressure to the SPs and asking the patient which was most tender. Before testing stiffness, the examiner used the PAS device to measure the patient’s tolerance to forces up to 80 N on the most tender SP. The patient was asked to indicate if there was pain while the device was pressed onto the SP. If the patient complained of pain during the tolerance test, the force level at which pain was first perceived was noted. In patients with tolerance less than 80 N, the target force was set at 5 N below their tolerance level. Patients who could not tolerate 50 N were not tested.

At the beginning of the test, the patient was instructed to take a deep breath, then exhale to a comfortable level and then hold his or her breath out during the duration of the test. A test on 1 segment was completed in 5 to 10 seconds. The examiner varied the inclination of the loading rod so that it was approximately perpendicular to the spine at the segment being tested. The end of rod was not padded, but was contoured in a saddle shape to cup the SP on the sides. If the rod was not oriented normal to the skin surface, there was a tendency for the rod tip to slip off the SP.

The threshold for force application was set at 80 N, or at the tolerance level if the patient could not tolerate that load. We chose 80 N as the target load to provide data into the higher-stiffness linear region of the force-displacement relationship, while still being comfortable to patients. The force was applied manually by the tester pushing the plastic rod tip onto the SP and indenting the tissues.

Audible feedback from the computer alerted the operator when the force threshold was reached. Force was applied in 5 smooth cycles to each of the lumbar SPs at a rate of approximately 1 load/unload cycle per second. The force and displacement data were stored to computer disk for later reduction and analysis.

Each of the SPs was tested in order, beginning with L1. After the first PAS test, the patient remained in place on the testing bench for 5 minutes, and the test was repeated by the same examiner, using the same marks on the SPs and same force threshold as for the first test.

**Data Reduction**

Force and displacement data were plotted and reduced using Visual BASIC for Applications routines in Excel.
RESULTS

Fifty-two pairs of PAS tests were recorded from 36 patients over a 10-week period (16 of the patients were tested on 2 occasions, 4 weeks apart as part of the trial’s protocol). The patients consisted of 22 males and 14 females. Patient age ranged from 24 to 70 years, (average, 49.1 years; SD, 14.2). All patients had LBP of at least 4 weeks’ duration (23 [64%], >12 months; 5 [14%], 6-12 months; 4 [11%], 3 to <6 months; 4 [11%], 4 weeks to <3 months). The baseline Roland-Morris scores ranged from 1 to 17 with a mean of 7.6 (SD, 3.3).

Force-displacement plots show the nonlinear, viscoelastic character typically seen in PAS tests in the literature (Fig 3). There is an initial low stiffness “toe” region, which transitions smoothly into a more steeply inclined region that appears nearly linear. The unloading cycle does not overlay directly on the loading cycle, indicating loss of energy (hysteresis) in the spinal tissues typical of viscoelastic materials.

The 52 tests resulted in usable stiffness measures on 256 segments. Data on segments that did not exhibit a linear force-displacement relationship on any cycle were rejected. There were no significant differences in average stiffness values between segments, but there was a statistically significant but clinically very small decrease in stiffness for the second test, compared to the first (mean difference, 0.31 N/mm; \( P = .03 \)) (Table 1). Stiffness values exhibited a wide range in this population, ranging from 4 to 26 N/mm. The standard error of the measurement (SEM) was 1.62 N/mm.

Reliability was estimated using the intraclass correlation coefficient (ICC) in a 2-way mixed effects model with stiffness effects random and between tests effects fixed. The single measures ICC (3,1) was 0.790 (95% confidence interval [CI], 0.739-0.832). A scatterplot of the first tests vs the second tests shows the relationship graphically (Fig 4).

Nearly 80% (40/52) of the patients were able to tolerate 80 N of force directly on their SPs during the tests; 6 patients could tolerate no more than 50 N. Ninety percent of the tests provided 4 cycles with suitable linear regions that could be used to produce a stiffness value. Less than 2% of the tests produced less than 2 usable linear regions.

Further data analysis was performed to compare the forces and rates of loading during the cycles as an indication of the consistency among examiners and between tests. We performed the cycle analysis only on those tests where the target load of 80 N was applied and the test provided an acceptable linear region for the stiffness calculation (\( R^2 > 0.90 \)). A total of 1912 cycles met these specifications from 39 PAS tests.

The examiners tended to overload the patients’ spines during testing by 2.6 N on average when the target load was 80 N (Table 2). Within the 5 cycles of each test, examiners were consistent in the magnitude of the load applied, differing on the average by less than 0.6 N. There were significant differences in the average indentation time for the first compression cycle when compared to the other cycles. Retraction rates were uniform between cycles, except for the last 2 cycles. A significant portion of the difference in retraction time was due to the manner in which it was detected during data reduction. The first 4 cycles all lead into another cycle, so the end of the cycle was the lowest dip in the force/time plot. The fifth cycle ended the test and was not as easy to detect with our automated reduction routines.

The time for retraction of the PAS sensor rod is less than half of the time taken for indentation. Hence, on average, the force/time profile will have a saw-toothed appearance with a slow indentation and a quicker release of the load. The total cycle time is consistent only for cycles 2 to 4 (mean, 1.71 seconds; SD, 0.63). It is also noted that the measured stiffness of the first cycle is significantly lower (2.2 N/mm) than the stiffness measured in subsequent cycles.

### Table 2. Loading factors and stiffness described by cycle

<table>
<thead>
<tr>
<th>Cycle 1 (n = 385)</th>
<th>Cycle 2 (n = 384)</th>
<th>Cycle 3 (n = 386)</th>
<th>Cycle 4 (n = 385)</th>
<th>Cycle 5 (n = 372)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force (N)</td>
<td>82.4 (82.0-82.7)</td>
<td>82.7 (82.4-83.0)</td>
<td>82.6 (82.2-83.0)</td>
<td>82.5 (82.0-83.0)</td>
</tr>
<tr>
<td>Indentation (s)</td>
<td>2.51 (2.40-2.63)</td>
<td>1.17 (1.12-1.21)</td>
<td>1.20 (1.15-1.24)</td>
<td>1.17 (1.12-1.21)</td>
</tr>
<tr>
<td>Retraction (s)</td>
<td>0.50 (0.47-0.52)</td>
<td>0.51 (0.49-0.54)</td>
<td>0.52 (0.50-0.55)</td>
<td>0.55 (0.52-0.59)</td>
</tr>
<tr>
<td>Cycle time (s)</td>
<td>3.01 (2.89-3.14)</td>
<td>1.68 (1.62-1.73)</td>
<td>1.72 (1.65-1.78)</td>
<td>1.72 (1.66-1.79)</td>
</tr>
<tr>
<td>Stiffness (N/mm)</td>
<td>9.2 (8.9-9.5)</td>
<td>11.4 (11.0-12.0)</td>
<td>11.6 (11.2-12.0)</td>
<td>12.0 (11.6-12.4)</td>
</tr>
</tbody>
</table>

Values are shown as mean (95% CI).

a One-way analysis of variance, post hoc least significant difference test. Mean difference between cycles is significant at \( P < .05 \).
DISCUSSION

In this study, we have quantified the intra-examiner reliability of a new PAS measuring system. In patients with LBP, repeat testing in the short-term showed good intra-examiner reliability, based on the ICC value of 0.79. Our reliability is somewhat less than that reported by Latimer et al.\textsuperscript{12} (ICC, 0.96), but still indicates considerably better reliability than that reported for purely manual evaluations.\textsuperscript{4-7} We have observed force-displacement relationships similar in character and magnitude to those reported in the literature for humans with and without LBP as measured with fully mechanical devices. Very similar data reduction methods are used to produce stiffness values and those values are comparable to reported values.

Physiotherapy researchers in Australia have done extensive work over the past 15 years to determine the specific factors that might contribute to PAS measures. Certainly, the table surface (“plinth” in Australia) supporting the prone patient should be unyielding to avoid displacement of the whole body downward during testing.\textsuperscript{24} Other factors that have been identified are the need to standardize the amount, direction, and rate of force application during the test, cessation of respiration during the test, whether the breath is held in or out, and control of patient posture on the testing bench.\textsuperscript{22,28-32}

We have taken these factors into account in the design and use of a new PAS measuring system. The system differs significantly from previous mechanical “palpators” in that the indentation force is provided by a human operator rather than by a mechanical device. Essentially, it is a fusion of the manual and mechanical methods. The human operator performs the test, but computer-interfaced sensors record the force and displacement data. The clinical measure is computed from the recorded information, rather than sensory impressions of the operator.

The main differences between our system and other mechanical systems are the use of different technology to measure displacement and the use of human operators to produce the indentation force. Either of these factors could affect the performance of the system.

Other systems in use measure displacement with electronic transducers directly attached to a rigid support frame. Our system uses a more freely moveable Polhemus electromagnetic position tracking system. The reported accuracy of the Polhemus system is on the order of 0.1 mm for small linear movements such as we are measuring. The total displacement during a testing cycle varies depending on the stiffness encountered, but ranges between 1.5 and 5.0 mm over the 20-N range that we use to assess stiffness.

There is some inconsistency of the human operators’ force application, when compared to a motor-driven device. However, the magnitude of forces applied to the spine by the operator is consistent from cycle to cycle. Most patients with LBP are able to tolerate 80 N of force, but in those cases where tenderness precluded that force, the system allows for adjustment of the alarm threshold so that the operator can apply a lower load. The precise load limit used could affect the calculated stiffness if the load applied only produced indentation in the lower stiffness “toe region” of the force-displacement plot.\textsuperscript{30} Care should be taken in clinical studies using this device to measure stiffness over the same 20-N range for all tests of a particular patient.

The force application by human operators does vary with respect to the rates of indentation and retraction of the PAS tip. Apparently, the first cycle is tentative, while the operator adjusts the inclination of the rod and senses the location of the threshold force. The greatest consistency occurs after the first cycle. The average cycle time for the middle 3 cycles is quite consistent at 1.7 seconds per cycle (0.6 Hz). This rate of loading is similar to the rates tested by Lee and Svensson\textsuperscript{31} who found no significant difference in stiffness measures in normal healthy individuals when the rate of displacement was either 1.0 or 0.5 Hz. They did find a significant apparent lowering of the stiffness with a quasistatic loading rate (0.05 Hz). Our operators did maintain enough consistency to be in the range of 0.35 to 1.1 Hz in 95% of the tests.

The rate of the retraction of the PAS tip was quite often quicker than indentation, which will complicate calculations if we later examine the viscoelastic behavior of the spine and supporting tissues using this method. Viscoelastic behaviors are typically especially sensitive to the rate of loading. Our operators will need to be trained to control the retraction rate more effectively.

If the reader has ever walked on a boat dock floating in the water, the challenge of this work can be appreciated. Like the dock, the lumbar spine is draped over underlying, flexible elements and is connected at least at one end to other structures. Unlike the dock, those connections, as well as the connections between the vertebrae, are viscoelastic in nature and can move with 6 degrees-of-freedom. Both passive and actively controlled components surrounding the lumbar region constrain and enable its motion. As people interact with their surroundings, the lumbar region is also affected by whole-body posture and contact with external objects. For instance, in the prone position, the mechanical properties of the surface on which the person is laying, and the mechanical behavior of the ribcage and the pelvic, have an influence on the lumbar region bridging the two. Taking all these mechanical factors into consideration, we expect this work will provide insight into the usefulness of PA stiffness as a sensitive indicator of the general condition of the interaction between the passive components in the lumbar spine and the trunk stabilizers.

Although our system is reliable, it still cannot differentiate the relative contributions of soft tissue compression and vertebral movement to the overall displacement seen during spinal PA loading. The addition by Kawchuk et al.\textsuperscript{26} of an ultrasonic transducer to measure soft tissue thickness
during PA testing should enable accurate measurement of both soft tissue compression and bony movement. Another method that may hold promise is to measure the displacement of the skin surface adjacent to the SP that is being depressed, but outside the zone where direct loading is compressing the soft tissue. A method somewhat similar to this was used by Lee and Svensson\textsuperscript{31} to show that there was considerable soft tissue compression (6 mm) even though the spine may have moved only 3 to 4 mm.

It remains to be seen whether our system is sensitive enough to detect changes in spinal stiffness of patients undergoing a course of manipulative therapy. Although, on the average, the difference between tests in our study was 0.31 N/mm, some patients showed an increase and some a decrease in stiffness (Fig 4). Hence, the average error is small as the positive and negative errors cancel each other out. A better measure of error would be to look at the SEM, which is similar to the root mean square error. In either case, the errors are squared before summing so that positive and negative errors do not cancel out. The SEM in our study was 1.62 N/mm, which is 14\% of the average PAS measured.

Bland and Altman\textsuperscript{33} have developed a method for assessing reliability which involves calculation of the 95\% CIs of the reliability of a measurement, based on the SEM. Our system would be capable of detecting changes 95\% of the time if the changes were in the range −2.87 to 3.50 N/mm.

In one study of the changes seen in patients with LBP over time, Latimer et al\textsuperscript{27} found only an 8\% change in stiffness values when patients were no longer in pain. Age- and sex-matched controls that were measured twice with timing similar to our study and using a motorized PAS system changed less than 1\%. Our device may not be accurate enough to detect change in individual patients, although it should provide precise enough data to look at changes between groups. The system is currently in use in 2 controlled studies which should provide us with information about the changes to be seen over time in patients compared to controls.

Limitations of the current study include that we have tested only intraexaminer reliability and only over a short period. Interexaminer reliability is typically found to be lower than intraexaminer. With our device, the examiner only operates the system and does not view the data as it is being obtained or judge the results. Reliability for this system might depend more on the ability of the operators to apply the loads to the spine in a similar manner. Load orientation, contact point, and rate of application may affect measurements so operators should be trained to ensure uniformity.

**Conclusion**

The equipment and method described here produced quite repeatable results over the short term. The ICC of 0.790 indicated very good agreement between the tests. The device measured a wide range of values in this population. The average stiffness in these patients with LBP was 11.22 N/mm with a standard deviation of 3.5. Repeated testing showed an SEM of 1.62 N/mm. The system may be sensitive enough to detect changes in spinal stiffness that occur with care. Further testing is needed to show whether PA stiffness measures are seen to change with chiropractic adjustment or improvement in pain scores.

**Practical Applications**

- A diagnostic system is described for measuring spinal stiffness incorporating manual force application with electronic monitoring of force and displacement.
- The system produces values comparable to those measured with mechanical indentation systems.
- Reliability testing in patients with LBP showed substantial intraexaminer agreement.

**Acknowledgment**

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**References**

Validity of a Computer Postural Analysis to Estimate 3-Dimensional Rotations and Translations of the Head from Three 2-Dimensional Digital Images

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Abstract

Objective: The purpose of this study is to describe and evaluate the validity/accuracy of the computerized system PosturePrint for measuring head posture.

Methods: Computer analysis was compared with 125 measured positions of a mannequin head in 5 degrees of freedom. For each mannequin position, 3 digital photographs were obtained (left lateral, anteroposterior, and right lateral) and were processed through the PosturePrint computer system. For the head analysis, a headgear with 3 reflective markers was placed on a subject; and there were additional click-on markers at the ear tragus, upper lip, acromioclavicular joints, and episternal notch. Head postures were calculated as lateral translation ($T_x$), lateral flexion ($R_y$), axial rotation ($R_z$), flexion-extension ($R_x$), and anterior-posterior translation ($T_z$). For an error analysis, PosturePrint algorithm calculations were compared with the true mannequin head positions. Furthermore, average head posture was determined in student volunteers ($n = 40$).

