XII. The Presence of Spinal Subluxation, Any Axial Pain, or Radicular Pain are Indications for Radiographic Evaluation

Introduction

In Section II of this document, 27 indications for spine radiography in children and adults were listed. Some of these indications were:

1. Somatic pain
2. Headache
3. Radicular pain
4. Pain during motion of the spinal or extremity joints.

Subluxation Defined

In a previous section (V), the six types of Structural Spinal Subluxation were delineated. These 6 types of subluxation are mechanical descriptions for the allowable spinal displacements.

1. Segmental subluxations,
2. Postural main motion and coupled motion:,
3. Snap-through buckling in the sagittal plane,
4. Euler buckling in AP/PA view,
5. Scoliosis,
6. Static or dynamic segmental instability.

Subluxation can be simply thought of as an alteration of the normal joint structural alignment and/or function, since altered position causes altered motion.[85] Vertebral subluxation, of course, is specific to any of the five regions of the axial skeleton (cervical, thoracic, lumbar, sacral, and pelvis). Extraspinal subluxation denotes the articulations of the extremities, including the foot, ankle, knee, hip, shoulder, elbow, wrist, hand, anterior ribs, and head (TMJ). Joint structure is defined as the alignment of two or more articulations of the musculoskeletal system. Joint function is defined as the kinesiological motion patterns comprising study of kinematics and kinetics to investigate joint motion and integrity. With these definitions in mind, radiological indications for the assessment of spinal subluxation will be discussed herein.

Nerve Supply to the Disc

Until the 1980s, it was conventional thought that the spinal discs and ligaments were not innervated. Since that time, numerous papers have been published establishing the nerve supply to the intervertebral disks, ALL, PLL, facet capsular ligaments, ligamentum flavum, intertranverse ligaments, interspinous ligaments, and the supraspinous ligaments.[9,14,15,23,63,91,95,96]

It is now known that the outer 1/3 of the intervertebral disc is innervated by the sinuvertebral nerve, which unions with branches from the Grey ramus communicantes (Figure 1). The upper dorsal root ganglion sensory fibers innervate the dorsal portion of the discs via the paravertebral sympathetic trunks, while the sinuvertebral nerves, from the lower dorsal root ganglions, innervate the same dorsal region of the disc.[14] The sinuvertebral nerve is a recurrent branch from the ventral ramus of the spinal nerve and it anastomoses with sinuvertebral nerves of adjacent segments. Nerve ingrowth along zones of granulation has been shown to extend into the nucleus pulposis of degenerated discs.[88]

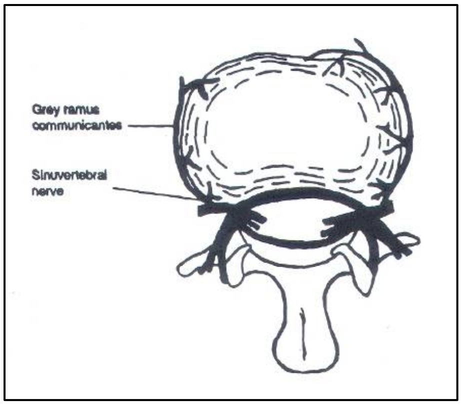


Figure 1. Nerve Supply to the Intervertebral Disc. The sinuvertebral nerve and branches from the grey ramus communicantes innervate the outer 1/3 layers of the intervertebral disc.

Nerve Supply to the Spinal Ligaments

Various spinal ligaments have been shown to possess innervation. The lumbar spinal dura mater has been shown to possess innervation.[57] Kallakuri, et al[57] described, "numerous fine nerve fibers and some small bundles were demonstrated in both the dura and the longitudinal ligaments." The ventral dura was more richly innervated than the dorsal. The authors also concluded that, "the significant number of putative nociceptive fibers supports a possible role for these structures as a source of low back pain and radicular pain."

The thoracic spine as with the other regions of the spinal column is surrounded by ventral and dorsal nerve plexuses which are interconnected. The ventral plexus consists of plexuses of the anterior longitudinal ligament. In the thoracic region, the ventral plexus is also connected to the nerve plexuses of the costovertebral joints.[116] The dorsal plexus is comprised of the nerve plexus of the posterior longitudinal ligament (PLL).

