# CHAPTER 16
# Instrumentation

## Chapter Outline

I. Overview

II. List of Subtopics

III. Documentation

IV. Recommendations

V. Comments

VI. References

## 1. OVERVIEW

In coming to an analytical conclusion about the nature of a patient's possible subluxations, the chiropractor uses many methods, including those of history-taking, inspection, palpation and instrumentation. Through information gained from research and personal experience, the chiropractor generally assigns a personal value to each procedure in any particular circumstance. The intent of this chapter is to describe and evaluate the various instruments that are presently used by chiropractors in the examination of their patients.

### Appropriate Use of Instruments

Instruments are all designed with various levels of sophistication and make use of underlying assumptions. Sapega has observed that many clinical tools available today are capable of generating more measurements than can be meaningfully understood. The technological explosion in health care delivery has advanced far beyond valid clinical utility.

The meaningful interpretation of changes in a subject's test results requires the reliability and validity of the procedures. The most effective means to ensure reliability is through test standardization and close attention to the correspondence of test conditions to those of the actual demands that the patient's lifestyle makes on his performance. The test clearly must be relevant to the individual's activities that have been impaired or to normative data and should be able to discriminate healthy from unhealthy people.

### Evaluating Instruments

Several qualities are found in common for instruments that ultimately prove to be clinically useful. Focusing on these qualities rather than on specific named instruments simplifies the task of evaluating instruments individually. They include the following:

1. Validity is the most clinically important quality. A test is valid when it accurately measures the desired function, and when that function is pertinent to the patient's condition.

2. Discriminability is determined by the ability to distinguish healthy from unhealthy individuals. In order to accomplish this, a normative date base consisting of studies of people from both groups is required. The relative frequency of false-positive (i.e., healthy persons who test positive) and false-negative tests (i.e., unhealthy persons who test negative) occurring for each group also helps to define a test's discriminability.

3. Accuracy of a measure is determined by comparison to a known value. Repeated use of some devices and the simple effects of passing time may cause loss of calibration which will alter accuracy.

4. Precision describes the variation of a measure across the range over which it is intended to be used. Both accuracy and precision can change over the possible ranges of test applications.

5. Reliability of a measure depends both on the accuracy of the instrument and the characteristics of the variable being measured.

For each category of instrument discussed below, knowledge of how each performs with

respect to the above test qualities is presumed.

**Patient Motivation**

Test results should be interpreted in conjunction with observations of the quality of patient performance and cooperation made while the test is being performed. As a result, only adequately trained ersonnel who can integrate clinically meaningful observations should perform most tests. Quality of patient performance, repeated measures testing and correlation of findings with other clinical information permit an accurate evaluation of patient motivations. Specific reasons for poor test performance include legitimate reduced capability, misunderstood instructions, apprehension of the test setting, fear of pain arising from the test and questions of secondary gain.

## II. LIST OF SUBTOPICS

A. Spinal Kinesiopathology
   1. Electrogoniometry
   2. Inclinometry
   3. Goniometry
   4. Optically-Based Systems
   5. Muscle Strength Testing
      a. Manual or instruments
      b. Dynamometer
      c. Modular-isometric

B. Neurophysiological
   1. Temperature Reading Device
   2. Thermography
   3. Current Perception Threshold Devices
   4. Electroencephalography
   5. Algometer

C. Myological
   1. Tissue Compliance Measurements
   2. Surface Electromyography
   3. Surface Electrodiagnostic Procedures
   4. Needle Electrodiagnostic Procedures
   5. Electrocardiography

D. Other Instrument Measures

   1. Doppler Ultrasound
   2. Plethysmography
   3. Spirometry
   4. Plumbline Devices
   5. Bilateral Weight Scales

## III. DOCUMENTATION

**Perceptual Measurements**

A. Questionnaires as Instruments:

Physical signs can be rather insensitive measure of a patient's disability. Standardized rating scales and questionnaires afford a simple means of appraising many aspects of patient life and health. Instruments commonly used in the chiropractic community assess any of the components of the vertebral subluxation and other malpositioned articulations and structures complex, pain, activities of daily living (ADL), somatization, depression and anxiety. Generally, questionnaires may be divided into two categories, self-reporting and practitioner-administered. Self-reporting questionnaires are often self-normalizing but suffer from reactivity which may result in an unintentional change in the patient's response when exposed to the same questions repeatedly. Practitioner-administered questionnaires benefit from the involvement of a trained observer whose skill can help in interpreting the patient's response. In administering either format, several error sources should be considered including 1) patient motivation; 2) acquiescence to positively worded items; and 3) patient's seeking social approval. Overall, functional questionnaires offer standardization of measurement, comprehensiveness, and generally good reproducibility and validity.