Results: Mean computational errors were $R_x = 1.3$° (SD 0.6°) and $T_z = 1.1$ mm (SD 0.5 mm) for sagittal displacements and $R_y = 1.1$° (SD 0.7°), $R_z = 0.6$° (SD 0.4°), and $T_x = 1.1$ mm (SD 0.5 mm) for frontal view displacements. For the normal group, mean head displacements were 1.1° or less for all rotations and 1 mm or less for lateral translations ($T_z$); and forward head posture ($T_z$) averaged 3 cm.

Conclusion: From the mannequin positions, small mean errors indicate that the PosturePrint system is accurate. In the future, statistical research determining the correlation between head displacements, neck pain, function, and health status should be performed. (J Manipulative Physiol Ther 2007;30:124-129)

Key Indexing Terms: Posture; Biomechanics; Photogrammetry

The problem of recovering 3-dimensional (3D) information of a position or movement from a set of 2-dimensional images has a long history in computer vision. 1-4 Clinically, postural displacements of the head and neck are common. Methods for measurement of head posture included the linear excursion measurement device, body photographs, the cervical range of motion device, and simple plumb line methods. 4-8 Problematically, these methods were not able to measure postural rotations and translations of the head, rib cage, and pelvis in 6 degrees of freedom in a right-handed Cartesian coordinate system, described as $R_x$, $R_y$, $R_z$, $T_x$, $T_y$, and $T_z$. 9

A further concern was the validity of measurement methods. Although anterior head translation was a horizontal movement relative to a vertical line at the shoulder, many of these methods used angles, measured at the acromioclavicular (AC) joint between a vertical line and a line through the ear, to measure head translations instead of distances in millimeters. In addition, these methods used photographs that were not corrected for projection errors. Thus,
dichotomous findings concerning the validity of posture as a cause of pain in studies might be due to lack of uniform classification and valid measurement for normal and abnormal head postures.4-8

Recently, a computerized system, PosturePrint, was developed that claims to measure head postures as rotations ($R_x$, $R_y$, $R_z$) and translations ($T_x$, $T_y$, $T_z$) in 3D from 3 digital photographs. If accurate, future postural studies could overcome the concerns with measurement validity/accuracy and account for complex postures, such as combinations of rotations and translations.

Besides axial, lateral bending, and flexion-extension rotations of a head, the translations were some of the parameters used in postural evaluation of a patient. Some common translational postures were lateral head translation and head protrusion.

Although university laboratories have expensive equipment to measure posture and locomotion, there is a need for an inexpensive and accurate clinical tool to measure human posture.

In this article, we wished to describe and evaluate the validity/accuracy of the computerized system PosturePrint for measuring head posture. It was hypothesized that the PosturePrint system would be sufficiently accurate for use in determining upright head posture from 3 digital photographs.

**METHODS**

There were 2 purposes for this project, as follows: (a) to evaluate the accuracy of the PosturePrint system for head positions and (b) to obtain average head posture positions in standing normal subjects.

The PosturePrint computer system (service provided by Biotonix, Montreal, Quebec, Canada) attempted to determine 3D positions of the subject’s head, rib cage, and pelvis from three 2-dimensional digital photographs. This computer analysis required that coordinates of anatomical markers on 3 digital photographs of a standing subject be evaluated over the Internet. The set of 3 digital photographs was composed of a left lateral, right lateral, and anteroposterior (AP) views. This set of 3 photographs was obtained in 125 mannequin head positions and in 40 normal student volunteers.

After determining the accuracy of the PosturePrint system by comparing the positions of the mannequin with the calculated results, the 40 university student volunteers were evaluated for standing head posture. This project was approved by the Ethics Committee of the Université du Québec à Trois-Rivières, Canada; and volunteers signed informed consent. The student volunteers filled out a numerical rating score for pain ($0$ = pain-free; $10$ = severe pain, bedridden). The mean numerical rating score for pain was $1.0$ (SD $1.3$), indicating a normal group.

### Table 1. The PosturePrint required 31 anatomical points for a full body analysis

<table>
<thead>
<tr>
<th>Region</th>
<th>Anatomical location</th>
<th>No. of markers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head (6)</td>
<td>Headgear</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Ear tragus</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Upper lip</td>
<td>1</td>
</tr>
<tr>
<td>Rib cage (9)</td>
<td>AC joints</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ESN</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>T2 spinous process</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>T12 spinous process</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Lateral margin torso at 8th rib</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6-in strip at inferior scapulae</td>
<td>2</td>
</tr>
<tr>
<td>Pelvis (6)</td>
<td>posterior superior iliac spine</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>anterior superior iliac spine</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6-in strip at gluteal prominens</td>
<td>2</td>
</tr>
<tr>
<td>Legs (10)</td>
<td>Lateral margins of upper thigh (AP view)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Posterior and anterior margins of upper thigh (lateral View)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Mid ankle (AP and lateral)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Big toe</td>
<td>2</td>
</tr>
</tbody>
</table>

Because the head is compared with the rib cage position, only 10 markers (6 head and the first 4 rib cage markers) were needed for the head postural analysis in the current study.

In the Université du Québec à Trois-Rivières’ biomechanics laboratory, these photographs were taken of a standing subject or of a mannequin on a stand at 61 cm (2 ft) in front of a calibrated wall grid. The camera was positioned on a tripod at a height of 84 cm (33 in) at a choice of distances between 244 cm (8 ft) and 335 cm (11 ft) from the wall grid (distance specified at time of analysis).

For a full body analysis, several reflective markers (13) were placed on the subject at specific anatomical points, whereas several (18) user-chosen points with the computer mouse were “clicked” on the digital photographs (Table 1). However, for head postures, only 3 markers on a headgear, 2 click-on markers at the ear tragus, 1 upper lip marker, 1 episternal notch (ESN) marker, a T2 spinous marker, and 2 markers on the AC joints (1 each) were required.

The 3 reflective markers on the headgear were fixed at known distances, creating a fixed triangle, and were positioned with the ear markers and the between-the-eyes marker parallel to the lateral canthus line of the subject’s eye (Fig 1).

To evaluate the accuracy of the PosturePrint system for head positions, 125 sets of 3 digital photographs (95 AP positions and 30 lateral positions) of a mannequin head were obtained, with headgear in place, at a camera distance of 335 cm (11 ft) from the wall grid in the university biomechanics laboratory (Fig 1). Before displacing the mannequin head from neutral/normal position, the camera and mannequin head were placed on a perpendicular line from the center of the wall grid. This established an origin (normal posture) from which displacements of the mannequin head were made. The normal head position was
defined as the glabella, philtrum, and ESN aligned in the median-sagittal plane while the external auditory meatus is aligned with both AC joints in the coronal place. We have adopted the Cartesian coordinate system suggested in 1974 for biomechanics, which has the positive y-axis directed vertically, the positive z-axis directed to the anterior, and the positive x-axis directly to the left. The head positions to be evaluated were lateral translation or side shift (\(T_x\)), axial rotation (\(R_y\)), lateral bending (\(R_z\)), flexion-extension (\(R_x\)), and forward-backward translation (\(T_z\)). Note that vertical translation of the head (\(T_y\)) has been omitted because of the difficulty of determining this posture without a lateral radiograph of a subject (ie, hyper- or hypolordosis of the cervical spine).

**Algorithm for \(T_x\), \(T_z\), \(R_y\), \(R_z\), and \(R_x\)**

From the coordinates of reflective and click-on markers, only simple geometry was required to calculate the head positions for the mannequin \(T_z\), \(R_x\), \(T_x\), and \(R_z\) locations, with special care to account for higher projection of the headgear’s ear marker in the lateral view and the headgear’s forward projected ear marker in the AP view during axial rotation. Specifically:

\(R_x\) was evaluated from the lateral views as the angle between the line connecting the ear marker with the between-the-eyes marker and the horizontal line.

\(R_z\) was evaluated from the AP view as the angle between the line connecting the right and left ear markers and the horizontal line.

\(T_x\) was evaluated from the AP view as the distance between midpoint of the ear markers and the line perpendicular to the AC joints line and passing through the ESN. In addition, reflective markers were placed on the stand to represent the ESN and AC joints.

\(T_z\) was evaluated from the lateral views as the horizontal distance between the ear tragus (click-on marker) and the origin of the head coordinate system, which is midway on the line through the AC joints.

\(R_x\) was much more difficult to calculate from the projections of the headgear markers (Fig 2). The 3 headgear
control markers were rotated around the y-axis by the angle $R_y = \beta$ (positive or negative); and their position was denoted by points A, B, and C. Points Ap, Bp, and Cp represented projection of the rotated control markers on the projection plane Oxy. It was assumed here that the lateral view motions (rotation $R_x$ around the x-axis and translation $T_x$ along the z-axis) were treated separately from the lateral view images.

Instead of relying on accurately recovering the true distance between end markers, we only used the distances extracted from the digital image. The x-coordinate of point Bp (Fig 2) was evaluated as:

$$x_{Bp} = \frac{ds\sin\beta}{1 - \frac{d}{2}\sin\beta}. \quad (1)$$

After several mathematical steps, the value of the axial rotation was estimated from the ratio $\rho$ of the projected distance between one of the end markers and the mid marker and the projected distance between end markers, that is, as

$$\beta \approx \arctan\left(\frac{W}{d}\left(2\rho - 1\right)\right). \quad (2)$$

Equation (2) was the method of choice for determining $R_x$ head rotations within the PosturePrint computer system.

### RESULTS

There were 95 positions of the mannequin head evaluated for single, double, and triple combinations of the postures of $T_x$ (lateral head translation), $R_y$ (axial head rotation), and $R_z$ (lateral head bending), which were easily observed in the AP view. The average errors comparing the positioned mannequin with these computed values were $R_y = 1.1^\circ$ (SD 0.7$^\circ$), $R_z = 0.6^\circ$ (SD 0.4$^\circ$), and $T_x = 1.1$ mm (SD 0.5 mm).

Although single ($n = 27$) and double combinations ($n = 44$) of head postures were studied in the AP view, Table 2 provides only the mannequin head postural positions of triple combinations ($n = 24$) of $T_x$, $R_y$, and $R_z$ and the computed values from the PosturePrint computer system.

There were 30 positions of the mannequin head evaluated for single ($n = 10$) and double combinations ($n = 20$) of the

### Table 2. Computational errors of the PosturePrint

<table>
<thead>
<tr>
<th>Position no.</th>
<th>$T_x$ (mm)</th>
<th>$R_y$ (°)</th>
<th>$R_z$ (°)</th>
<th>$T_x$ (mm)</th>
<th>$R_y$ (°)</th>
<th>$R_z$ (°)</th>
</tr>
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<tbody>
<tr>
<td>72</td>
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<td>-5.2</td>
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<td>-9.6</td>
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<td>-4.5</td>
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<td>-12.1</td>
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<td>+9.9</td>
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<tr>
<td>Average error</td>
<td>1.51</td>
<td>1.36</td>
<td>0.38</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Different mannequin head positions were compared with computational results by the PosturePrint system. Although single, double, and triple combination postures were studied, only the errors for triple combinations of postural positions of a mannequin head in the AP view were compared with computed results by the PosturePrint system.

### Table 3. Computed head positions in lateral view

<table>
<thead>
<tr>
<th>Position no.</th>
<th>$R_y$ (°)</th>
<th>$T_x$ (mm)</th>
<th>$R_z$ (°)</th>
<th>$T_x$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>+8.3</td>
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<tr>
<td>108</td>
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<td>-7.0</td>
<td>+18.9</td>
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<tr>
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<td>-6.9</td>
<td>+28.8</td>
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<tr>
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<td>+30</td>
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<td>+30.7</td>
</tr>
<tr>
<td>Average error</td>
<td>1.38</td>
<td>1.11</td>
<td></td>
<td></td>
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</tbody>
</table>
Table 4. PosturePrint combined results for computation error and mean data for head positions in normal subjects

<table>
<thead>
<tr>
<th>PosturePrint use</th>
<th>$R_x$ (°)</th>
<th>$R_y$ (°)</th>
<th>$R_z$ (°)</th>
<th>$T_x$ (mm)</th>
<th>$T_y$ (mm)</th>
<th>$T_z$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannequin: computatioinal error</td>
<td>1.1 (0.7)</td>
<td>0.5 (0.4)</td>
<td>1.3 (0.6)</td>
<td>1.3 (0.9)</td>
<td>1.1 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Normal subjects: mean and SD</td>
<td>$-0.1$ (1.7)</td>
<td>1.1 (2.3)</td>
<td>$-0.6$ (6.0)</td>
<td>$-1.2$ (5.7)</td>
<td>30.1 (9.1)</td>
<td></td>
</tr>
</tbody>
</table>

The total computational error (mean and SD) between actual mannequin head positions and computed values is provided. Studied postures were lateral translation ($T_x$), axial rotation ($R_x$), lateral flexion ($R_y$), flexion-extension ($R_z$), and forward-backward translation ($T_z$). Average (SD) head measurements with the PosturePrint system for normal student volunteers ($n = 40$) is reported.

posts of $T_z$ and $R_z$, easily observed in the lateral view. Mean and standard deviation of computational errors for sagittal displacements were $R_z = 1.3^\circ$ (SD 0.6°) and $T_z = 1.1$ mm (SD 0.5 mm). Table 3 provides the mannequin double postural positions of $T_z$ and $R_z$ with the computed values from the PosturePrint computer system.

Table 4 provides the average and standard deviation of all errors between the 125 mannequin head positions and the calculated values.

For the normal subjects, the mean head positions were $1.1^\circ$ or less for all rotations ($R_x$, $R_y$, $R_z$), less than 1 mm for lateral translation ($T_x$), and 3 cm for forward head posture. Table 4 also reports mean values for these head positions ($R_x$, $R_y$, $R_z$, $T_x$, $T_z$) in upright static posture in the 40 normal subjects.

**DISCUSSION**

Our purposes were to (1) to evaluate the validity/accuracy of the PosturePrint computer program by comparing computed results from 3 digital photographs with true positions of a mannequin head and (2) to provide data for head position in normal subjects. Because the average errors between the true position of a mannequin head and the calculated values were less than 1.5° for all rotations and less than 1.5 mm for all translations, the PosturePrint computer system was sufficiently accurate for clinical evaluations of head posture.

As expected, the normal subjects had very little mean displacements from normal neutral head position ($1.1^\circ$ or less for all rotations and less than 1 mm for lateral translations), except for 3 cm of forward head translation ($T_z$). We speculated that this relatively large forward head translation posture might be due to the forward head position of students required during long hours of studying for university courses.

The limitations of any computerized measurements were the errors due to approximation, which in this case were small and not clinically relevant. Thus, in clinical situations, the errors due to palpation and placement of the reflective markers by the clinician will be the major errors involved. Because the data here due to program approximation indicated small errors in validity/accuracy, the next step would be a clinical reliability/repeatability study.

The 3D reconstruction of human body features from digital images has recently received tremendous attention because of its application in object recognition, robotics, bioengineering, video games, animations, surveillance, and visualization. Very often, proposed systems involved specialized and expensive hardware (eg, laser scanners). Other methods based on photogrammetry or computer vision obtained 3D models of objects with low-cost acquisition systems, using photographs or video cameras. These methods, however, usually required very precise acquisition and calibration techniques and enough space around the object to take a series of pictures.