The PLL in the cervical spinal region has been shown to receive sympathetic innervation.[116] Sensory fibers in the cervical dura mater and the PLL have different sensory and sympathetic innervations.[116] The ventral spinal dura contains a dense longitudinally running plexus receiving its contents from the sinuvertebral nerves, the nerve plexus of the PLL and the nerve plexus of the radicular branches of segmental arteries.[40] The dorsal region of the dura mater is less richly innervated, with fibers extending up to eight segments, with significant overlap between adjacent nerves.[41]

Mechanisms of Pain

In this present Section XII, the rationale for the inclusion of pain indications for radiography are discussed. The necessity for radiological examination in the presence of pain is further explained by knowledge of publications in the literature from several different fields of study including:

1. Neuroanatomical Research
2. Neurophysiological Research
3. Surgical Studies and Nerve Block Studies on Spinal Tissues
4. Biomechanical Studies of Stress/Strain on the Spinal Tissues from Loading

To understand the basic mechanisms for somatic pain, a review of neuroanatomical studies is necessary. The presence of mechanosensitive receptors and afferents in this context establishes the framework to begin our discussion. Recent advances in immunohistochemistry techniques have allowed for histological visualization of mechanoreceptors and nociceptive afferents in the soft tissues of the spine. The presence of these afferent receptors and fibers is the starting point for action potential generation and intuitively are responsible for the symptomatic complaints that patients present with and the musculoskeletal structure and functional changes that accompany pain syndromes. Neurophysiologic studies have furthered the understanding of the relationships between electrical, chemical, and mechanical stimulation of the respective afferent units.

Receptor & Fiber Classifications

Based on the work of Polacek, Freeman and Wyke[38] published their afferent terminal classification system in 1967 which is currently the most commonly used.[114] Wyke characterized articular receptors from facet capsules into four categories determined by the individual morphological and behavioral characteristics of the receptor or ending (Table 1).

Because of confusion in the literature regarding differences in classification systems among receptors and nerve fibers,[101] it is further necessary to expand upon the nerve fiber classifications to formulate a basis for further discussion. There are two classification systems for peripheral nerve fibers. The Erlanger-Gasser classification system uses capital letters (A, B, and C) to categorize both afferent and efferent fibers. Another system, the Lloyd-Hunt classification system uses Roman numerals (I-IV) as its designation. While this system was originally designed to classify muscle afferents only,[19] enhancement in recording techniques have made it possible for sensory physiologists to subgroup nerve fibers, and thus it is used today.

Such mechanoreceptors through their respective afferents initiate sensory signals following stress and strain applied to the ligament during spine loading or motion that arrive at the spinal cord's dorsal horn. These receptors have different sensitivities to loading depending on their composition and position. Each receptor/channel once stimulated above threshold opens allows Na+ to enter and the resulting depolarization can result in the generation of action potentials. The intensity of the stimulus can be encoded by the frequency of action potentials.

Afferent input from the periphery arrives in the dorsal horn of the spinal cord. Specifically, nociceptive afferent transmission enters the central nervous system at lamina II, while mechanoreceptive afferent transmission arrives at lamina VII. Acting upon substantia gelatinosa neurons through interneuronal connections nociception transcends contralaterally cephalad through the spinothalamic and spinoreticular tracts to respectively arrive at the thalamus and reticular formation where signals are processed and may ultimately transcend to the cortex depending upon its regulation for interpretation of pain. Mechanoreception, in contrast, transcends ipsilaterally cephalad via the dorsal columns to the cerebellum and other higher centers for proprioception. Simultaneously, via local reflex responses signaling the anterior primary motor neurons in the anterior horn of the spinal cord, neuromuscular reflexes are generated. Further, through interneuronal connections acting upon the intermediolateral cell column, pre-ganglionic sympathetic efferent stimulation is generated, more commonly referred to as somato-visceral reflexes.