There is no consensus on the use of a particular questionnaire for a specific clinical problem. For the measurement of the same clinical problem, different questionnaires may not yield interchangeable findings. Screening questionnaires may be used to obtain a broad patient overview in a comprehensive and timely manner. With the recent intensive development in the outcome measurement field, future field standardization on use of questionnaires is to be expected.

**Pressure Algometry**

Pressure algometry is a comparatively new procedure which uses a pressure manometer to estimate pain threshold from applied pressures to the myofascial structures. Normative data shows that pressure pain thresholds are highly symmetrical and are generally lower in females than in males. Reeves et al. have reported reliability coefficients ranging from 0.71 to 0.97. Pressure pain threshold levels are sensitive to a variety of care interventions. Good inter-rater and test-retest reliability has been shown.

**Functional Measurements**

1. Measurement of Position/Clinical Anthropometry

    1. Posture
    Studies in ergonomics have shown that trunk, head and joint positions adopted during work can be used as an objective index for evaluating the intensity of physical work stress, mental concentration of manual dexterity. The choice of a particular position may be the most important factor contributing to whether an attempted physical activity is risky or safe. Individual instruments and automated measures are available to quantify posture or body segment position.

    2. Plumbline analysis
    The plumbline was one of the first tools to be used in chiropractic to analyze posture. The plumbline provides a visual frame of reference for the influence of the center of gravity from each body segment, enabling the clinician to detect postural deviation, asymmetry and suspect areas of postural stress. Patients are observed in the anterior, posterior and lateral stances.

    4. Bilateral weight scales used to determine spinal balance and disturbed proproceptive reflex balance mechanisms.

**Measurement of Movement**

In the general course of patient care, range of motion is examined using goniometers, inclinometers and optical based systems. Most devices quantify the regional movement of a part and express it as an angular displacement about some center of rotation.

1. Goniometers

The degree of peripheral joint movement can be measured throughout active or passive ranges. Its usefulness is greatest in the extremities, particularly the small joint of the hands and feet. The reference point for measurement is the long axis of the part being measured and is determined by judgment. Accuracy is limited to a range of 10 to 15 degrees. Usage for spinal measurements is no longer considered acceptable practice because of the advent of better methods.

2. Inclinometers

Inclinometers use the constant vertical direction of gravity as a reference and require only that a side rests against the body segment surface. Digital or analog, and mechanical or electronic versions are available. Greater accuracy of measurement is available to ranges of 3 to 5 degree being possible under typical clinical conditions. Inclinometers are the more suitable instrument for assessing spinal function and are capable of separating components of motion, e.g., pelvic versus lumbar.

3. Optically based systems

Aside from research applications, the most prevalent clinical use of opto-electronic systems is in conjunction with the use of force plates for assessing gait abnormalities. Video-monitoring is often used in industrial practice to capture the salient features and at least semi-quantify motions and postures at the work station. Work related spine injuries, carpal tunnel syndrome and other cumulative trauma disorders are frequent areas of concern where these methods are used. The primary parameters of importance are joint angle, angular velocity and angular acceleration. Coupled with appropriate software and external load measurements, joint loads and patterns of behavior can provide information on relative risk of work related tasks.

2. Measurement of Strength

The term strength denotes the capacity for active development of muscle tension and through the resulting muscle force generates joint torque. Computerized muscle dynamometer systems quantify more variables than the average physician can properly interpret. In the case of employment-related tests, the evaluation must closely simulate critical job tasks.

The emphasis on computerized muscle-dynamometry systems (isometric, isokinetic, isotonic and isoinertial) has overshadowed earlier isometric and psychophysical testing methods. No single method of strength evaluation is decidedly superior or more valid for measuring muscular strength. Each method also has a number of advantages and disadvantages. For valid interpretation of test results, the unique characteristics of each must be kept in mind. It has yet to be shown conclusively that testing can clearly predict that a patient can return to a certain activity level and will have less risk of re-injury under actual functional conditions. Only continued research and development of broader normative data bases than are now available will finally test the underlying assumptions currently used in these clinical applications.