Using a mechanical engineering approach, in the early 1980s, upright human posture was categorized as rotations and translations of the global objects (head, thoracic cage, and pelvis) about or along the axes of a 3D Cartesian coordinate system. This analysis provided 12 simple motions (6 rotations and 6 translations) in 6 degrees of freedom for each of the global objects. It was imperative to accurately describe and constrain initial starting points when studying postures and when all 6 degrees of freedom were in need of determination. In this study, we focused our attention on the problem of extracting a value of rotations and translations of a subject’s head.

In previous postural studies, very few of the 12 movements of the head have been measured by researchers. Predominantly, forward and backward translations and flexion-extension of the head were measured as part of a postural analysis. Importantly, axial rotation was a degree of freedom of the head that is commonly measured for its’ range of motion and spinal coupling (vertebral displacement) pattern. To the best of our knowledge, previous reports have presented neither a method to extract a value of axial rotation nor a value of other rotations and translations of a subject’s head from photographs.

Currently, upright posture evaluation is recommended as part of a comprehensive but focused spine-related physical examination of the cervical spine. Despite this, static postural displacements of the head on photographs have not been measured accurately in the anterior to posterior view as a displacement within the range of motion. Our study provided a method of objective measurement of the rotational and translational degrees of freedom for the human head; therefore, improvement or worsening of a patient’s condition could be reliably documented.

There were a few types of sonic and mechanical digitizers. There was a sonic digitizer, FreePoint (GTCo CalComp, Inc, Columbia, Md), that can be used to measure...
any part of the body in upright static position. It claimed to measure posture as rotations and translations. No published research could be located for the FreePoint. Furthermore, the point-by-point digitization was slow, requiring the user to manually touch numerous points. Any movement of the patient during data capture could cause significant errors. This system was also sensitive to the environment, background noise, and metallic objects in the room. The Metrecom Skeletal Analysis System (Faro Technologies, Lake Mary, Fla)\(^\text{17}\) was an electromechanical digitizer with computer. Although it permitted acquisition of x, y, and z coordinates for points in 3D space, it obtained values for characterizing the shape of the back and skeletal alignment and measured extremity range of motion but did not measure the head, rib cage, or pelvis as rotations and translations.

**CONCLUSION**

The PosturePrint system was developed to assist health care providers in the assessment of musculoskeletal form and postural displacement detection. It required 3 digital photographs as input data, while calculating postural position as rotations and translations in 3D. The small errors between positions of a mannequin head and the program’s computed positions indicated that this computer system may be sufficiently accurate for clinical use. The average values for head posture could be used for clinical comparisons with further research.

**Practical Applications**

- Mean computational errors were 1.38\(^\circ\) or less for rotational positions and 1.1 mm for translational positions.
- Average head posture of a normal group of students (n = 40) was obtained, which was 1.1\(^\circ\) or less for all rotations and 1 mm or less for lateral translations (\(T_x\)); but forward head posture (\(T_z\)) averaged 3 cm.

**Acknowledgment**

The authors are grateful to the Université du Québec à Trois-Rivières, Canada, and CBP Nonprofit, Inc, Evanston, Wyo, for funding support. We acknowledge the assistance of Drs Marin Wendell and Joseph R Ferrantelli in data collection.

**REFERENCES**

Objective: The objective of this study was to identify the prevalence of back pain and treatment satisfaction in a population of low-socioeconomic pregnant women.

Methods: This study used a cross-sectional design to determine the prevalence of self-reported musculoskeletal pain in pregnancy for 599 women. Women completed an author-generated musculoskeletal survey in the second trimester of their pregnancy that addressed pain history, duration, location, and intensity, as well as activities of daily living, treatment frequency, and satisfaction with treatment.

Results: Sixty-seven percent of the total population reported musculoskeletal pain, and nearly half presented with a multi-focal pattern of pain that involved 2 or more sites. Twenty-one percent reported severe pain intensity rated on a numerical rating scale. Eighty percent of women experiencing pain slept less than 4 hours per night and 75% of these women took pain medications. Importantly, 85% of the women surveyed perceived that they had not been offered treatment for their musculoskeletal disorders.

Conclusion: Multi-focal musculoskeletal pain in pregnancy was prevalent in this underserved patient population. The pain in this population negatively affected sleep and treatment appeared inadequate.

Low back pain (LBP) in the general population is recognized as a major health concern, and left untreated, this malady can lead to chronic, disabling morbidity. According to the Centers for Disease Control and Prevention, 10% of adults in the United States have LBP on any given day, and 30% of adults experience LBP at least once a year. Additionally, chronic pain is a major health care expense in the United States, and LBP is responsible for the majority of chronic musculoskeletal pain. Low back pain and pelvic pain (PP) in pregnancy, however, are frequently viewed as transient conditions that are anticipated to subside after childbirth. In fact, recent studies have identified that women who do have LBP/PP during pregnancy receive little recommendations and/or treatment for their complaints. Although the prevalence of LBP/PP during pregnancy in the United States is unclear, reports from populations in other countries imply that the condition is prevalent and has a negative effect on quality of life. Importantly, women who have been pregnant have the highest incidence of chronic LBP after pregnancy, and up to 40% of pregnant women continue to experience pain 18 months postpartum. Therefore, LBP/PP in pregnancy, although largely ignored, may contribute to a substantial level of morbidity and cost in pregnant women and, particularly, women postpartum.

Studies from Scandinavia suggest that morbidity associated with pregnancy is a major expense for society. For example, 1 in 5 pregnant women in Scandinavia is on sick leave for back pain during or after pregnancy. The average sick leave for these women is 7 weeks, a duration added to the
normal pregnancy leave. Surprisingly, sick leave for LBP/PP surrounding pregnancy is the single largest social health care expense in Scandinavia.7 Certainly, complicating factors during pregnancy and child rearing could have extensive and vital effects on women at important time points in their life.

We aim to identify and classify back pain surrounding pregnancy in an underserved patient population and hypothesize that back pain during pregnancy has negative effects on quality of life. We performed an analysis of collected data on a population of pregnant women attending a multidisciplinary clinic at Barnes-Jewish Hospital in the Washington University Medical Center in St Louis, Mo. The objectives of this study were to (1) identify the prevalence of back pain, (2) classify the locations of the pain, and (3) evaluate patient perception of care and satisfaction with treatment.

METHODS

The protocol was approved by the Institutional Review Board of Washington University School of Medicine and was compliant with Health Insurance Portability and Accountability Act rules. This study used a cross-sectional design to determine the prevalence of self-reported back pain, the intensity and location of pain, the treatment modalities used, and the level of patient satisfaction with treatment. Participants in this study were recruited at the Women’s Wellness Center of Barnes-Jewish Hospital and the Washington University School of Medicine in St Louis, Mo. This clinic is staffed by faculty in the Department of Obstetrics and Gynecology and serves predominantly an uninsured, underinsured or Medicaid-insured population that delivers at Barnes-Jewish Hospital. The Women’s Wellness Center includes the following: low-risk pregnancies, high-risk pregnancies, the Center for Diabetes in Pregnancy, the Teen Pregnancy Center, and the Musculoskeletal Pain in Pregnancy Center. Certified nurse midwives, nurse practitioners, and residents in obstetrics and gynecology provide care at all clinics. Attending physicians from the Washington University Department of Obstetrics and Gynecology staff all clinics. Chiropractic physicians, chiropractic residents, and chiropractic interns staff the Musculoskeletal Pain in Pregnancy Center. Coordinating staff for this center includes obstetrical practitioners, physiatrists, nurses, and nurse assistants.

Surveys were offered to all obstetrical patients in the Women’s Wellness Center. The average week of gestation was 22. As part of routine obstetrical care, women completed a screening questionnaire containing information on general medical health and a targeted questionnaire about the patient’s back problems (Fig 1). The questionnaire was designed to collect information about pregnancy-related pain and quality-of-life issues.

Pain intensity was assessed by the Numerical Rating Scale, with a score of greater than 8 considered severe. A critical measure of quality of life is sleep, and we defined sleep problems as sleep duration of less than 4 hours per night.11,12 The admitting receptionist collected the questionnaires. Using Excel software (Microsoft Inc, Redmond, Wash), a research physician entered information into a de-identified database. The analysis was unadjusted for covariates, and frequencies were compared by χ² analysis using α = .05 for significance. For inference, 95% confidence intervals were computed using normal approximation methods. For dependent frequencies, McNemar’s test for agreement was used.

RESULTS

Ninety percent (599/666) of the women enrolled during a 15-month interval complied with the request to complete the
The 67 women not completing the survey gave the following as reasons for nonparticipation: not interested, 48; no time, 16; other, 3. Completed surveys (n = 599) were entered into the database. The average age of patients was 22.7 years (SD, 4.5). The average weight of the women was 177.4 lb (SD, 56.7). The average period of gestation was 17.1 weeks. The sample group had racial self-identifications of 70% African American, 20% white, 6% Bosnian, 3% Hispanic, and 1% other.

We found that two thirds of the population reported back pain. The women identified pain at 3 sites: LBP, PP, and mid-back pain (MBP) (Fig 2). Although LBP was reported in a majority of women complaining of musculoskeletal pain, the data indicate that nearly half of the women presented with a multi-focal pattern of pain involving 2 or more sites: 1 in 3 of the women reported pain at 2 sites and 1 in 10 reported pain at all 3 sites. Figure 3 illustrates the back pain data by anatomical location. Only a small fraction of cases involved PP or MBP alone, yet these areas were frequently sites of pain in combination with LBP.

Low back pain produced the largest number of severe pain cases, whereas MBP alone was never reported to be severe. However, in combination with other sites, MBP and PP were components of the multi-focal pain complex reported as severe. Low back pain alone or in combination with other sites was the major source of severe pain; 90% of the reports of severe pain involved LBP (Fig 4). Indeed, we found a significant relationship between the number of pain sites and pain severity (P < .01).

Sleep is a quality of life measurement that can affect many other activities of daily living. Sleep disturbance was frequently associated with back pain; the test for this association was significant (P < .01). Sleep problems were reported in 37% (CI, 32.8-41.2) of respondents. Importantly, 80% (CI, 74.7-85.3) of women reporting sleep disturbances had back pain, whereas only 8% (CI, 4.8-11.2) of women without pain reported any problems sleeping.

Because pain often leads to medication use, we asked the women if they were taking pain medication. We found a significant relationship (P < .05) between reports of musculoskeletal pain and the amount of pain medication use. Of women reporting use of pain medication, 75% (CI, 69.2-80.8) had back pain. Taken together, nearly 3 of 4 women with sleep disturbance, pain medication use, or both had back pain.

We next determined whether there was a relationship between pain in a previous pregnancy and pain in the current pregnancy. Of the respondents surveyed, 60% (CI, 55.3-64.7) reported back pain in their first pregnancy. In women who reported a previous pregnancy, 53% (CI, 48.2-57.8) reported pain in the current pregnancy. However, 85% (CI, 80.6-89.4) of women who reported pain in a previous pregnancy reported pain in the current pregnancy; the test for this association was significant using McNemar’s test of agreement (P < .0001; Fig 5).

Based on the high prevalence of back pain that we observed during pregnancy, questions arose about the effectiveness of the treatment provided. Surprisingly, 85% (CI, 81.9-88.1) of women reported they had not received any treatment for their pain. Of the 15% (CI, 11.5-18.5) who perceived that their back complaints were addressed, less than 10% of these, or 1% of the 401 women with pain, were satisfied with the symptom relief they obtained.

**DISCUSSION**

The data show a high proportion of patients in an underserved population of pregnant women experience back pain. Although LBP is the most common source of pain, PP and MBP frequently contributed as symptoms. Multi-focal pain related to reports of severe pain. The pain experienced predisposed those patients to sleep disturbances, a measure of quality of life. Pain reports were correlated with frequent use of analgesic medications. The data also indicate that pain in a previous pregnancy predicts a high risk for back complaints in future pregnancies. Despite the high prevalence of musculoskeletal symptoms, few patients had received treatment during standard obstetrical care and even less were satisfied with the treatment received.
This study examined pregnant women using an author-generated survey to gather patient perception on their back pain and treatment. Because this survey has not been studied in previous populations of pregnant women, it cannot be assumed as reliable. In addition, the women did not clearly indicate whether they had expressed their pain to their obstetric practitioners before completing their back pain survey. This could be seen as a limitation; however, they were questioned on average after their third obstetric visit. The survey did not include other areas of musculoskeletal pain such as neck pain or wrist pain either. These other areas of musculoskeletal pain could have individual significance in this population and/or could have overlapping influence on back pain reports. Lastly, the type of medication was not identified as over-the-counter or prescription; therefore, the use of medication is not clear. Nevertheless, such a high percentage of medication use in a pregnant population is somewhat alarming.

Previous studies suggest that LBP/PP may be frequently encountered in pregnancy, although these studies have largely involved populations outside the United States.6,8,13 These studies involved populations of women from mixed socioeconomic backgrounds and older age groups than in our study, yet the prevalence rates for LBP are similar. Ostgaard et al6 and Kristiannson et al13 determined that previous pregnancy (regardless of pain history) predisposed women to experience back pain in the current pregnancy. Our results indicate that previous pregnancy does not increase risk of experiencing pain during the current pregnancy overall. However, patients who had pain in a previous pregnancy had a high rate of pain in the current pregnancy. Fully, 85% of women who experienced pain in a previous pregnancy reported pain in our survey. This is in agreement with the distinction made on risk factors related to pain in pregnancy by Orvieto et al14 and Wu et al15.

Previous studies have identified that the most frequent locations for pain in a population of women with PP in pregnancy were at bilateral sacro-iliac joints, pubic symphysis, coccyx, and groin, whereas the highest intensity of pain was in the lower back and sacro-iliac joints.6,16 Consistent with our findings, these populations with multifocal pain have more severe pain and, thus, more disability.13,17 Taken together, our results are consistent with a model where the low back is a primary site of pain generation, and where the pelvis and mid back increase the pain severity.

Poor sleep has been shown to be associated with back pain and to negatively impact quality of life.11,12,18 As pregnant women experience changes in shape and size of the body, it is a common notion that the pregnancy experience involves pain and difficulty with sleeping. However, structural changes with weight gain and spine posture during pregnancy do not parallel pain occurrence or intensity.14,19,20 Accordingly, few of the women in the study reported sleep problems in the absence of back pain. With women who experienced back pain, sleep disturbance was commonplace. Therefore, in our population of gravid women, we saw a direct association between sleep deficiency and back pain. We speculate that such disruption in life quality, left untreated, may become a chronic pain issue.

Altered pain medication use is recognized as a clinical outcome measure for nonpregnant patients with chronic LBP.21 There are implicit concerns on the use and overuse of pain medications, and particularly in pregnant populations.22-24 Thus, although the type of medication was not identified in this study, the fact that three fourths of the women who reported pain also described use of pain medication suggests increased risk of morbidity for these women. These results raise the question of whether or not the high incidence of pain medication use reflects a lack of education about potential risks of medications or more an inability for the pregnant woman to cope with the pain.

What can be done to effectively treat back pain in pregnancy and, thereby, to enhance the coping skills in pregnant women who experience pain? We suggest that substantial improvements in the well being of pregnant patients might result from programs that proactively address back problems experienced by these women. Accordingly, obstetrical care might include early back pain screening to identify risk factors, such as previous pain in pregnancy, multi-focal pain, or severe pain. Such self-reporting of risk factors for back pain would be a proactive step to allow early education and/or treatment to reduce the risk for pain in the current pregnancy.