Neuroanatomical Identification Spinal Somatic Afferents

Animal Studies

In reviewing more recent neuroanatomical studies in animals, encapsulated mechanoreceptive endings (Types I-III receptors), and non-encapsulated free nerve endings (Type IV receptors) have been found to be present within the soft tissues of the lumbar, thoracic, and cervical spine (including the intervertebral disc, zygapophyseal joint, anterior and posterior longitudinal ligaments, ligamentum flavum, interspinous and supraspinous ligament, and the deep musculature surrounding the posterior elements).[24,25,55,56,74,77,115,117] which causes reflexogenic contraction of the paraspinal muscles to protect and possibly prevent ligamentous damage while at the same time maintaining stability through local reflexes.[104] Similarly, afferent input acting through spinal pathways contributes to proprioception and suprasegmental motor control.[113] Type IV afferent fibers (nociceptors) signal noxious stimulus through mechanical deformation, or by chemical depolarization and transmit information regarding tissue damage to higher centers where pain may be qualified and other physiological responses occur.[89]

Human Studies

Recently, investigators have identified the presence of mechanoreceptors, nociceptors and their respective afferent fibers (units) in human spinal tissues, including the ligaments, facet joints, and intervertebral discs.[34,39,54,56,69,70,91,106,108] In a histological analysis of normal human thoracic and lumbar facet capsules, McLain and Pickar,[69] reported the presence of Types I-IV receptors and noted their presence to be a smaller proportion in comparison to that previously reported in the cervical spine. It is the connection of these receptors to respective afferent nerve fibers that provides the innervation of the lumbar spine. The dual nerve supply of the intervertebral disc via the sinuvertebral nerve and gray rami communicantes, and the branches of the dorsal rami are responsible for providing innervation of the soft tissues of the lumbar spine.[14]

The Effects of Inflammation on Afferent Sensitivity

The effect of inflammation on the mechanosensitivity and discharge rates of afferent units has also been investigated by some of the above referenced researchers. Substance P and other neurotransmitters such as Calcitonin Gene Related Peptide (CGRP) that are released during nociceptive stimulation cause peripheral sensitization of the nociceptive fibers making them more susceptible to mechanical and chemical stimulation.[118] In other work, Cavanaugh et al.[22] injected carrageenan and kaolin, commonly used products that result in acute tissue inflammation with the release of histamine, bradykinin, and prostaglandins, into the extracellular tissue. They discovered in the presence of inflammation, elevated baseline discharge rates and there occurred vigorous multi-unit response to stretch by moving the facet joint approximately 1 mm in inferior-superior, anterior-posterior, and lateral-medial directions. This research, and other studies[83,84] demonstrates that peripheral nerve endings become sensitized by chemical mediators released as part of the inflammatory cascade in the face of tissue damage. Consequently, inflamed joints have been found to have an ongoing background nerve discharge that can cause constant pain at rest and sensitized nerve endings can cause increased pain during ordinary movements. Thus, afferents in the adjacent tissues that normally fire only when mechanical stress is clearly noxious, will fire at much lower stresses in the presence of inflammation, and can maintain a background discharge even without mechanical stress.[23]

Another clinical implication resulting from these studies demonstrates that inflammation resulting from damage to spinal structures associated with degeneration or capsule, ligament, disc, or muscle sprains or strains could cause prolonged nociceptor excitation. This may contribute to a vicious cycle including muscle spasm and secondary hyperalgesia, that leads to persistent pain and perpetuated spinal joint dysfunction.[23]

Table 1.

Classification of articular receptors. (Modified from: Wyke BD. Articular Neurology and Manipulative Therapy. In: Idezak RM, ed. Aspects of Manipulative Therapy. Carlton Lincoln Institute of Health Science, 1980; and McLain RF. Mechanoreceptor Endings in Human Cervical Facet Joints. Spine 1994; 19:495-501.)