1. Manual hand-held strength testing

Manual muscle strength testing provides only a rough approximation of capability and its use is limited. Accuracy in manual assessment requires differences in strength of 35% or more. Hand-held dynamometers, while not eliminating all the problems of manual testing, provide greater degrees of accuracy and reliability.

3. Instrumented strength measurement testing

Patient assessment naturally falls into three categories: 1) preventive evaluation (as in employee job-matching); 2) post-injury evaluation; and 3) outcome monitoring following care. Significant clinical information can be obtained toward these objectives, but careless interpretation of test data can result in inappropriate clinical decisions. Acute disorders are a contraindication to strength test protocols. The average discrepancy between symmetrical muscle groups for healthy populations has been reported as much as 12%. When evaluating an individual's performance, differences of 20% or more may be needed to discriminate abnormalities.

a. Isometric testing

There are several technical concerns in the performance of isometric tests: 1) the inertial effects at the onset of the test; 2) patient fatigue; 3) patient posture; and 4) patient motivation. The objective of the test is to identify and record the maximum voluntary contraction force that can be sustained. At this time, the tasks that can be adequately represented with isometric tests are sagittally symmetric. Up to 70% of work postures can be approximated symmetrically. Normative data for occupational classifications of lifting activities as well as for reciprocal trunk strength ratios are available. Normative data is used to evaluate extremity strength for post-injury assessment or seasonal sports fitness. Bilateral differences greater than 15-20% indicate abnormality.

The patient's motivation to supply a maximum effort can be assessed by repeated measurement and acceptable maximum effort protocols. Quantitative knowledge of the patient's posture during the performance of the strength task is critical to any effort to relate the test result to joint loads or NIOSH standards.

b. Isokinetic testing

The primary measurement obtained is the torque generated which is only valid during the controlled part of the motion. The maximum voluntary effort will coincide with the greatest mechanical advantage of the joint for the motion that is being attempted. There are two technical concerns with isokinetic measurements. They are: 1) gravitational effects; and 2) torque overshoot. Both may be corrected through computerized correction routines and damper setting. Standard isokinetic measurements are commonly taken at increments of 30 degrees per second using 2-6 repetitions with the maximum single torque value used as the measure of performance. As with isometric evaluation, the normal extensor/flexer trunk ratio falls when impairment is present. Kannus, Nuan and Mayhew feel the side-to-side comparison of extremity testing has some importance.

c. Isoinertial testing

While no testing method yet devised allows an assessment of free dynamic motion

such as would occur at a work site or in sports, isoinertial equipment may come closer than others. Several authors have examined the ability to predict performance by controlling torque during movement. Isoinertial systems can be made capable of monitoring position, velocity and torque simultaneously. Measures of regional coupled motions appear to hold promise in discriminating fatigue effects from healthy movement. Likewise, velocity measurements appear to be sensitive to lumbar spine disorders. Normative data is available for a number of occupational subgroups, including sedentary workers.

**THERMOGRAPHY**

Since the introduction of the neurocalometer by Zvins in 1924, skin temperature measurements have played a significant role in the clinical practice of chiropractic. In the 1960s, thermographic imaging was being used by investigators to evaluate spinal lesions. Sensory nerve irritation is believed to produce reflex vasoconstriction of the arterioles, of the skin, altering thermographic patterns. Urrichio described thermography as a physiological test that aids primarily in the diagnosis of sensory nerve irritation. He stated that when a sensory nerve is irritated, the sympathetic nerve associated with it causes vasoconstriction of the capillaries under the skin.

Early thermographic research in spinal disorders resulted in equivocal findings. Karpmen et al noted that "Traumatic back injuries were readily evaluated thermographically," and reported that "No patient ... had a normal thermogram in association with an abnormal x-ray film."

Standardized protocols and computer assisted analysis have dramatically improved the diagnostic sensitivity of thermography in neuromuscular disorders. Uematsu et al developed a computer-calculated method of collecting thermographic data. They compiled normative data on 90 asymptomatic patients. Readings were obtained from 40 matched regions of the body surface. They then examined thermal asymmetries in 144 patients with low back pain. When asymmetries exceeded more than one standard deviation from the mean temperature of homologous regions in control subjects, the positive predictive value in detecting nerve root impingement was 94.7%. The specificity, or proportion of persons without the condition who have a negative test result, was 87.5%. Chafetz et al compared thermographic examination with CT of the lumbar spine. Fifteen asymptomatic subjects and 19 patients with CT scans demonstrating thecal sac contour distortion or nerve root displacement were examined. All 19 patients with positive CT scans had abnormal thermograms, a sensitivity of 100%. The specificity, however, was 60%.