**Conclusion**

Our findings highlight the prevalence and complexity of back pain in pregnancy, and, notably, in a population in the United States. Importantly, we have identified that pregnancy-related pain is related to sleep disturbance and this may influence the patient’s quality of life. In addition, at least within this population, little care was offered, and the
care provided was not satisfactory. Taken together with the current understanding of chronic musculoskeletal pain and that no other population has more chronic LBP than women who have been pregnant, back pain in pregnancy can no longer be considered normal. We feel this study raises serious consideration for determining strategies and treatments to alter back pain in pregnancy.

**Practical Applications**

- There appears to be a high prevalence of musculoskeletal pain in pregnancy.
- Multi-focal pain in pregnancy leads to greater pain severity.
- Previous pain in pregnancy is a high-risk factor for future pain in pregnancy.
- The care that is offered for musculoskeletal pain in pregnancy needs to be expanded.

**REFERENCES**

RESULTS OF CHIROPRACTIC TREATMENT OF LUMBOPELVIC FIXATION IN 44 PATIENTS ADMITTED TO AN ORTHOPEDIC DEPARTMENT

Jan Roar Orlin, MD, PhD, and André Didriksen, DC

OBJECTIVES: The objectives of this study were to report on and evaluate the results of chiropractic care for patients with low back pain in an orthopedic department.

METHODS: The target group consisted of 44 consecutive patients who experienced sudden and painful low back pain caused by lumbar flexion and rotation without axial loading. Clinical and neurologic examinations by orthopedic surgeons revealed no pathology; in addition, skeletal radiography, computerized tomography, and magnetic resonance imaging findings were all normal. Diagnosis before hospitalization was acute sciatica in all cases. Examination by the doctor of chiropractic indicated that the patients had lumbopelvic fixation. According to preestablished inclusion and exclusion criteria, 33 patients were treated in the chiropractor’s clinic, whereas 11 who could not be transported were initially treated by the chiropractor in the hospital. The mean follow-up was 2 years.

RESULTS: All but two patients returned to work. The period of sick leave among the patients was reduced by two thirds as compared with that associated with conventional medical treatment.

CONCLUSIONS: To our knowledge, this is the first report on the work of a chiropractor participating within an orthopedic department of a Norwegian hospital as initiated by the hospital and with full support of the staff. The results support the initiative of the Norwegian government to increase reference to chiropractors in treating patients with neuromusculoskeletal dysfunctions. Based on our experience, we believe that the inclusion of chiropractors within hospital orthopedic departments is feasible and provides a patient care resource that may benefit not only the patients but also the department as a whole. (J Manipulative Physiol Ther 2007;30:135-139)

KEY INDEXING TERMS: Sciatica; Manipulation, Chiropractic

In the past, some members of the medical profession have expressed suspicion toward joint manipulation as performed by chiropractors. A few unfortunate patients who have had adverse reactions to chiropractic care have sometimes been used to discourage patients from seeking chiropractic treatment. Differences in professional jargons may have hindered further understanding and cooperation in the best interest of patient care. A common nomenclature has not been agreed upon but may gradually be achieved through joint education in the first 3 years of medical and chiropractic studies, as is the case in Odense, Denmark. Under the initiation of the orthopedic department, the objectives of this study were to define a basis for chiropractic efforts and to describe the results of such.

METHODS

Twenty-six women and 18 men were treated between 2001 and 2003 for low back pain in the orthopedic department of our institution. Their mean age at the time of hospitalization was 39 years (range = 18-60 years), and the mean observation period of results was 2 years (range = 1.5-3.0 years). The duration of the patients’ low back pain and stiffness before hospitalization, that of their sick leave at the time of hospitalization, and the presence of radiating pain were recorded. The prehospitalization diagnosis was acute sciatica in all cases. The patients underwent clinical, neurologic, and radiological examinations as well as laboratory screening, including urine specimens, parameters of infection, and system diseases. The radiological exami-
nation included skeletal radiography and lumbar computerized tomography or lumbar magnetic resonance imaging (MRI). None of the patients experienced difficulty with emptying the bladder and expressing stools; neither did any of the patients experience unintentional leakage of air.

**Chiropractic Examination**

The chiropractic examination focused on the patients’ biomechanics, including analysis of the neuromusculoskeletal system and assessment of possible dysfunction relating to the patients’ symptoms. A patient report of pain and restricted movement during the clinical examination served to confirm the origin of the pain. In detail, using a plumb line, we examined for a compensatory deviation from normal stature and a dysfunctional gait pattern caused by faulty weight bearing. We compared the active range of motion in all movement planes in the lower back, the pelvis, and other affected body parts (the sciatic leg) with that in the opposite and supposedly normal side. This examination gives information on muscular hypertonicity, pain threshold, and possible somatization as each patient controls the movements. The passive range of joint motion was examined with the patient relaxed and the practitioner controlling the movements. Whether dysfunction was caused by joints and/or muscles was determined by the signals given by the patient during active and passive motions. Kemp’s test was used to provoke a recognizable symptom pattern. This was performed by applying rotation, lateral flexion, and extension of the lumbar spine. Other chiropractic techniques included fingertip palpation of each separate joint, seeking an abnormal end feel when moving separate vertebrae. This could be masked if unnecessary pain was provoked by the initial examination. Pain on distraction is a signal of ligament, capsule, and/or muscle damage, whereas that on compression relates to irritation of disks, facet joints, or nerves.

**Chiropractic Treatment**

Patients were placed in a prone or supine position to relax them, and soft tissue techniques aimed at affecting muscle tone at the sites of primary joint lesions and at secondary compensatory lesions were used. These techniques included pressure on local muscular trigger points, often in combination with passive stretching, to achieve relaxation. The main treatment consisted of joint adjustment techniques of the lumbopelvic fixations, usually performed in a side posture position. The adjustment technique was a fast passive stretch of deep structures around the joint, with the utmost importance placed on the appropriate force, speed, amplitude, and movement specificity. The adjustment usually caused a clicking sound (audible release) as the joint surfaces separated. Joint adjustments in other parts of the spine and limbs were usually necessary as a result of the compensatory dysfunction. Positioned on an adjustable table that can be moved in several planes, some patients received traction that was slightly different from that used in standard physical medicine. These patients received a pumping mobilization of disks and joints.

After the initial manipulation, ice packs were applied locally for 30 minutes to decrease local pain and edema. General advice and instructions were given on subsequent use of ice, increased general activity, home exercises, and possible inexpedient motions. Exercise was recommended after pain reduction and improvement in each patient’s condition. Electrical devices were not used as part of the treatment. Patients were treated daily while they were in the hospital; they were treated for 3 days a week for the first 2 weeks while they were in the clinic. Depending on need, some patients received follow-up treatment once or twice a week for some time. Following Norwegian public health regulations, cost refunding is limited to 14 treatments; therefore, the total number of treatments rarely exceeded this number.

**Inclusion and Exclusion Criteria**

Patients were included in this study if they exhibited pain-adjusted gait with compensatory deviation, showed a characteristic posture of lumbopelvic fixation, and signaled that the faintest touch or weight bearing resulted in great pain. Another condition of entry was having a job to return to after treatment for employees or full-time studies to return to after treatment for students. Patients were excluded if they were older than 60 years or had rheumatic diseases, spinal structural changes, neurologic defects, or major depression or anxiety.

**Criteria for Success**

Success was defined as the patient returning to work permanently. Evaluation of results was achieved with the use of a mailed questionnaire with prepaid return postage.

**RESULTS**

All patients experienced 3 or more weeks of low back pain and stiffness before the acute lumbopelvic fixation leading to hospitalization occurred. None of the patients had a history of violent trauma. The appearance of a typical patient was that of lumbar flexion and rotation as well as lateral flexion deviating from the painful joints in focus.

Eleven of the 44 patients initially were treated by the chiropractor in the hospital. The remaining 33 patients were transported to the chiropractic clinic. There was no significant difference in age and sex between the groups. Before treatment, no patient had changes in clinical, neurologic, and laboratory parameters. The straight leg test provoked pain in all patients, but not the typical nerve root pattern of a Lasèque test with positive findings. Kemp’s test caused excruciating pain and buckling of the sciatic leg in...
all patients. Joint motion palpation indicated that the main cause of lumbopelvic fixation in all 44 patients was a unilateral combined dysfunction of the sacroiliac joint and the L5-S1 joint. In addition, the L4-5 joint was involved in 23 patients and the L3-L4 joint was involved in 3. Lower lumbar radiographs were taken for all patients; 35 underwent lumbar MRI, whereas 7 did lumbar computerized tomography. No structural change was found. Some patients initially felt insecure because the chiropractic treatment was offered outside the hospital. All patients responded to follow-up, with reminders being unnecessary.

For all patients, the initial chiropractic treatments were accompanied by soft tissue soreness, which was reduced immediately by applying ice. After chiropractic treatment, 40 patients returned to work full time, including 2 students, within an average period of 21.1 days. One patient returned to work at 80% capacity, and another did at 50% capacity. One of the 40 patients who returned to work availed of a leave for pregnancy but subsequently returned to work full time. Of the 40 working patients, 3 were subsequently retrained to less physically demanding full-time jobs. The female patient returning to employment at 80% capacity reduced her working hours by 20% for reasons other than musculoskeletal problems. The female patient returning to employment in a heavy industry at 50% capacity no longer had the necessary physical competence for the job, but the 50% reduction was not related to the chiropractic treatment. One patient was temporarily referred back to the general practitioner because of increasing myositis accompanying the treatment. Five of the patients returning to full-time work were referred to physiotherapists for rehabilitation and further supportive treatment near their homes. Of the 40 patients returning to full-time employment, 3 needed a temporary treatment break owing to stress and anxiety caused by the chiropractic treatment. Another patient was referred to a repeat MRI because of apparent new signs of a nerve root lesion, but this was not regarded as a complication of the treatment; neither did the patient give any sign of dissatisfaction with the treatment. Two patients experienced no improvement from the treatment and were referred back to their general practitioner; 1 patient reported increased soreness and pain in the lower lumbar region. We learned that these 2 patients subsequently availed of a permanent sick leave after repeated examinations by orthopedic surgeons.

**DISCUSSION**

This study illustrates the benefits of cooperation between orthopedic surgeons and chiropractors. We worked hard to achieve a basis of mutual understanding and a common nomenclature. The mutual acknowledgment necessary for successful cooperation grew from this study. In our location, and in spite of the intent to cooperate, we considered it necessary to conduct the present study as a first step toward randomized studies. A limitation of this study might be the strict criteria for inclusion and exclusion; however, in view of the many professional differences that we had to overcome, we felt obliged to narrow the material to young persons motivated to get well. On the other hand, the strict criteria made the evaluation of treatment response easier. The observed patient anxiety caused by treatment outside the hospital was overcome by eventual good results, but this is an argument in favor of locating the chiropractor inside the hospital.

The positive effects of cooperation between orthopedic surgeons and chiropractors may be measured in the reduced duration of sick leaves. Statistics from the Norwegian Health Department in 1999 showed that, on average, patients with sciatica reported being sick for 72 days. We have no information on the treatment offered to patients similar to ours within that period. The duration of sick leaves among the patients included in this study was 21.1 days. Compared with the figures cited on the period of absence from work after conservative treatment, this amounts to a reduction to less than one third. It is also worth remembering that only 49% of workers return to work after more than 8 weeks of being on sick leave. It seems important to offer to patients a workload adaptation during the first week of their return to work.

A lack of mutual understanding may have hindered medical doctors from recognizing the content of chiropractic treatment. The characteristic appearance of a patient with lumbopelvic fixation is one of lumbar flexion and rotation with lateral flexion deviating from the painful joints in focus. A simple explanation is that of capsular ligamentous and muscular tension resulting in articular fixation. The typical gait observed in such a patient is that without axial loading on the painful side that leads to flexion in the lower extremity joints. In correct terms, the chiropractor corrects functional spinal lesions (FSLs), which are “the concept of joint fixation” (see subsequent discussion). The concept of FSLs has been used for more than 10 years in most articles concerning muscular joint fixation. To define FSLs, we must assume that a normal function can be defined on the basis of a movement pattern that contains an interaction balance between the spinal joints and the musculature. Activity in the spinal muscles results in spinal joint movement. Receptors in the spinal joints provide continuous feedback about the joint movements via the nervous system such that deep muscle activity can be adjusted. This is a monosynaptic activity. An FSL includes disturbance of the interaction between the nervous system, joints, and the deep muscles.

A brief synaptic activity in monosynaptic links from muscle spindles caused by sprain strain has been shown to be capable of starting a long-lasting train of action potentials in the motor neuron (ie, long-lasting muscle contraction in the motor unit in question). Similarily, a brief inhibitory impulse, such as that from antagonistic muscles, may stop the signal train in the motor neuron. Chiopractic joint adjustment...
probably provides a similar inhibitory impulse. The chiropractic joint adjustments must cross the barrier of passive joint motion range to stimulate muscle spindle receptors.

Human experiments have shown that the activity pattern in the deep spinal multifidus muscles changes if tissues of the disk and facet joints are irritated. Irritation of the tissues causes changes in the activity pattern both bilaterally and over several segmental levels, depending on the stimulated structures. Based on these findings, tissue irritation may probably result in an imbalance in the normal activity pattern in the form of an FSL. In patients with acute or subacute low back pain, ultrasound scans have shown unilateral atrophy in the multifidus muscles in one level. The level of atrophy corresponded with the clinical level of the painful segment.

Tissue damage causes the release of potassium, prostaglandins, bradykinin, and other signal substances with a local effect that activates peripheral pain receptors. Persistent static contraction of deep back muscles will probably have the same effect on the pain receptors owing to the accumulation of metabolites. The pain receptors are free nerve endings, and the pain signal is led into the spinal cord's posterior horn. Reduced mobility results in less activity in the fast-conducting sensory fibers from the mechanoreceptors in the spinal muscles, tendons, and joint structures. According to the gate theory, the signal traffic in these fibers normally inhibits the pain signals from slow-conducting C fibers. Effective pain relief from the onset of pain may prevent the development of chronic pain. Because chiropractic treatment has a documented pain-relieving effect, it may also play a role in preventing chronic pain.

All patients were initially admitted to the hospital because of sciatica or radiating pain. Mechanical or chemical stimulation of the pain receptors in the back may produce distal pain or so-called referred pain. Disks and facet joints are well-documented pain sources in the case of back pain and neck pain, whereas the role of the musculature as a source of pain is more uncertain. When an FSL produces referred pain, this is usually felt along the corresponding levels of sclerotomes. These differ slightly from the corresponding dermatomes of the same levels. Localized muscular tension (eg, trigger points) in the gluteal region might result in a more diffuse referred pain down the leg.

**Conclusions**

Forty-four consecutive patients with lumbopelvic fixation caused by simultaneous lumbar flexion and rotation without axial loading presented with pain perceived by general practitioners and hospital doctors as sciatic pain. After the exclusion of nerve root compression and system diseases, a chiropractor treated the patients in the orthopedic department and in his clinic, depending on patient mobility. All but two patients returned to work. Until now, patients similar to those included in our study have experienced long-lasting disability as well as pain and have availed of sick leaves. This study shows that a chiropractor may play an important role in an orthopedic department by reducing pain and shortening the duration of sick leaves among patients.