Type	Morphological Appearance	Average Dimensions	Location	Functional Characteristics	Other Terminology
I	Thinly encapsulated globular corpuscles usually found in clusters.	400-100µm long	Fibrous capsules of joints, and in periarticular ligaments and tendons; usually in the superficial layers	Static & Dynamic Mechanoreceptors, low threshold, slowly adapting afferent ending.	Ruffini's ending, Golgi-Mazzoni ending, Meissner's corpuscle, basket or spray-type ending.
II	Thickly encapsulated conical or cynlindrical corpuscles	250-300µm long & 100µm wide	Fibrous capsules of joints in the deeper subsynovial layers, and at junctions of fibrous tissue and fat; often accompanied by vascular leash; oriented along with the connective tissue fibers	Dynamic Mechanoreceptors, low threshold, rapidly adapting afferent ending.	Pacinian corpuscle, Vater-Pacinian corpuscle; modified Pacinian corpuscle; Paciniform corpuscle; Meissner's corpuscle; Golgi-Mazzoni body; bulbous corpuscle; club-like ending
III	Thinly encapsulated fusiform corpuscles	Up to 600µm long; 100µm long	Applied to surfaces of joint ligaments and tendons (Collateral & intrinsic), as well as in dense fibrous connective tissues	Dynamic mechanoreceptors, high threshold, very slowly adapting afferent ending	Golgi's ending, Golgi tendon organ, Golgi-Mazzoni corpuscle
IV	(a)Traditional plexuses of unmyelinated nerve fibers (b) Free unencapsulated, unmyelinated nerve endings	0.5-1.5 µm in diameter	(a) Fibrous capsules of joints. Adventitial sheaths of articular blood vessels (b) Joint ligaments (Collateral and Intrinsic)	Nociceptive mechanoreceptors; very high threshold, non-adapting afferent ending chemosensitive (to abnormal tissue metabolites); nociceptive receptors	Nociceptor, free nerve ending

Surgical Studies and Nerve Block Studies on Spinal Tissues

Other areas of investigation have clinically identified the viscoelastic elements of somatic musculoskeletal soft tissues as being pain generators. In the spine, the medial branch of the dorsal primary rami has been identified as the innervating structure to the facet joints.[16-18,31,96] Pain provocation studies and subsequent anesthesia including medial branch blocks have identified the facet joints to be significant pain generators involved in musculoskeletal pain.[9,10,15,36,95-100] Provocation discography has also provided insight into the prevalence of discogenic pain and the underlying annular lesions structurally associated with this clinical spinal pain syndrome.[13,20,68,71,78,79,93,94,109] These studies and others have identified the spinal joints as being a significant source of somatic (referred or scleratogenous) musculoskeletal pain,[63] while the spinal nerve roots through compression or chemical radiculitis, have been identified as the major source of radicular pain.[12,21,27,37,58-61,87,102,111]

Posture

To further explore the necessity of radiographic examination to determine clinically relevant articular alignment, a discussion of posture is necessary. Human posture may be defined as the position or carriage of the body as a whole having genetic, habitual, and injury influences. Posture literature has often held that the relationship of the line of gravity to the body has a functional significance to the musculoskeletal system since rotational (bending) moments are created if the line of gravity and the centers of weight-bearing joints do not coincide.[90] While some have considered the relationship between posture and musculoskeletal pain controversial, the majority of studies have found a positive correlation between abnormal posture/altered joint alignment and musculoskeletal pain (see Section X for a complete review of each region).[30,52,107] Abnormal posture increases load on pain sensitive discoligamentous tissues causing extraneous efforts to be endured by the muscular stabilizing system of the spine.[29] Increased muscular activity of the trunk muscles has been associated with back pain.[8,26,49] Posture also has an effect on resultant spinal function including coupling patterns.[28,85] and range of motion.[32] Postural changes and sustained loading on the spinal joints have further been found to increase stress concentrations in the intervertebral discs,[3;4;6] and posterior elements of the spine.[5] Increased loading and spine injury have been found to be a precursor to spinal degeneration.[2,43] This concept of abnormal posture, has led to a number of investigations to define normal posture.[44,46,48,53]

Biomechanical principles (applying mechanics to a living organism) can be applied in the assessment of posture. A basic theorem in physics and engineering holds that the movement of any object can be decomposed into a *rotation*, *translation*, and *deformation*. *Rotation* can be defined as a circular movement in degrees, *translation* as a linear or straight-line movement, and *deformation* as a change in size or shape of an object. By the 1970s, researchers were using this fundamental engineering principle to describe the motion of spinal segments as rotations and translations in 6 degrees of freedom (DoF). The possible movements of a spinal segment are illustrated in Figure 2. These movements can be qualitatively classified as rotations (R) on each axis denoted with the listings of Rx, Ry, and Rz and translations (T) along each axis, listed as Tx, Ty, or Tz.[112]