Several other investigators have compared thermographic finding with those of other diagnostic modalities. Weinstein and Weinstein compared cervical thermography with EMG, CT, myelography, and surgical exploration. 500 patients with neck or upper extremity complaints were studied. 197 (39.4%) were found to be positive for root pathology. Of these, 190 (96.4%) were ultimately confirmed by EMO, CT, myelography, and/or surgery.

Hubbard conducted a study of 85 thermographic examinations. A high correlation was reported (94%) between pain distribution patterns and cervical and lumbar thermograms. The thermographic results were well correlated with EMO, myelography and CT studies. 52 control thermographic studies were performed on young asymptomatic patients, and 90% were reported as "normal."

At least two state Appellate Court decisions have found that evidence relating to liquid crystal thermography results are admissible as evidence to demonstrate injury resulting from automobile accidents. See Fay v. Mincey, 454 So.2d 587 (Fla. 2nd DCA 1984); Crawford v. Shivashankar, 474 So.2d 873 (Fla. 1st DCA 1985).

To strengthen the value of thermography as a diagnostic tool in the evaluation of soft tissue lesions, there are procedural elements that must be effectively addressed:

1. Strict protocols must be followed to minimize artifacts.
2. Interpretation requires a high level of training and experience.
3. The examination is relatively time consuming.
4. The use of thermographic imaging to evaluate motor nerve involvement is not supported in the literature.

The principal application for thermography in the evaluation of soft tissue lesions appears to be in demonstrating and characterizing sensory nerve involvement.

Body heat loss to the environment takes place passively by convection, conduction and radiation. Regional body temperature is governed by the interaction of central autonomic control mechanisms and multi-segmental spinal vasomotor reflexes. Regional variations of sympathetic thermoregulation produce a complex pattern of temperature distribution including cephalocaudal, diurnal and circadian patterns. Accurate measure requires accommodation of the skin to room temperature, which should be kept at between 33.5 to 34 C. For reproducible measures, the patient needs to establish constant patterns of work and rest and follow-up testing should be performed at the same time of day. Measurements of skin temperature and the amount of heat radiated from anatomically symmetrical regions yields useful information about the relative circulatory volume to each part. Areas of increased cutaneous temperature have been ascribed to vasodilation occurring during a migraine headache, inflammation or muscle spasm. Decreased cutaneous temperature may reflect vasoconstriction, vascular obstruction, fibrous and fatty replacement. An abundance of literature is available documenting employment of thermography as a screening tool; e.g., detection of deep vein thrombosis, identification of allergic reaction, qualification of vascular phenomena, and the identification of pain.

1. Thermocouple devices

   Several thermocouple devices have been marketed to be used for the determination of local paraspinal temperature variations. Patterns of heat along the spinal column and their changes following spinal adjustments, provide useful data in some chiropractic techniques.

2. Telethermography

   Measurement of skin temperature differences across the torso, head and extremities as a means of evaluating functional changes from somatic lesions. Various forms of "gold standard" comparison have been used including surgical confirmation of disc herniation and percentage agreement of statistical correlation with other more widely accepted diagnostic procedures. Normative data are available; for example, see Chang et al., 1985, Feldman and Nickolff 1984, Goodman et al., 1986, and Uematsu et al., 1988. A number of efforts to evaluate diagnostic truth from telethermographic measures have been made. The results of comparative studies of thermography and other diagnostic procedures for nerve root entrapments are quite varied. Where some studies claim that thermography has little diagnostic and uncertain prognostic value in the evaluation of low back pain and radiculopathy, others praise its sensitivity and positive predictive value. Thermographic images have been used in the diagnosis of myofascial pain syndromes and their respective pain referral zones. Perhaps the strongest evidence for use of telethermography is for cases of suspected neurodystrophy. There has been a high correlation between the thermographically defined referral zones and those as described in the literature. Additional zones, not previously identified, have also been recognized.