**Practical Applications**

- The typical presentation of patients in this study included lumbar flexion and rotation as well as lateral flexion deviating from the painful joints.
- An explanation for the patient presentation is that of capsular, ligamentous, and muscular tension resulting in articular fixation.
- Based on these preliminary results, positions for chiropractors should be considered within orthopedic departments.

**Acknowledgments**

We thank Ine M. Hansen, MD, Kristina Mjäset, MD, and Trygve Thorsen, MD, for having participated in a pilot project conducted before this study. Their work was decisive in selecting the inclusion and exclusion criteria used in the study.

**References**

10. Cassidy JD, Lopes AA, Yong-Hing K. The immediate effect of manipulation versus mobilization on pain and range of motion.
OBJECTIVES: We describe the case of a woman with a headache later found to be a result of an intracranial aneurysm. Through this article, we aim to raise awareness regarding the red flags that should lead doctors of chiropractic to suspect the presence of this condition to facilitate appropriate patient management that increases the likelihood of patients’ recovery.

CLINICAL PRESENTATION: A 32-year-old woman sought care for a constant headache of 4 days’ duration. She described the headache as severe throughout her entire head, centralized at the base of the occiput, and unlike any headache she had experienced. She had concomitant neck pain. Her left eye deviated toward the midline and had excessive tearing 12 hours after the onset of the headache.

INTERVENTION AND OUTCOME: No chiropractic adjustment was administered; immediate transfer for emergency treatment was arranged instead. The diagnosis of a bleeding intracranial aneurysm was confirmed by magnetic resonance imaging. The patient was transferred to a local university hospital for surgical intervention. Unfortunately, she died of vasospastic complications.

CONCLUSIONS: The red flags to be considered in evaluating patients with such headache as that described for our case patient include a history of hypertension, cigarette smoking, oral contraceptive use, alcohol consumption, pregnancy, and cocaine use. Practitioners need to be aware of the signs and symptoms that indicate whether a headache may be a result of serious problems such as an aneurysm. (J Manipulative Physiol Ther 2007;30:140-143)

KEY INDEXING TERMS: Intracranial Aneurysm; Subarachnoid Hemorrhage; Cerebrovascular Accident; Headache; Manipulation, Chiropractic

Chiropractors routinely treat patients with headaches. In a typical week, complaints of headaches place second to those of spinal subluxation/joint dysfunction.1 Headaches are also the main complaint of patients experiencing an aneurysmal subarachnoid hemorrhage (SAH). Chiropractors evaluating patients need to be aware of certain red flags that may lead them to detect the abnormal or unusual case that may come to their attention. Subarachnoid hemorrhage is one of the conditions that a doctor of chiropractic will rarely encounter but must recognize if a patient seeks chiropractic care. In the chiropractic literature, not much has been written to educate practitioners on the diagnosis of SAH. Four specific cases in the medical literature were reviewed in chiropractic journals since the early 1990s, but no case in a chiropractic office was identified.2-5

An intracranial aneurysm (also known as a cerebral or an intracerebral aneurysm) is defined as a weak or thin area on a vein or artery in the brain that balloons out and fills with blood.” Because SAH has a relatively infrequent occurrence (~1 in 10000 Americans annually), health care providers who encounter a patient with SAH are not in accord with the severity of the condition and may have difficulty with recognizing its key components.7 We discuss the case of a woman with a headache caused by an intracranial aneurysm and the various red flags that may help practitioners identify patients who possibly have SAH.

CASE REPORT

The patient was a 32-year-old woman who walked into the clinic with no apparent gait abnormality seeking care for a constant intense headache of 4 days’ duration that had an abrupt onset. She described the headache as a very sharp
and centralized pain at the base of the occiput; this pain also extended throughout the entire head. She said she had never had a headache like this before; in addition, she said that, because she had been helped by chiropractic in the past, she just “...knew an adjustment would help her now.” She told us that, approximately 12 hours after the headache began, she noticed that her left eye turned in toward her nose and that it began tearing persistently.

The patient was a 32-year-old moderately obese white woman in obvious distress. She was orientated to place as well as time and cooperative during the examination; however, she appeared to be very lethargic, laying her head down on the table during the interview phase of the examination. When possible, she assumed the fetal position. Pronounced photophobia was exhibited, but the patient denied diplopia. She had normal speech and was without noted facial paralysis, and her responses to commands were appropriate. She reported smoking approximately 20 cigarettes per day. She denied having any preexisting condition and/or taking any medication.

The patient’s vital signs were a right arm blood pressure of 136/96 mm Hg (indicative of mild hypertension according to the National Institutes of Health’s guidelines8), a pulse rate of 64 beats per minute, and a respiration rate of 16 breaths per minute. Her left eye was deviated to the midline, and that pupil appeared to be fixed, dilated, and unresponsive to light, indicating cranial nerves III and VI involvement.9 Her left eye also exhibited excessive lacrimation. The right eye was responsive to light with normal pupillary reaction. Incidentally noted were enlarged lymph nodes within the cervical chain with palpable tenderness of the maxillary and frontal sinuses. The rest of the head and neck examination findings appeared to be unremarkable, including cranial nerves II through XII.

The patient had received chiropractic care during the period of 1998-2001 for treatment of residual carpal tunnel symptoms and neck pain resulting from a motor vehicle accident that she had in 1996. After that period, the patient did not receive chiropractic care at our institution until she entered the clinic with severe headache.

Our working diagnosis was a probable cerebrovascular accident, placing the patient in a potentially life-threatening situation. Despite the patient’s repeated requests for chiropractic care, she was told that her condition was most likely not a chiropractic case. The patient was informed that the potential diagnosis was a cerebrovascular accident and that it was imperative for her to go to the emergency department immediately. After arranging for transportation, the emergency department was informed of the patient’s condition, probable diagnosis, and estimated time of arrival.

Local hospital records indicate that computed tomography without contrast was performed and revealed a bleeding intracranial aneurysm. Based on the finding, the patient was transported via ambulance to a nearby university hospital for treatment. The preoperative diagnosis was SAH secondary to an anterior communicating artery aneurysm. According to hospital records, a microdissection of the aneurysm with placement of a lumbar subarachnoid catheter was performed 24 hours later. Unfortunately, the patient never regained consciousness after the procedure and subsequently died later in the day as a result of a vasospastic complication. Release to print this case information was obtained from the next of kin and a representative of our institution.

**DISCUSSION**

The typical presentation of aneurysmal SAHs is usually characterized by the abrupt onset of a severe headache that may initially be localized but generalizes quickly. Headache is the most common symptom in more than 90% of cases and is classically described as “the worst headache of [one’s] life”.10-12 One of the cardinal factors that can help identify SAHs is the description that a patient provides of the headache. The headache is usually described as unique and distinctive. Most descriptions include phrases such as “the worst in my life,” “10 of 10 in intensity,” “the top of my head is blown off,” “someone hit me in the head with a hammer,” and “hammer blow.”13 There are 3 main factors to consider when taking the history of and conducting a physical examination for a patient: (1) if the onset of the headache is abrupt; (2) if it is a very severe
headache (eg, the worst headache that the patient has ever experienced); and (3) if the quality of the headache is distinct or unique for the individual patient or how it compares with prior headaches. Patients with SAH frequently have an additional warning sign, a sentinel headache, described as the occurrence of an undervalue or even ignored oppressive headache in the weeks preceding the aneurysm. Other symptoms may include nausea and vomiting (77%) as well as loss of consciousness (53%).

Associated symptoms, including syncope, diplopia, and seizure, make SAHs more likely. Figure 1 offers a summary of the signs and associated risk factors that a chiropractor should look for when taking a patient’s history.

If the patient is seen hours after the onset of symptoms, examination may show nuchal rigidity (35%), cranial neuropathy (the third or sixth cranial nerve most commonly), or localized neurologic deficit, including aphasia and/or hemiparesis; however, in most cases, major neurologic signs are not present. Signs of meningeal irritation, including nuchal rigidity, especially in flexion, and photophobia are often present within 4 to 8 hours after the onset of SAH. The neurologic signs and symptoms depend on the location and size of the aneurysm and on the severity and location of the hemorrhage.

The most common type of intracranial aneurysm is the saccular aneurysm (also known as berry aneurysm), which is a round pouch-like sack of blood attached by a neck or stem to an artery or a branch of a blood vessel most commonly found along the base of the brain. Its rupture results in hemorrhage into the subarachnoid spaces. Intracranial aneurysms are the second most common cause of hemorrhagic strokes, placing second to intracerebral hemorrhages.

The incidence of aneurysmal SAHs ranges from 6 to 15 per 100 000 individuals annually, of which 80% to 90% are the result of ruptured saccular aneurysms. It is estimated that 1% to 6% of the general population have unruptured aneurysms.

Intracranial aneurysms for the most part show no racial predisposition; however, they have been noted as a risk factor among individuals of Afro-Caribbean and Japanese descent. Intracranial aneurysms can occur in anyone at any age, but most ruptured aneurysms occur in individuals between 35 and 65 years old, with the highest incidence rates among those between 55 and 60 years old. Women appear to be slightly more susceptible to the development of SAHs for reasons that are unclear. Approximately 60% of all ruptured aneurysms are found to occur in women.

A familial occurrence of intracranial aneurysms is uncommon, but the risk for a ruptured aneurysm in patients who have a first-degree relative with SAH is 4 times greater than that in the general population. There is evidence that genetic factors play some part in SAHs because of the documented association with heritable connective tissue disorders, such as autosomal dominant polycystic kidney disease, Ehlers-Danlos syndrome type IV, neurofibromatosis type I, and Marfan syndrome. However, patients with aortic coarctation and polycystic kidney disease are at greater risk.

Almost all intracranial aneurysms are acquired, most arise spontaneously, and some can occur after a trauma or infection. Saccular aneurysms are believed to be the result of prolonged hemodynamic stress and resultant local arterial degeneration at branch points and the bifurcations of major cerebral arteries.

There are only 3 consistently reported risk factors for SAHs: hypertension, smoking, and heavy drinking. Hypertension is the most common risk factor, accounting for more than 50% of clinically significant hemorrhages. Other risk factors are oral contraceptives, pregnancy, and cocaine use. Trauma, atherosclerosis, and bacterial endocarditic infection are also known risk factors.

Early diagnosis and treatment are absolutely critical for the best possible outcome. The gold standard for the diagnostic evaluation of intracranial aneurysms is intraarterial catheter angiography, but, generally, standard computed tomography confirms SAHs. Elimination of an intracranial aneurysm is the cornerstone of treatment. Once an aneurysm is confirmed, the two options for invasive treatment are open craniotomy and endovascular treatment by interventional radiology. Open craniotomy removes the aneurysm from the intracranial circulation while restoring and maintaining normal cerebral blood flow. In endovascular treatment, thrombogenic platinum coils are introduced via a microcatheter system and are custom fitted to occlude the vessel abnormality.

Without surgical intervention, aneurysmal SAHs carry an extremely high risk for death and/or disability. Cerebral vasospasm, which occurs in up to 70% of patients, is the leading cause of death and morbidity after treatment of ruptured aneurysms. Cerebral vasospasm is the term used to refer to the clinical condition of delayed-onset ischemic neurologic deficits associated with aneurysmal SAHs and the narrowing of cerebral vessels. Symptomatic vasospasm typically appears 4 to 5 days after the hemorrhage and is characterized by insidious onset of confusion followed by a decreasing level of consciousness. It may progress to focal neurologic impairment, infraction, coma, and death.

In spite of the advances in their recognition, diagnosis, and treatment, the prognosis for ruptured saccular aneurysms is guarded. Approximately 10% to 15% of all patients who have SAH die before reaching medical care. Among those who obtain medical care, 40% do not survive the first 24 hours and 25% die over the following 2 weeks. Of the surviving patients, 20% to 30% have significant neurologic deficits leaving them with severe disabilities and requiring a lifetime of care. Even considering all the recent advances, a misdiagnosed SAH is one of the highest sources of emergency department litigation claims and malpractice payments. Obviously, a patient’s well-being is the primary concern. However, protecting providers from the perception of negligence and/or malpractice is an additional outcome of an appropriate response to the red flags.
CONCLUSIONS

Chiropractors manage and treat patients with headaches and neck pain routinely.29-31 However, it is important to be aware of the red flags associated with SAHs. Knowing the red flags and making the necessary referrals for appropriate medical treatment may not only save the lives of patients but also potentially enhance their ability to survive their life-threatening condition.

Practical Applications

- Practitioners need to be aware of the red flags associated with SAHs.
- Headache is the primary symptom.
- One should probe for associated risk factors.
- Patient management includes immediate referral to a medical facility.
- The 3 main factors to consider when taking the history are the onset, severity, and quality of the headache.

REFERENCES

A Patient With Deep Vein Thrombosis Presenting to a Chiropractic Clinic: A Case Report

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Abstract

Objective: The objective of this article is to present and discuss a case of deep vein thrombosis in a chiropractic clinic setting.

Clinical Features: A 33-year-old male patient presented for follow-up chiropractic care for a long-term low back complaint. A working diagnosis of facet joint syndrome was made. Despite improvement of low back symptoms, the patient experienced right-sided groin pain. The patient was referred to the hospital with a provisional diagnosis of deep vein thrombosis.

Interventions and Outcomes: The patient consulted a physician, and within 2 hours of chiropractic consultation, his entire leg had become painful. Doppler ultrasound revealed extensive thrombosis. He was placed on heparin and was hospitalized for 8 days. On discharge, a full-length right leg stocking and moderate exercise were recommended. Consecutive checkups were scheduled with the clot almost resolved at 19 months postdiagnosis.

Conclusion: This case report highlights the importance for the manipulative therapist to be aware of cardiovascular disease mechanisms and associated risk factors, so comanagement via referral to the appropriate specialist can occur. (J Manipulative Physiol Ther 2007;30:144-151)

Key Indexing Terms: Venous Thrombosis; Chiropractic; Aerospace Medicine

A cute deep vein thrombosis (DVT) of the legs is a serious and potentially fatal disorder. It can complicate the course of a patient’s stay in hospital and may also affect patients not admitted to hospital or otherwise healthy people.1 Deep vein thrombosis involves the formation of clots in one of the body’s deep veins, and although it is rare in children younger than 15 years, its frequency increases with age.2 Deep vein thrombosis affects 1 to 2 per 1000 of the adult population per annum in Western societies.3 Other studies have found the incidence of DVT in the general population to be approximately 5/10,000 per annum.4 The incidence is similar between males and females, although the risk for first DVT has been reported to be slightly higher in men than in women.2 The most serious complication of a DVT is pulmonary embolism (PE), which is associated with 50,000 to 200,000 deaths each year.5 Other studies have found PE to carry a 10% fatality rate.3 Another major complication of acute DVT is the long-term socioeconomic consequences of postthrombotic syndrome. Along with the emotional consequences of pain, extended isolation and impaired social interaction, these affect every aspect of the lives of patients with DVT.6 Postthrombotic syndrome is characterized by chronic and persistent pain, swelling of the leg, secondary varicose veins, and ulceration.3,7

Deep vein thromboses are often clinically silent.4 They may occur spontaneously or after surgery.8 Deep vein thrombosis is a serious and complicated aspect of orthopedic surgery, especially surgical procedures involving the hips and knees.6 When symptomatic, DVTs can mimic or mask musculoskeletal conditions. Deep vein thrombosis presents a clinical challenge for the treating practitioner. As a consequence, a thorough medical history taking, knowledge of acquired and inherited risk factors, and a thorough physical examination can help the chiropractor in identifying a DVT. This case report discusses key clinical features, including DVT pathophysiology, genetic factors, air travel, signs and symptoms, diagnosis, treatment, prevention, and implications for the chiropractic practitioner.