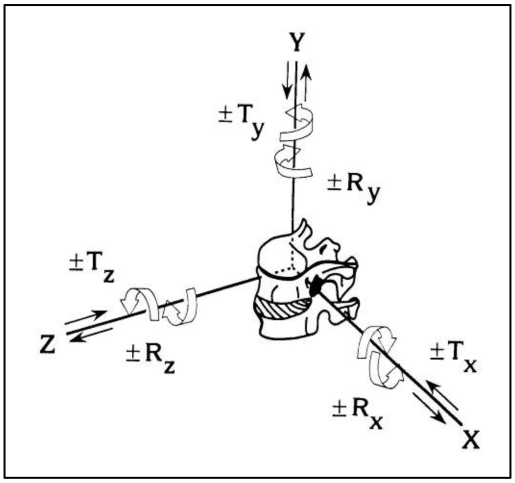


Figure 2. Degrees of freedom of a typical lumbar vertebra. A vertebra can rotate (Rx, Ry, Rz) around the three axes of a 3-dimensional Cartesian coordinate system. It can also translate (Tx, Ty, Tz) along these axes. This provides 6 degrees of freedom. (Reprinted with permission from Harrison DE et al. Three-dimensional spinal coupling mechanics: Part I. A review of the literature. J Manipulative Physiol Ther 1998; 21(2): 101-113)

In the early 1980's, Harrison applied the Cartesian coordinate system to upright posture in categorizing the possible permutations as combinations of the simple postural rotations (Rx, Ry, Rz) and translations (Tx, Ty, Tz) of the head (H), thoracic cage (TC), and pelvis (P).[45] Breaking posture down into an assessment of rotations and translations of the head to thorax, thorax to pelvis, and pelvis to feet in 6 degrees of freedom (DoF) is Harrison's original contribution to the knowledge base of postural assessment.[45] As opposed to qualitative assessments describing a head tilt or a high shoulder, posture can be quantitatively described as measures of the rotations (Rx, Ry and/or Rz) (in units of degrees), and translations (Tx, Ty, and/or Tz) (in millimeters or centimeters) can be made. Combining single postures in combination provides *128 million* possible upright human postures in static equilibrium.

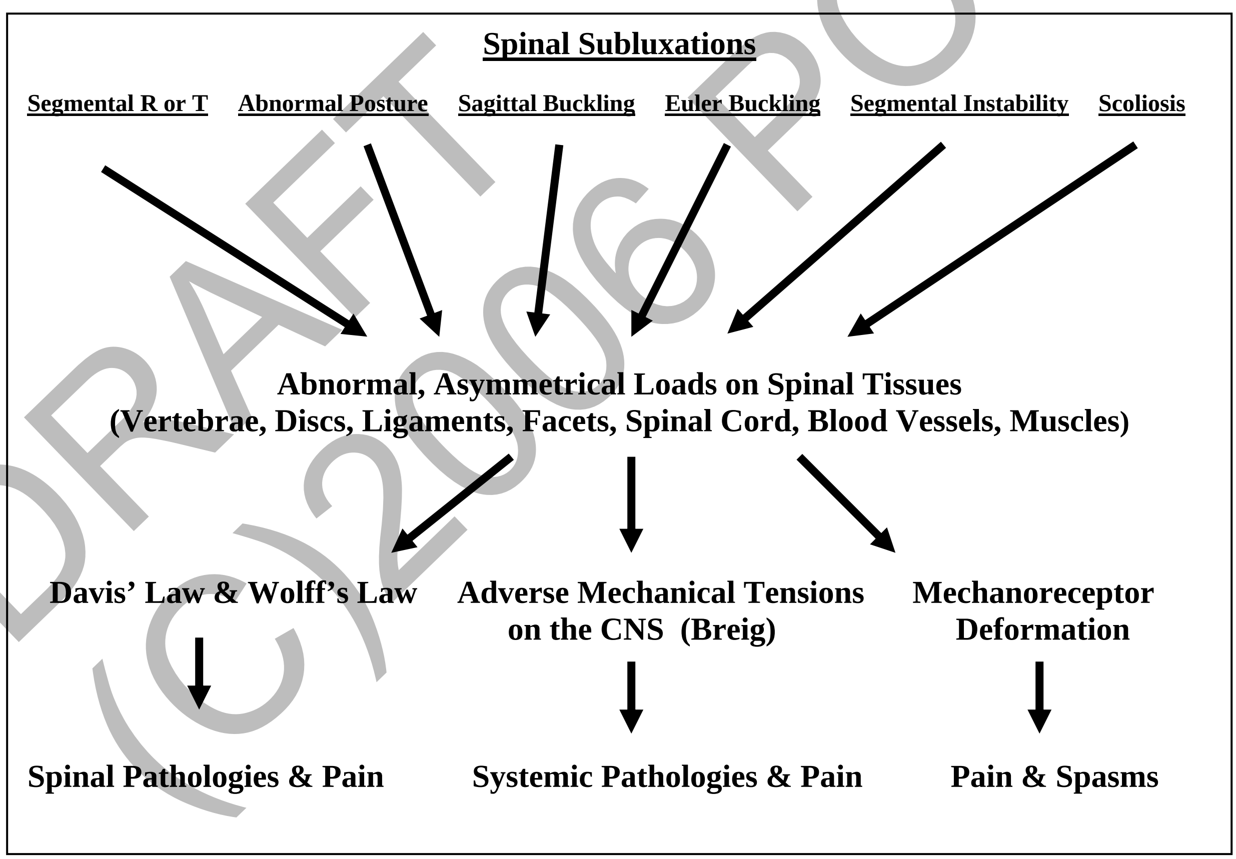
To perform a postural analysis, anatomical landmarks are viewed visually, or marked on photographic images and digitized using computer software to quantify each posture from defined points. The suggested landmarks are medial and lateral maleolus, mid-knee, mid-lateral thigh, pubic symphysis, mid-ASIS in AP view, ziphoid, episternal notch, upper lip, glabella, EAM, the shoulder AC joint, medial elbow, hand, and posterior gluteus muscles. Using grid photography, a quantitative analysis of posture can be performed utilizing fixed reference points. In this manner, translational displacements can be measured in degrees and rotations can be measured in degrees to quantify postures of the head, thorax and pelvis. Postural analysis requires training and skill, as many postures present as combined postures of two or more main motions. For example, since the mass of the thoracic cage is large, as mentioned above, the anterior/posterior translations of the thoracic cage ($\pm Tz^{TC}$) not only will cause mid thorax to be displaced a perpendicular distance from a vertical line through mid-pelvis in the lateral view, but will also cause the opposite pelvic translation with concomitant pelvic tilt. Inasmuch, this may be cause for confusion when looking at a superior global body part without determining the position of the immediate inferior global part. Using a consistent postural assessment protocol, the global object being evaluated can be systematically compared to the global object below.