**GALVANIC SKIN RESPONSE (GSR)**

Devices to detect differences in paraspinal regional electrical skin resistance have been employed by the chiropractic profession for many decades. Loci of lowered skin resistance were thought to be related to areas of cutaneous hyper of hyposympathetic activity.

**ELECTROPHYSIOLOGIC RECORDINGS**

Numerous variables affect all electrophysiologic recordings: 1) the size and location of the recording electrode; 2) the configuration of the electrode position relative to the structure being recorded; 3) characteristic resistance of the tissues; 4) the pathophysiology of the patient's problem and 5) artifacts.

1. Electrodiagnosis

Several specialized procedures are available to evaluate select neuromuscular functions. These include measures of myoelectric activity during muscular loading, fatigue studies, conduction velocity tests, H-wave and F-wave responses, and evoked potentials. Generally these studies can be simply grouped as either 1) stimulation studies; or 2) electromyography (EMG). The clinical procedures are sometimes divided according to whether needle or surface electrodes are used. The International Chiropractors Association does not support the use of needle electrodes in chiropractic practice because of the invasive nature of the procedure.

Surface electrode studies may be used in many cases, but are traditionally applied to the examination of nerve conduction velocities, reflex studies and kinesiological evaluations. In kinesiological applications, up to 16% of the surface recordings from the upper leg muscles, for example, is from co-contraction activity. Surface electrodes may be used with repetitive stimulation to examine suspected myoneural junction disorders. Somatosensory evoked potential (SEP) are performed with surface electrodes. SEP serve to discern between peripheral and cord (dorsal column) lesion sites. Needle electrode studies are classically termed electromyography. This technique may be used in all varieties of electrodiagnostic studies, but it is required to detect denervation, myoneural junction disorders, cerebellar and brainstem tremors, anterior cord disease and motor unit potentials.

2. Nerve stimulation studies

Nerve stimulation studies can be performed using either surface or needle electrodes. Basic information may be gained about the neuromuscular peripheral sensory and motor components using conduction velocity and reflex responses of the nerve (i.e., H-reflex and F-waves). Practically, this information may be used to evaluate the nerve trunk integrity as well as significant compression, or temporal dispersion from entrapment of utabolic neuropathy. Both sensory and motor studies permit analysis of wave form, amplitude and duration of the impulse. Nerve compression from lumbar root lesions can be quantified. While nerve conduction velocity is a poor index for radicular syndromes, F-waves and H-reflexes are more useful. Similar use can be made for study of complaints from the upper extremity. Sensitivity and specificity for each of the following electrodiagnostic procedures are well studied. Sequencing of tests often increases the diagnostic yield. Timing of tests performed with respect to the onset of symptoms is important since their appearance and disappearance can be temporally dependent.

Evoked, transforaminal responses (surface or needle): Peripheral motor nerve fibers of major nerve trunks from the extremities may be evaluated by use of the F-wave of Maglodery. Adequate assessment requires a sequence of supramaximal stimuli with measure of several response latencies. These signals may be absent in diseases of compression affecting the anterior horn or peripheral nerve.

For lesions involving the peripheral motor or sensory fibers from L5/S1 or SI/S2, the Hoffman reflex may be used. A series of progressively increasing sub-threshold to supra-threshold stimuli are used to evaluate sensory and motor fiber responses.

Nerve conduction studies (surface or needle NCV): Motor nerves can be evaluated for site and severity of lesions from mechanical or pathological causes. Stimulation of major nerve trunks at a series of sites along their path can locate the region affected. Characteristic wave form and relative conduction velocity changes may also be important to differentiate between causes of nerve damage. Sensory nerve conduction is studied in a similar fashion.

Somatosensory evoked potentials (Surface or Needle SSEP): Similar to conduction velocities, these procedures stimulate the peripheral nerve either at accessible nerve trunks or by dermatomal sensory nerve endings. Responses may be monitored along the nerve pathway traversing the IVF, spinal cord, brainstem and cortex.

3. Electromyography

Kinesiologic studies: A surface measurement that monitors myoelectric volitional responses can be used to examine superficial layer muscle recruitment and fatigue. When calibrated against known exertional efforts, biomechanical estimates of muscle tensions for simple isometric tasks can be made. Clinical applications to the evaluation of spine related disorders has been proposed under the heading of surface paraspinal scanning EMG using either poststyle or adhesive tape-on electrodes.