Case Report

A 33-year-old man presented with lower back and right leg pain upon attending a bimonthly chiropractic review of a long-term lower back complaint (chronic nonspecific sprain/
strain injury of the lumbosacral extensor muscles). He presented with mild lower back discomfort after a 5-hour plane flight 3 days previously. Numerical rating of his pain on a scale of 1 to 10 was 5. He denied taking any medication for this presenting complaint.

Orthopedic examination revealed pain on standing lumbar extension and right standing Kemp’s maneuver. Spinal intersegmental motion palpation at L5/S1 was tender on the right, producing the patient’s low back pain. Prone springing of the left and right sacroiliac joint was painless. Neurological testing included the seated slump and straight leg raise; both were limited to hamstring tightness bilaterally, and both produced no lower extremity radicular symptoms. Vascular examination of bilateral, distal peripheral pulses (posterior tibial and dorsalis pedis bilaterally) was unremarkable. Abdominal examination did not reveal a palpable pulsating mass. Based on this examination, a working diagnosis of right L5/S1 facet joint syndrome was made. His treatment that day consisted of soft tissue massage (trigger point therapy to the right gluteal and lumbosacral erector spinae muscles and deep tissue massage), interferential therapy (10 minutes over the L5/S1 right facet at a setting of 80-120 Hz), and side lying lumbar Diversified manipulation (no cavitation). The patient reported a small amount of posttreatment improvement with increased lumbar extension range of motion when standing and was asked to return to the clinic for review 3 days later.

Before his return, the patient experienced right-sided groin pain the day before the scheduled appointment and did not attend work due to an unusual feeling of fatigue. He saw a local physician the day of the scheduled treatment, who diagnosed him as having a groin strain. The patient went home and rested while watching television. On presentation to the chiropractic clinic for his treatment a day later, he reported that his lower back had improved (pain scale 3/10).

However, he reported that his right lower leg had become painful, and he experienced cramping after walking to the clinic (a 200-m mild uphill walk). The cramping was reported to be located in the popliteal crease and between the 2 heads of the gastrocnemius muscle. The patient was wearing long pants at the time and did not notice any other symptoms. Physical examination of the right leg was noteworthy for a 50% enlargement of the calf and a bluish appearance. It was cold to touch. Capillary refill was markedly delayed. The patient was referred to the hospital with a provisional diagnosis of DVT.

The patient saw a medical practitioner within 2 hours of being referred and reported that within that 2-hour period, the whole leg had become painful on weight bearing and was aggravated by sitting, standing, and lying. Doppler ultrasound of the right leg revealed an extensive thrombosis (Figs 1 and 2). Based on these findings, the patient was immediately admitted to hospital. He was placed on heparin and fluids. He then received a computed tomography pulmonary angiogram that revealed a deep vein thrombus, which commenced at the knee and extended to the distal aspect of the inferior vena cava. A thrombophilia gene screen revealed the patient to have a heterozygous factor V Leiden mutation (G1691A in the factor V gene). The patient was hospitalized for 8 days. On day 5 postadmission, he was asked to begin walking, which he described as very painful and slow. At discharge on day 8, he was told to rest with no walking (other than around the house) for 1 week. He was instructed to slowly increase the duration of the walk as tolerable. He was given a full-length right leg light compression stocking and was instructed to wear the stocking for the next 3 months. He saw a vascular surgeon 2 weeks postdischarge, who told him to exercise as much as comfortable and to sit with the leg elevated. A follow-up examination was scheduled 3 months later.
Four months after the initial hospitalization, he was reevaluated using an angiogram. The scan showed the clot had reduced in size. The angiogram also revealed that the patient had an anomalous inferior vena cava and portal circulation. At this time, he was told to continue increasing the amount of exercise and to try running and cycling, in addition to walking, but not if he experienced pain. The patient tried running once but discontinued because it was very painful. Cycling was also discontinued because it caused an increase in swelling. The patient continued with a slowly progressing walking program.

Three months later, the patient saw the vascular surgeon again. At that time, he was told that there had been no change in the clot size. He was again told to continue exercising and wearing the compression stocking (now only below the knee), although he could take the stocking off on alternate days. Eleven months after hospitalization, he could exercise with no pain, although the leg would occasionally tire depending on use. At 19 months postdiagnosis, the clot had almost resolved, and his activities had returned to normal. The patient had been consuming heparin throughout the 11 months with weekly blood testing to determine the dosage. At 5 months posthospitalization, his dosage was between 0 and 5 mg, with an average of 3 to 4 mg; after which, he was dosed at 3.5 to 4 mg.

The patient had no preexisting vascular complaints, although when asked about family history, he reported that his mother had a history of blood clots after knee replacement surgery. In addition, his father had previously had multiple myocardial infarctions and strokes with a heart-related diabetic condition. When asked about his recent flying history, he reported that he had flown to Japan and back within 10 days, 4 months before the initial presentation (10-hour flight each way). Six weeks after that trip, he again traveled. This second trip involved a total of 57 hours within a 2-week period. In addition and just before his initial presentation to the authors, he had completed a 9-hour trip. In the recent 7-year period, he had made approximately 40 trips of 2- to 4-hour duration (combined return trip length).

**DISCUSSION**

Pathophysiology

The pathophysiology of DVT involves 3 interrelated factors, which are the classical risk factors of Virchow triad—venous stasis, vessel wall injury, and clotting abnormalities. Although still considered to be important prerequisites for venous thrombosis,9 Virchow’s initial model of thrombosis has been extensively refined.10 Activated coagulation is now recognized to be of primary importance in venous thrombogenesis. The concept of venous injury has been expanded to include molecular changes in the endothelium, and stasis has been redefined as a largely permissive factor.10

- Advancing age
- Obesity
- Previous venous thromboembolism
- Surgery
- Trauma
- Active cancer
- Acute medical illnesses:
  - acute myocardial infarction
  - heart failure
  - respiratory failure
  - infection
- Inflammatory bowel disease
- Antiphospholipid syndrome
- Dyslipoproteinemia
- Nephrotic syndrome
- Paroxysmal nocturnal haemoglobinuria
- Myeloproliferative diseases
- Behcet’s syndrome
- Varicose veins
- Superficial vein thrombosis
- Congenital venous malformation
- Long distance travel
- Prolonged bed rest
- Immobilisation
- Limb paresis
- Chronic care facility stay
- Pregnancy/puerperium
- Oral contraceptives
- Hormone replacement therapy
- Heparin-induced thrombocytopenia
- Other drugs:
  - Chemotherapy
  - Tamoxifen
  - Thalidomide
  - Antipsychotics
- Central venous catheter
- Vena cava filter
- Intravenous drug use

**Fig 3. Conditions associated with increased risk for DVT. Reprinted with permission from Lancet 2005;365:1163-1174.**

The Virchow triad may all occur during or after muscle injury.11 Delicate blood vessels are commonly injured due to trauma in all areas of the body. The force required to damage muscle tissue or the compressive effects of edema may be sufficient to cause intravascular micro tears or damage, roughening the vessel wall.11 Classically, this may lead to platelet aggregation and thrombus development. Thrombosis is the formation, within a vascular lumen, of an aggregate of coagulated blood containing platelets, fibrin, and entrapped cellular elements that can lead to a vascular obstruction at the point of thrombosis formation, usually a site of endothelial damage on the vessel wall.

Practitioners must be aware of the common risk factors, the presentation, and complications of DVT. Figure 3 outlines clinical conditions associated with increased risk for DVT. Although DVTs and PEs are often silent and difficult to detect by clinical examination, they rarely occur in the absence of risk factors. This knowledge can improve clinical prediction considerably. Thrombosis can occur anywhere in the circulatory system. Anatomy of the venous system throughout the thigh and lower leg may help explain...
the wide variation in DVT signs and symptoms. Three major veins (peroneal, anterior tibial, and posterior tibial) are contained in the lower leg, which drain superiorly into the femoral vein. The femoral vein ends posterior to the inguinal ligament, becoming the external iliac vein. Within the femoral triangle, the femoral vein receives the profunda femoris and greater saphenous vein and other small tributaries. In the lower leg, the sinusoidal veins drain the soleal and gastrocnemial veins. Thrombosis may develop in all of these locations.

**Genetic Factors**

Several genetic factors are believed to predispose to thrombophilia (thrombosis secondary to abnormalities in hemostasis). Deficiency of naturally occurring anticoagulant proteins include antithrombin, protein C, protein S, and activated protein C resistance (APC resistance) due to a gene mutation of factor V, known as factor V Leiden. Factor V Leiden is the most frequent molecular defect seen in thrombophilia among whites. It has been found in 20% of consecutive patients with DVT. The carrier frequency of factor V Leiden mutation in healthy control populations ranges from 3% to 7% in Europe and the United States and may be as high as 15% in some selected groups. It is notably uncommon in the Asian and African populations. When the risk of venous thrombosis is caused by a genetic defect, the resulting hypercoagulation state is a life-long risk factor for thrombosis.

Factor V is a clotting factor. Its normal role is to help blood clot when an appropriate trigger is present. However, in the clotting cascade, factor V is regulated so clots do not form too rapidly. The regulators are APC and protein S. Under normal circumstances, APC interacts with protein S, and together slow down factor V, preventing excessive clotting. When a genetic factor, such as factor V Leiden, is present, the APC/protein S regulation is rendered less effective and inhibition of clotting is less efficient. Factor V Leiden is often called APC resistance. Factor V Leiden is an autosomal dominant condition, in which the coagulation factor V has a mutation and cannot be destroyed by APC. Factor V cannot be inactivated; it continues to facilitate production of thrombin, and consequently thrombi can form in the veins.

There are no clinical features for factor V Leiden. Diagnosis of factor V Leiden thrombophilia is suspected in individuals with a history of venous thrombosis or in families with a high incidence of venous thrombosis along with women during pregnancy or associated with oral contraceptive use. The relative risks for individuals heterozygous for factor V Leiden is reported as 7- and 80-fold for those who are homozygous. Factor V Leiden is reported in 12% to 30% of patients with spontaneous DVT, and it is therefore important to evaluate any individual who had factor V Leiden for other inherited or acquired thrombophilic disorders. DNA mutations in protein C or protein S can have a profound effect on the risk of thrombosis for factor V Leiden carriers.

**Air Travel and DVT**

Air travel has been linked with the development of DVT since the 1950s. Today, in-flight venous thrombosis is an increasingly recognized potential complication of prolonged air travel. Travelers with cardiovascular disease may be at risk for venous thrombosis as a result of depressed ejection fraction of the left ventricle or lower limb immobility. The sitting position can cause venous stasis and increased blood viscosity in the legs. Venous flow velocity is two-thirds lower in a person who is sitting than one who is supine. Seat compression may lead to vessel lesions, although it is unclear whether business class travel (more leg room) carries a lower thrombosis risk than economy class travel (less leg room). Air travel may cause relative hypoxia in the cabin of the airplane reducing the fibrinolytic activity, which may lead to the release of vein wall relaxin factors.

A systematic review and meta-analysis found no definitive evidence that prolonged (>3 hours) travel, including air travel, increased the risk of DVT. However, there is evidence to suggest that flights longer than 8 hours increase the risk of DVT if additional risk factors exist. When thrombophilia or oral contraceptive use is present, the risk increases 16- and 14-fold, respectively. Hence, those with risk factors for DVT should carry out additional protective measures, such as aspirin or low-molecular-weight heparin (LMWH). Ideally, they should consult their general practitioner before flying. General protective measures for all passengers should include avoiding excessive alcohol and caffeine, drinking plenty of water, and performing leg stretching exercises. Walking is a form of leg exercise but should be done in moderation. Care should also be taken with elderly patients with DVT and walking recommendations because they may risk falling and having a fracture.

**Signs and Symptoms**

Most DVTs arise in the deep veins of the legs, with the remainder involving the pelvic veins. Occlusive DVT in the femoral and iliac veins may reveal severe congestion, edema, and lower limb cyanosis. In the deep venous system, the patient may exhibit changes in pigmentation, edema, skin discoloration, and ulceration of the skin on the leg. In addition, calf tenderness, distension of the superficial veins, increased warmth in the area, mild fever, and the demonstration of pitting edema may all make up the patients complaint. A 2- to 3-cm calf swelling on the affected side is a clinically significant sign. Practitioners should also be aware of the patient who fails to respond fully to treatment within the expected time frame. Conditions like a
recalcitrant calf strain ought to alert the clinician to rethink the original diagnosis and consider a more unusual cause of leg pain. Similarly, a Baker cyst may also be difficult to distinguish from a DVT. Transient chest pain, tachycardia, and dyspnea are early indicators of a PE.4

### Diagnosis

At least 1 established risk factor is present in approximately 75% of patients who develop DVT. Hospitalized patients and nursing home residents account for one half of all cases of DVT.26 Ultimately, diagnosis requires objective testing. The clinical prediction rule is a reliable estimate of the pretest probability of DVT (Table 1). It combines signs, symptoms, and risk factors of DVT, allowing an effective and cost-efficient application of diagnostic tests. Patients are given 1 point for each criterion and then stratified into low, moderate, or high incidence of clinical DVT probability, depending on their total points. Despite the clinical prediction rule assessment being affected by many alternative diagnoses, extensive reviews show it can be accurately applied by medical staff with various degrees of training. Based on the results of the clinical prediction rule, treatment may be considered without delay as other diagnostic tests are ordered. Simplified prediction rule models have been successfully validated in emergency departments.2 Because of its high sensitivity, D-dimer is a rapid, simple, and inexpensive test to rule out DVT, although published literature does not support it as a stand-alone test.2 D-Dimer measures the products of fibrin degradation that increase with venous thromboembolism.4 Ultrasound diagnosis of DVT is the most useful initial imaging test,2 with emergency physicians using it with increased frequency.27 Ultrasound has a sensitivity of 97% to 100% and a specificity of 98% to 99% for the detection of proximal thrombosis.2 It is less accurate in the diagnosis of distal (calf vein) thrombosis with a sensitivity of 70% and specificity of 60%.2 Deep vein thromboses, however, often require venographic confirmation because of discrepancies among clinical probability, ultrasound scan, and D-dimer estimation.28 Venography is the most sensitive and accurate test for DVT diagnosis and is regarded as the gold standard, yet it is invasive, costly, inconvenient, and requires high technical skill from the operator.4,29 Venography should be reserved for those patients with negative noninvasive tests and high clinical probability or for those whom noninvasive tests are ambiguous or nonfeasible.2 D-Dimer testing can rule out PE without an invasive or expensive investigation.26 Extensive evaluation is suggested in patients younger than 50 years with an idiopathic episode of DVT, patients with recurrent thrombosis, and patients with a family history of thromboembolism.26

Long-term follow-up studies have shown that venous thromboembolism is a chronic disease, as the rate of recurrent DVT continuously increases after the first thrombotic episode.30 Recurrent thrombosis risk is higher with certain biochemical abnormalities, including homozygous factor V Leiden.31