Certain postures require radiographic confirmation for differentiation. For instance, thoracic cage flexion/extension is more difficult to visualize, without checking vertical alignment of T1 and T12 on a lateral radiograph, and will also cause the opposite pelvic forward/backward translation concomitantly.[47] Vertical translations of the thoracic cage ($\pm Ty^{TC}$) are difficult to decipher without noting a straightening or hyper-lordosis of lumbar spine on a lateral radiograph. Extremity joint positions and anomalies can also be responsible for errors in postural analysis.

Biomechanical Studies of Loading

The correlation of visual postural analysis with radiographic images assists the clinician in identifying etiological and causative factors responsible for the patients presenting complaints; a necessary step in chiropractic differential diagnosis. Indeed, abnormal loads from abnormal posture has been found to be associated with soft tissue remodeling (Davis' Law), and hard tissue (bony) remodeling (Wolff's Law). For example, a number of studies have determined correlations between increased intervertebral disc loading and subsequent degeneration.[6,47,51,62,65] Other studies have determined degenerative spinal changes in response to anular injury.[7,80-82,103] Still other work has idenfied the progression of degeneration to osteophytes limiting mobility and function of musculoskeletal articulations.[64,66,75,76,86,105] Figure 3 summarizes the biomechanical relationships between spinal subluxations and clinically relevant pain syndromes.

Figure 3. Spinal Subluxations (over time) Cause Pathologies and Pain



Clinical Considerations of the Pain Patient & Radiological Necessity

Observations made from the moment a patient enters the office can reveal much about their condition. Antalgic postures, altered gaits and guarded movements are examples of presentations that reveal important information. After reviewing the patient history, even more knowledge is gained. Does the patient have pain or paresthesia in a dermatomal distribution suggesting possible nerve root involvement? Conversely, does the patient have local or referred (scleratogenous) type pain possibly arising from somatic structures such as the disc, facet, ligament, muscle, or viscera? While a standard neurological examination may help to confirm the presence of nerve root involvement, the same examination is poor in *discriminating* patients with somatic pain. Even more complex are the uncertainties regarding psychosocial factors and patient motivations to consider when evaluating the pain patient. Within this context, this section will conclude with the necessity for radiographic evaluation in the musculoskeletal pain patient.