Clinical examination should include orthopedic, neurologic, and peripheral vascular examinations, particularly the lower limb pulses.4 Femoral, popliteal, posterior tibial, and dorsalis pedis pulses should be palpated bilaterally. Symptoms and pain referral from a lumbar sprain/strain injury, muscular pain, disc injury, sacroiliac, or facet joint dysfunction can be easily confused with leg and groin pain of vascular pathology.4 Homans sign has been used for the assessment of DVT. With the patient in the supine position, the practitioner dorsi flexes the patient’s foot and squeezes the calf, with deep pain in the posterior leg or calf indicating DVT. Homans sign, however, has been found to be of dubious value and is also thought to risk thromboembolization.5

### Treatment and Prevention

Treatment goals include stopping clot propagation, preventing the recurrence of the thrombus, PE, and the development of pulmonary hypertension, which can be a complication of multiple recurrent PE.32 In initial stages of treatment, patients are admitted to hospital for intravenous treatment with unfractionated heparin (UH).3 Unfractionated heparin dosage is unpredictable; thus, the patients’ blood must be closely monitored. Fractionated or LMWH is given subcutaneously once daily and requires no monitoring.3,33 For all patients, hospitalized or not, subcutaneous LMWH likely represents the best therapeutic alternative.34

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### Table 1. Standardized prediction rule for assessing pretest probability of acute DVT

<table>
<thead>
<tr>
<th>Clinical feature</th>
<th>Score</th>
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<tbody>
<tr>
<td>Active cancer (treatment ongoing or within previous 6 mo or palliative)</td>
<td>1</td>
</tr>
<tr>
<td>Paralysis, paresis, or recent plaster immobilization of the leg and feet</td>
<td>1</td>
</tr>
<tr>
<td>Recently bed ridden &gt;3 d or major surgery within 4 wk</td>
<td>1</td>
</tr>
<tr>
<td>Localized tenderness along the distribution of the deep venous system</td>
<td>1</td>
</tr>
<tr>
<td>Entire leg swollen</td>
<td>1</td>
</tr>
<tr>
<td>Calf swelling 3 cm greater than asymptomatic leg (measured 10 cm below tibial tuberosity)</td>
<td>1</td>
</tr>
<tr>
<td>Pitting edema (confined to the symptomatic leg)</td>
<td>1</td>
</tr>
<tr>
<td>Collateral superficial veins (nonvaricose)</td>
<td>1</td>
</tr>
<tr>
<td>Alternative diagnosis as likely or greater than that of DVT</td>
<td>-2</td>
</tr>
<tr>
<td>For patients with symptoms in both legs, the most symptomatic leg is used</td>
<td></td>
</tr>
</tbody>
</table>


Key: score ≤0, low-risk DVT; score 1 or 2, moderate risk DVT; score ≥3, high-risk DVT.
Outpatient treatment is safe in reliable patients with minimal comorbidities along with significant cost-saving implications. Rymes et al. compared the outcome in 172 patients treated at home with 172 thrombotic risk factor–matched inpatients treated at their institution with UH and found the complication rate was lower in the home treatment group, in particular the incidence of recurrent thrombosis was significantly less in the home therapy group. This method is likely to be preferred by patients.

Low-molecular-weight heparin is the treatment of choice for treating DVT in pregnant women and cancer patients. The treatment of DVT in pregnant patients is difficult because UH and LMWHs may have significant maternal side effects. Long-term protection from thrombus progression can be accomplished by a course of vitamin K antagonists started simultaneously with heparin. The reader is directed to Kyrle and Eichinger for further information on vitamin K antagonists.

Warfarin therapy (taken as oral medication) depends on the history of the individual patient, risk of recurrence, and risk of anticoagulant-induced bleeding. The risk of recurrence is low if thrombosis was provoked by a major reversible risk factor such as surgery; 3 months of treatment is usually adequate. The risk of recurrence is high if thrombosis was unprovoked or associated with a nonreversible risk factor such as active cancer; at least 6 months and sometimes indefinite anticoagulant therapy is indicated in such patients. In relation to pregnancies, warfarin can cause embryopathy and other adverse fetal effects. Some patients with thrombophilia require lifetime anticoagulation. Approximately 30% of DVT patients have a thrombophilia. Elastic compression stockings are useful in patients at lowest risk for thromboembolism. Daily use of compression stockings after DVT might reduce the incidence and severity of postthrombotic syndrome. Morris and Woodcock found that all the major types of intermittent compression systems are successful in emptying deep veins of the lower limb and preventing stasis in a variety of subject groups. Compression stockings appear to function more by preventing distension of veins. A study by Partsch found a low incidence of recurrent and fatal PE, affirming the value of early ambulation with heavy leg compression. The most important factors in selecting a mechanical prophylactic system (especially during and after surgery) are patient compliance and appropriate site compression. Pulmonary embolism management is similar to that for DVT. However, because of the risk of hypoxemia and hemodynamic instability, in-hospital management is advised.

**Implications for the Doctor of Chiropractic**

Complication from spinal manipulation has centered mainly on serious vascular accidents of the cervical spine. Less life-threatening adverse effects from manipulation of the lumbar spine have been largely overlooked, but vascular complications such as thrombosis due to manipulation and manipulation performed on a patient in the presence of warfarin therapy have been reported. Vascular complications could be prevented if the practitioner favors a soft tissue or mild traction treatment approach. However, therapies such as deep tissue massage, heat packs, electrical muscle stimulation, ultrasound, or trigger point therapy over the thrombosis area could see a portion of the clot break loose and thus should be avoided. Effects of the thrombus breaking away and forming an embolus could result in fatal consequences. As a result, patients with vascular thrombosis or patients taking anticoagulant therapy should both be considered a relative contraindication to spinal manipulation.

The meticulous taking of the clinical history by the chiropractic practitioner can reveal the presence of DVT, with key features including the patients age, past medical and family history, medication list, recent trauma (within 2-4 weeks), hereditary factors, and a history of flying. This case presentation had a strong family history with the patients’ mother having blood clots and the father having multiple myocardial infarctions and stroke. The patient had factor V Leiden as an inherited risk factor and a long history of frequent air travel over the previous 7 years.

When in doubt, the chiropractor can at the very least become familiar with the clinical prediction rule. In this case, the patient could have at least scored 3 to 4 points, placing him in the high probability category of DVT. In addition, awareness of Virchow triad as a pathophysiologic process and knowledge of risk factors can further enhance the establishment of a working diagnosis.

Finally, initiating communication with the appropriate medical doctor or vascular specialist for appropriate referral can be potentially life-saving in such cases. This case was referred appropriately because of evidence supporting the diagnosis of a DVT after examination after the complaint of groin pain. Despite patients complaining of lower limb symptoms, how many practitioners dismiss assessment of the patients’ lower limb by not asking to directly observe the legs by the removal of garments? On examination, this case showed 50% enlargement of the right calf, cyanotic discoloration, and alteration in temperature. These points raise the importance of chiropractors being methodological in the taking of the clinical history and the completion of the physical examination.

**Conclusion**

Deep vein thromboses are life-threatening and require medical attention. They can present with signs and symptoms that mimic commonly presenting musculoskeletal disorders. Practitioners who use spinal manipulation should perform a thorough history taking and physical examination and acknowledge the impact of potential vascular disorders as they determine a clinical working
diagnosis. It is not known whether DVT is a definite contraindication to spinal manipulative therapy, although it has been reported as a relative contraindication. Practitioners should be aware that they may be some risk of dislodging a thrombosis through patient positioning and thrusting procedures, in addition to effects associated with taking anticoagulant therapy (LMWH and warfarin). This case report highlights the fundamental importance for chiropractors and manipulative therapists having an understanding of cardiovascular disease mechanisms, including acquired and inherited thrombotic risk factors, so that comanagement via referral to appropriate specialist (ie, vascular specialist) can occur.

**Practical Applications**

- Deep vein thrombosis is life-threatening with symptoms that can mimic other types of musculoskeletal disorders.
- Patients should be assessed for known risk factors associated with DVT.
- If part of the differential diagnosis, DVT requires an immediate medical referral.

**REFERENCES**

Spinal synovial cysts have been noted as a rare occurrence in a number of case reports. However, given the increasing number of case reports, the frequency of synovial cysts associated with spinal degenerative changes in the elderly may be more common than initially thought. These cysts occur as a consequence of degenerative apophyseal joints but have also been noted in disc degeneration and with posterior longitudinal ligamentous changes. In addition, 40% of the time, they are associated with spondylolisthesis. Most often, the cysts are found when clinical examination reveals positive neurological findings and a follow-up magnetic resonance imaging (MRI) scan or computerized tomography is ordered. The importance of recognizing the possibility of synovial cysts as a cause of neuropathology cannot be overstated because these cysts can continue to expand, resulting in progressive neurological deficit. However, one must also recognize that if a synovial cyst is present, it may wrongly be attributed to the source of pain and may not be clinically significant because of its frequent association with degenerative joints and spondylolisthesis. Each may be a contributing factor or the sole source of symptomatic complaints and physical examination findings. The clinical decision making for the appropriate course of treatment should take into account the history, neurological findings on physical examination, and the duration and progression of the condition. The care may involve an initial course of conservative care with manual therapy, physiotherapeutic modalities, and targeted exercise therapy, or it may necessitate immediate surgical referral. Appropriate evaluation of the onset and progression of the symptoms along with the duration and the extent of progressive neurological deficit must be taken into account.

The purpose of this article is to present a case that shows a possible inappropriate association of neurological findings with the presence of lumbar synovial cyst.

**Case Report**

A 67-year-old retired white woman had pain across the sacrum with radiation down the left buttock, posterolateral thigh and leg to the ankle. There was periodic radiation down the right lower extremity. The symptoms were of 3 months duration and were of gradual onset. The patient attributed the onset of the pain to diminished activity since she retired. It was described as moderately severe achy pain in the low back and graded as an 8/10 on a numeric pain scale. The bilateral posterior thigh and leg pain was...
described as a stabbing type of pain. Pain was worse in the
mornings, and it would be aggravated by prolong standing
or any extensive walking (>1/4 miles). She was previously
diagnosed by her primary care physician as having arthritis
of an undescribed type and was put on a treatment regimen
of Vioxx. The patient had an initial 30% Oswestry low
back disability.

There was a previous episode of similar symptoms of
low back and bilateral leg pain in November 2001 (3 years
prior). At that time, she consulted a neurosurgeon. Magnetic
resonance imaging performed at that time revealed an L3-4
and an L4-5 grade 1 spondylolisthesis as graded on a 1 to 5
basis indicating less than 25% slippage, although this was
not visibly noted when the previous films were obtained.
She also had an L4-5 posterior synovial cyst with efface-
ment of the dural sac. A surgical decompression with
laminectomy and cyst excision was performed at that time.
A review of the postoperative notes indicated response to
the surgery with only residual periodic night discomfort.

The current episode physical examination revealed a
mesomorphic patient with normal vital signs. There were
surprisingly good global ranges of motion of the thoraco-
lumbar spine, but intersegmental joint restriction was noted
at L4-5-S1 in left lateral bending by means of motion
palpation analysis. Although there was reflex hypertonicity
and guarding of the right gluteal muscles with trigger points,
the patient was neurologically intact, and there were no
positive orthopedic tests.

The initial radiating distal pain was thought to be
scleratogenous in origin because of osteoarthritic changes,
facet locked syndrome, the lack of neurological signs, and
the fact that it was mainly prevalent on the opposite side
from the previous synovial cyst. The patient was therefore
put on a therapy trial of flexion distraction therapy with
localization of the distraction through manual contact at the
L4-5 intersegmental motion unit as per the Cox method
for facet syndrome to gap and mobilize the facet joints.
This was performed at a frequency of 3 times per week
over the next 2 weeks, along with interferential current
therapy at a low frequency of 0 to 10 Hz in quad-polar
setup over the L4-5 area with recommendations of
administration of glucosamine sulfate 500 mg 1 times a
day to promote healing at the facet and disc. She was also
instructed to continue at home the performance of the
standard series of Williams flexion low back exercises with
periodic ice applications.

The patient followed a course of improvement in symp-
toms with a decrease in pain as measured on a numerical
scale of 0 to 10 from an 8 to a 2 over a period of 3 months,
and there was a successive reduction in the dosage of care.
However, as the treatment frequency diminished to once
every 2 to 3 weeks, the patient would have recurrences of the
back pain symptoms with some periodic pain referral into her
left foot and sometimes into her right thigh and ankle. Six
months post-initiation of care, although the patient was under
bimonthly supportive care, the patient had an insidious
aggravation of severe low back pain graded as a 7/10 on a
numerical scale. She had associated sharp pain radiating
down the right lower extremity to the ankle. This was after an
unremarkable presentation 2 weeks earlier and a current lack
of any left-sided lower extremity pain or paresthesia. No
additional neurological or orthopedic findings were present.

Follow-up MRI was ordered by the chiropractic office,
and the MRI revealed an L4-5 synovial cyst, which
appeared slightly more lateral (Fig 1) than the previous

![Fig 1](image.png)
cysts, along with a progression of the spondylolisthesis (Fig 2), which was likely a result of the ongoing degenerative process and further development of the instability. The cysts were present adjacent to the right L4-5 facet joint with impingement on the right thecal sac and with mild spinal stenosis and neural foramina keyhole deformity. The previous surgery 3 years earlier consisted of L4-5 decompression with removal of the previous synovial cyst. Subsequent to the current MRI findings, there was a referral to the neurosurgeon who evaluated the patient and declined surgical reintervention.

Reimplementation of flexion distraction with a change in the contact to the L3 spinous process with the intention of reversing the spondylolisthistic slippage at L4-5, as per the Cox protocols for spondylolisthesis, resulted in temporary relief. However, recurrences persisted. The patient was offered instruction in lumbar stabilization exercises to activate the neurological pathways to the middle layer muscles of the lumbar spine, especially L4-5. This included specific multifidi and transverse abdominal exercises, individually and then with cocontractions. The multifidi muscles are the only intersegmentally innervated muscles of the lumbar spine. When there is a direct or reflex inhibition in the action potentials of the posterior primary rami as a result of injury or decrease in mechanoreceptor stimulation, there is subsequent loss of muscle fiber contraction, atrophy, and fatty deposition. The MRI did reveal such a situation in the multifidi at this level. In addition, palpation revealed a soft lack of tone of the multifidus muscles at L3-5. The intent of the exercises was to activate the neurological pathways and to strengthen the multifidi and the weak, unstable spondylitic and osteoarthritic joint to improve biomechanical function, decrease abnormal joint stress, and diminish the aggravating episodes. The stabilization exercises differ from the Williams low back exercises, as they are more specific in activation of the neurological pathways to the low back stabilizing muscles and in retraining cocontraction of the multifidi and transverse abdominus muscles for strengthening. The Williams exercises are for general erector spinac flexibility and strengthening without regard for the specific intersegmentally innervated stabilizing muscles. In performance of the Williams exercises, there is often compensation for the weak multifidi and/or transverse abdominus and quadratus lumborum. This patient needed coaching in the initial performance of the exercises because of the inability to contract the muscles. The patient had an immediate response with diminishment of symptoms and increased functional activities. She was subsequently able to fly round-trip across the nation and perform extensive walking with no excessive aggravation of pain. Whenever any symptoms would arise, the patient would perform the exercises, and the pain would diminish (Fig 3).

Follow-up was conducted 2.5 years after initial presentation and 2 years after the exercises were first initiated. The patient had 12% low back disability as measured by the Oswestry method, and pain was still only mild and periodic in the low back and left posterior thigh, again indicating no involvement from the synovial cyst on the contralateral side of the spine. The pain would periodically return when she went for a period without performing the exercises. The patient related that she continues to perform the exercises, and this diminishes the pain.

**DISCUSSION**

The initial alleviation of symptoms with flexion distraction was initially thought to be a result of alleviation...
of facet syndrome. When spinal cysts were revealed on MRI, the facet syndrome was brought into question as being pathognomonic of the symptoms. Reimplementation of the distraction with a change in contact hand over L3 spinous versus L4 spinous continued to give temporary relief. However, recurrences persisted until the rehabilitative back stabilization exercises could be accomplished. It is theorized that the spondylolisthesis 1 joint motion segment was stabilized via multifidi and transverse abdominal strengthening. This further led to the proposed conclusion that the cyst was not likely to be the pathological cause of the symptoms, and there was a possible false initial association when it showed up on the MRI, although other pain generators could not definitively be ruled out without more intensive and invasive testing. Although post-MRI is not available, the patient had extensive flexion distractive therapy with recurrences until there was a palpable improvement in the tone of the multifidi along with improved ability of voluntary contraction and the spondylolisthesis was stabilized. In addition, the preponderance of symptoms was contralateral to the side of the cyst. It is therefore hypothesized that in a certain percentage of spinal synovial cyst cases, the spondylolisthesis is the symptomatic pathology causing altered stress distribution on the joint complex versus the synovial cyst. The presence of the cyst on MRI, although important in the differential diagnosis, resulted in an inappropriate association with the symptoms and a delay in the stabilization treatment of the spondylolisthesis. The stabilization exercises diminished the episodes due to the strengthening of the multifidi and transverse abdominus, as palpated on examination during voluntary contraction and as shown in the increased ability of the patient to perform the exercises. This resulted in stabilization of the joint, possibly altering the shearing stress and localized joint pressure.

The symptomological presentation in this case was similar to the earlier presentation that she experienced. Surgery at that time provided temporary and partial relief. The initial working diagnosis for the episode presenting to the chiropractic office was facet locked syndrome. Upon the initial treatment for this episode at the chiropractic office, the patient obtained relief with the flexion distraction therapy. However, frequent exacerbations of the pain would occur. Subsequent MRI revealed the recurrence of a synovial cyst that was initially falsely attributed as the pain source. But the variable course of the symptoms brought into question whether the treatment to date was in fact affecting symptoms as a result of changes to the cyst. Subsequent long-term relief could not be obtained until stabilization of the spondylolisthesis was addressed. The appearance of synovial cysts and the reports that they can often expand and cause pain and neurological signs and symptoms often leads the physician to immediately attribute such an abnormal finding as the root of many presenting symptoms. The conclusion of this case led to a question of the frequency of false association of lumbar synovial cysts with the presenting neuropathology and pain presentation in clinical practice.

Symptomatic synovial cysts are typically found in the lumbar spine, posterolateral to the thecal sac, where they contribute to central and lateral recess stenosis with nerve root compression. There is a reduced incidence in the cervical spine. The incidence in the lumbar spine is most common at the L4-5 level followed by the L5-S1 level, and then the L3-4 level. Synovial cysts usually arise from overlying facet joints, which in itself can contribute to development of degenerative spondylolisthesis. However, there are reported associations with trauma. They may occasionally be associated with repetitive microtrauma, even in younger active patients. The incidence of synovial cysts has been estimated to be 0.6% in the general population.
population. They occur more frequently in the lumbar area than other areas of the spine and are most common in the 50 to 60 age group, although the range is from 25 to 85 years. Neurogenic claudication is usually a result of spinal stenosis, either by the expansion of the cyst or as a result of the spondylolisthesis (40% incidence). The locations can be juxta-articular, posterolateral, and epidural. They may contain fluid and may contain some microcalcification from old hemorrhages into the capsule. Magnetic resonance imaging evaluation would show the different tissue densities. Salmon et al found MRI to be more sensitive than computerized tomography in its diagnostic accuracy (77%). Spinal synovial cysts have also been found to contain air, and if they are long-standing, they may be thickly fibrous in the peripheral tissue. It is speculated that the thinly fibrous capsules are more likely to herniate or expand. These expansions are more likely to cause neurological complications necessitating surgery.

Conservative treatment of synovial cyst has shown a wide range of success, from one third to three fourths of the cases studied, indicating difficulty in differentially diagnosing those cases that are most likely to respond to conservative care. The conservative management described and used in these referenced studies consisted of facet steroidal injections with and without aspiration. This type of treatment would decrease the inflammation but would not necessarily change the cyst or the spondylolisthesis. More invasive management consists of laminectomy, cyst excision, aspiration, and sometimes fusion to stabilize the spondylolisthesis.

In this particular case report, the conservative care consisted of flexion distraction therapy, interferential therapy, and back stabilization exercises. Braza et al also reported successful treatment of lumbar synovial disc with an undescribed type of neutral-based spine stabilization exercises, with adjunctive nonsteroidal anti-inflammatory medication therapy and flexion distraction therapy. Cox and Cox reported on 2 cases of lumbar synovial cysts that were reportedly symptom-free after 6 to 8 weeks of flexion distraction therapy. However, this reported treatment also includes back stabilization exercises, positive galvanism, iontophoresis, tetanizing electrical stimulation, and home cryotherapy. Therefore, although there is little literature on the efficacy of modalities on cysts and related analgesia, it is difficult to really distinguish which therapy was the contributing or significant factor in the alleviation of the pain, leaving his particular conclusion of the distractive therapy as the only contributing factor not fully substantiated by this case. Cox also showed a posttreatment diminishment in size of the cyst. The Cox study is in parallel with the finding in this study, which again had the complications of multiple treatments creating a difficulty in allotting all the treatment effect to the distractive therapy. A future study with a distraction group without any other therapy compared with an electrical therapy group, exercise group, and combination group would allow further distinguishing of the optimum care. There have been reported cases of spontaneous regression of the cysts that were shown clinically and on MRI, as well as reports of acute expansions of the cyst.

This case suggests the possibility that lumbar synovial cysts may be static and not clinically relevant. However, the presence of the spondylolisthesis may be a more clinically relevant factor. When such a concurrent clinical entity is present, then it is appropriate to consider a trial therapy period of 2 to 4 weeks of flexion distraction therapy followed by a subsequent 2- to 4-week trial of back stabilization exercises addressing the spondylolisthesis. This would be particularly appropriate when the spondylolisthesis is at grade I, and there are no progressive neurological deficits. The combination of the active and passive therapies would be important for normalization of biomechanics, diminishing slippage, and then strengthening the motion segment for stabilization for optimal outcomes. When there is radiating pain along with degeneration and spondylolisthesis, further imaging may be appropriate to assess the presence of, and/or expansion of, the cyst. If imaging is positive for a synovial cyst without the neurological compromise, the pain often can be scleratogenous in nature from the additional stress put on the ligaments, joint capsule, or periosteum. Therefore, conservative trials of care may still be appropriate.

Although infrequent and often reported as a rare occurrence, spinal synovial cysts along with the spondylolisthesis and the degenerative joint disease should all be considered in the differential diagnosis of the elderly patients with low back and leg pain, with or without neurological signs and symptoms. The subsequent findings of a synovial cyst should be followed up with an assessment of the degree and rate of expansion and the relationship of the cyst to the presenting symptoms. Conservative care measures should be considered before surgical options in nonaggressive cases.

The conclusions of this study are limited because this is only one case report, and the literature review only reveals other case reports without any higher levels of evidence. Given the limited number of cases reported in the literature with various different treatment responses and reports of resolution with the natural history, a cohort study of different conservative care measures for stable nonexpanding synovial cysts is recommended.

Conclusions

In a certain percentage of spinal synovial cyst cases, associated spondylolisthesis may be provocative of symptoms, and alleviation of the symptoms is possible by conservative flexion distractive therapy to the level of the spondylolisthesis. Stabilization of the unstable motion unit
may also be necessary to reduce recurring episodes. Non-surgical management for these nonexpansive cysts is therefore preferable for the first course of treatment to correct the associated pathomechanics by chiropractic care, and excision may not be necessary.

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**REFERENCES**

BOOK REVIEW


Nearly every chiropractor in the world and many others from the medical profession are familiar with the previous editions of Yochum and Rowe’s Essentials of Skeletal Radiology because their radiology content, image quality, and inclusion of extremely valuable clinical information in an easy-to-read and concise format were second to none. What could these authors possibly do to improve on the successes of the first two editions? The third edition, which came out in 2005, includes 1000 new references, incorporating a vast quantity of new information constantly arising in the field of diagnostic imaging. It also adds 500 new illustrations, all of which are of outstanding quality and size to make even the novice understand the concepts presented.

From the perspective of an academic teaching undergraduate and postgraduate radiology, the only thing missing from the first two editions of the textbook was information on chest and abdomen imaging, although one should not expect a textbook on skeletal radiology to include such data. Nevertheless, Yochum and Rowe have now added an entire chapter focusing on the head, neck, chest, and abdomen entitled “Masqueraders of Musculoskeletal Disease.” These 127 pages offer the essentials of diagnostic imaging for these areas necessary for students and clinicians treating primarily musculoskeletal disorders. The section on “named signs of the chest,” with beautiful cases combining plain film imaging with advanced imaging for each particular sign, is particularly useful.

Risk management strategies have been added to the report writing chapter. These common sense principles are easy to understand and apply in daily clinical practice. These strategies complement the many sections included throughout both volumes of the textbook on the medicolegal implications of the various conditions discussed. This is certainly one of the unique strengths of Essentials of Skeletal Radiology. It not only is a radiology text but also includes important clinical information and relevant management implications for the various disorders discussed. The authors have expanded this information in the third edition by adding examples of pathologic conditions alongside the normal radiographs in chapter 1 to emphasize the importance of understanding normal radiographic appearances.

Other new sections found in the third edition include very valuable information on technology, the uses and advantages of digital radiography, the use of ultrasound for musculoskeletal imaging, and an expanded chapter on the use of advanced imaging in general. The chapter dedicated to advanced imaging is exceptional in its inclusion of all relevant topics in a manner easy for anyone to understand. Certainly, these are not the only areas that are new or expanded in the third edition, but they highlight the thorough, thoughtful, and meticulous way through which this textbook was planned and written. It is written for clinicians treating patients and for radiologists.

All of the wonderful qualities of the first two editions continue into the third edition by Yochum and Rowe with refining touches. The capsule summaries are wonderful highlights of the important clinical, radiological, and other important features of a condition, in bullet-point format, covering all of the critical information needed by clinicians. For undergraduate students, these are the best notes available. The figures showing the target sites for the various conditions provide an excellent visual picture, underpinning the information in the text. The way that the references are organized by topic at the end of many of the chapters is innovative and very useful for clinicians and students needing to find primary sources of information. The use of color and shading throughout the two volumes, particularly in the tables, figures, topic headings, and capsule summaries, makes the textbook a pleasure to read esthetically and easy to find information in when in a hurry.

Yochum and Rowe’s Essentials of Skeletal Radiology, 3rd edition, published by Lippincott Williams and Wilkins, more than fulfills the needs of new students as well as expert clinicians and radiologists. I have found all three editions to be extremely user friendly and thorough yet concise, with “a great day in radiology” found on most of the pages!

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ERRATUM

In the October 2006 article by Kawchuk et al, Figure 1 is incorrect. The proper figure is printed below. We apologize for the error and regret any misunderstandings that this may have caused.

Fig 1. A, Mean forces and standard deviation bars of forces generated by 4 operators (2 experts and 2 novices) using four instruments (maximal force settings) and 4 different operators (2 experts and 2 novices) using a manual technique. For instruments operators, Expert 1 = E1, Expert 2 = E2, Novice 1 = N1 and Novice 2 = N2. For manual operators, Expert A = EA, Expert B = EB, Novice A = NA and Novice B = NB. B, Log plot of mean force durations and standard deviation bars of force durations generated by 4 operators (2 experts and 2 novices) using 4 instruments (maximal force settings) and a manual technique. For instrument operators, Expert 1 = E1, Expert 2 = E2, Novice 1 = N1 and Novice 2 = N2. For manual operators, Expert A = EA, Expert B = EB, Novice A = NA and Novice B = NB.

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Letters to the Editor

PREDICTORS OF PERFORMANCE OF STUDENTS FROM THE CANADIAN MEMORIAL CHIROPRACTIC COLLEGE ON THE LICENSURE EXAMINATIONS OF THE CANADIAN CHIROPRACTIC EXAMINING BOARD

To the Editor:

Lawson and Till\(^1\) conclude “the admissions interview is not a predictor of success” on various outcome measures yet fail to offer any data in their article to inform the reader or allow such a conclusion.

They give a purpose of their study as being the determination of whether “the Canadian Memorial Chiropractic College [CMCC] structured admissions interview and other outcomes measures predict success” on the Canadian external licensure examination.

The reader may thus reasonably expect to see data of the admissions interview in addition to the reported data such as Grade Point Average. In the absence of either summary data or a table identifying the elements within the structured interview, the authors can only offer an invalid conclusion.

The absence of reported data should but does not prevent the authors making the unsubstantiated statement in their discussion that “none of the noncognitive characteristics used in the admissions process at CMCC were identified as predictors of success on the CCEB examinations.” Apart from stating that “appropriate noncognitive qualities (are) required” and admitting to a “lack of reliable and valid processes…to identify the noncognitive qualities of…applicants,” they fail to provide any description of the noncognitive components of the CMCC admissions process. The reader is thus forced to presume that these include a structured interview with no knowledge of the content or structure of that interview.

Quite simply, the claimed lack of any predictive value of the admission interview could be due to either poor quality content of the interview or poor processes to accord ranking or other outcome measures. In the absence of the data, the reader is unable to make their own interpretation or indeed replicate the processes, both being strong indicators of weak research methodology and immature reporting.

In Reply:

Doctor Till and I would like to thank the reader for bringing this matter to our attention. The reader is correct in stating that the data on the admissions interview should have been included with the other data. Because of the low correlation of the admissions interview to outcomes data from both the Canadian Memorial Chiropractic College (CMCC) and Canadian Chiropractic Examining Board (CCEB) and its poor prediction as based on the regression analysis, the values for the admissions interview were left out of the article. The correlations between the admissions interview and CMCC grade point averages for years 1, 2, 3, and 4 were \(-0.19, \ -0.18, \ -0.16, \text{and} \ -0.09\). The correlations between the admissions interview and CCEB examinations of Basic Science, Applied Science, Clinical Decision Making, and the Clinical Skills Examination were \(-0.14, \ -0.18, \ -0.08, \text{and} \ -0.01\).

The reader also requests “a table identifying the elements within the structured interview.” At CMCC, the individual marks allocated to different elements of the interview are not used individually but are combined to calculate a final score for the interview; and that score is used in the selection process. Only this final score could therefore be used in the regression analyses of the study reported in this article. Just as the authors did not explain in depth how CMCC calculates their grade point average scores for each year or how the CCEB determines the scores on their individual papers, we also felt that it was not necessary to explain the different elements of the admissions interview and exactly how the individual checklist items or structured questions are used to calculate the final interview score. A further study could be planned to investigate these aspects in more depth. Comments on the admissions instrument with regard to its structure and makeup, the suitability of the rating scale used, the reliability of the instrument, or the validity of its scores—other than its low predictive value—was outside the scope of this study.

Our conclusions were not meant for generalization to other interview processes. Simply, we conclude that the admissions interview as administered to this one cohort of applicants was not predictive. No such claim is made against any other admissions interview.

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REFERENCE


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