In recent years, there have been significant advances in the understanding of the physiologic and biochemical processes that are involved in pain processing at a spinal level. The elucidation of these multifaceted processes has meant a shift away from the conceptualization of pain as a simple "hard-wired" system with a pure "stimulus-response" relationship. In fact, many patients report pain in the absence of tissue damage or any likely pathophysiological cause, which may be due to psychosocial factors,[1] or be related to plastic changes within the nervous system.[33] *The International Association for the Study of Pain* defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage.[1] Naturally, pain is subjective, and highly individualistic. Theorists view pain as not simply a sensation, but as a multidimensional phenomenon involving sensory, evaluative, emotional, and response components.[72] Each person learns the meaning of the word, pain, through experiences related to injury in early life,[1] and personal, social, and cultural influences all are thought to play important roles in the pain phenomenon. Because pain, particularly persistent pain, is not often directly tied to specific pathophysiology, but rather is linked to integrated perceptions arising from neurochemical and biomechanical input, cognition, and emotion, the mind greatly influences the intensity of the pain.[73] Moreover, there is a poor association between objective measures of physical pathology and the amount of pain and disability that a patient may express.[42] These factors must be taken into consideration in the realm of patient management.

Clinical decision-making is based upon securing a working diagnosis from a review of the patient history, physical examination, standard tests, and imaging studies. At the center of this mix, lays the patient and their complaints. Patient evaluations are not as simple as looking at test results. Comorbid factors such as patient motivation can further influence patient responses on a number of levels, from questionnaire responses to actual test performance. Patients have been known to amplify symptoms or functional status for a variety of reasons based in the human nature. Anxiety, stress, and emotional disturbances such as depression or hysteria may be responsible for elevated pain scores.[67] In addition, the effects of compensation, litigation, and employment have been named as influences in patient status and outcome.[35,92] It is clear that comorbid factors exist in patient status and recovery, thus, attentiveness in assessment of the *big picture* is important for clinicians to consider.

Recent models of spinal pain have been proposed to assist clinicians and researchers in developing useful evaluation and management protocols. Waddell[110] conceptualized the back pain problem as possessing three distinct elements:

Pain: an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage;

Disability: diminished capacity for everyday activities and gainful employment; and

Impairment: an anatomical or physiological abnormality leading to loss of normal bodily ability. While the three elements may be related, it is noteworthy that the strength of the relationship is not perfect and disassociation of the elements can occur.

Another model of disablement has been adapted to the physiotherapy management of low back pain.[11] This model is slightly different to Waddell's as it makes the distinction between a functional limitation and a disability.

Functional Limitations*:* restrictions in performance at the level of the individual (i.e., the ability to perform a task of daily living);

Disability*:* restrictions in the ability to perform socially defined roles and tasks expected of an individual (i.e., inability to work or participate in family social functions).

The distinction between functional limitations and disability helps explain why two patients with similar impairments and functional limitations may have very different levels of disability.[11] In common, however, is the fact that clinicians must make decisions based on interpretation of a multitude of test results.

Four kinds of measurements provide relevant information about patient clinical status and/or response to treatment. In general, they are:

1. Perceptual measurements (i.e. reports of pain severity and pain tolerance),
2. Structural measurements (i.e. anomalies, pathology, spinal subluxation, and abnormal posture),
3. Functional measurements (i.e. range of motion, strength, stiffness, activities of daily living), and
4. Physiologic measurements (i.e. neurologic assessment, laboratory examinations) (Figure 2).

The most prevalent complaint among patients presenting to a chiropractic office is musculoskeletal pain.[50] Thus, issues relevant to pain and patient motivations are noteworthy to understand the meaningfulness of spine instrument measures. Research aimed at assessing the quality and effectiveness of health care as measured by the attainment of a specified end result, or outcome is known as *outcomes assessment*. Such measures include parameters such as improved health, lowered morbidity or mortality, and improvement of abnormal states (perceptual, *structural*, functional, and/or physiological). Thus, radiographic analysis of possible structural spinal subluxations can be considered of paramount importance in the overall assessment of a presenting patient's condition.

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