**SURFACE VS. NEEDLE TECHNIQUES**

Electromyography is the technique of recording electrical potentials associated with muscular activity. Electrodes may be inserted in the muscle being monitored, or surface electrodes may be placed on the skin overlying the muscles being studied. Both techniques have been used in the examination of paraspinal and peripheral muscles. Needle techniques are frequently used to evaluate abnormalities in peripheral muscle activity. Such abnormalities may be due to spinal disease, nerve root involvement, peripheral nerve entrapment, or disease of the muscle itself. In contrast, surface techniques are most commonly employed in kinesiological studies, biofeedback applications, and chiropractic analysis. The following table summarizes the features of each technique:

**SURFACE ELECTRODES**

Record composite potentials of muscles working together.

Non-invasive; painless.

Easy to duplicate protocols for longitudinal studies.

Some high frequency loss.

No insertion potentials.

Very good test-retest reliability.

In summary, needle techniques are appropriate for the evaluation of specific muscles, while surface electrodes are appropriate for kinesiological studies of the "global" function of groups of muscles.

Cobb et al reported that pain was more likely to demonstrate change in surface electrode EMG activity than needle EMG potentials. They concluded that "...muscle spasm (even when mild) is accompanied by muscular hyperactivity which can be evaluated by suitable electromyographic techniques. Our data suggest that surface electrodes allow better sampling than Teflon coated needles..." and that "...integration procedures allow better quantification than does the visual evaluation of an EMG..." Komi and Buskirk compared the test-retest reliability of needle vs. surface electrode electromyographic measurements. The average test-retest reliability for surface electrodes was 0.88, compared to 0.62 for inserted electrodes. Spector conducted a study of the reliability of surface electrode paraspinal electromyography. Results of the study yielded correlation coefficients ranging between 0.73 and 0.97. Thompson et al of the Mayo Clinic found EMG scanning correlates highly with attached electrode technique. Surface techniques, therefore, appear superior to inserted electrode methods for longitudinal studies where case progress and care response are being evaluated.

**NORMATIVE DATA**

Cram has published normative data for paraspinal EMG potentials in pain and non-pain populations. His protocol was limited to scanning five sites. These sites were the cervical paraspinals, T-1, T-6, T-10, and L-3. In addition to calculating the mean, criteria for mild, moderate, and radical elevations are offered. The cutoff for mild elevation is the first standard deviation. For a moderate elevation, it is the second standard deviation. For a radical elevation, it is the third standard deviation. Test-retest reliability was also reported by Cram. The median for the correlation coefficients of EMG scans was .83.

In an effort to more specifically characterize paraspinal activity (Kent) developed a protocol for scanning 15 paraspinal sites. These include C-l, C-3, C-5, C-7, T-1, T-2, T-4, T-6, T-8, T-10, T-12, L-1, L-3, L-5, S-1. This protocol scans every other segmental level, plus the transitional areas of the spine.

Kent collected normative data using this protocol. A ProScan 2000 two channel EMO scanner was employed. This equipment has an input impedence of 1,000,000 megohms, and noise rejection exceeding 180 db. A bandwidth of 100-200 HZ. was employed. The preamplifier is mounted in the electrode assembly, eliminating the noise which may be induced in cables when the preamplifier is separate from the electrode assembly. The two channel system permits simultaneous recording of potentials on both sides of the spine.

Each electrode/preamplifier assembly has three silver/silver chloride electrodes in a triangular configuration. Two are active electrodes, and one is a ground reference electrode. By maintaining a constant distance between active and ground reference electrodes, artifacts caused by inconsistent electrode placement are minimized. During data collection, an electrode assembly applied to each side of the spine, approximately 1 cm lateral to levels scanned except C-1. At the C-l level, an electrode assembly is placed over each atlas transverse process, inferior to the mastoid process.

52 student volunteers at Palmer College of Chiropractic-West met the criteria for participation and were scanned. Prospective subjects were required to complete a questionnaire concerning back or neck pain which they had experienced. The prospective subjects were not advised of the criteria for selection when presented with the questionnaire. To be included in the normative population, a

subject had to be free of any back or neck pain of greater than 48 hours duration for a period of at least one year. The subjects selected ranged from 21-42 years of age. The mean age was 26.6 years. 33 subjects were males and 19 subjects were females.

The mean and standard deviation of the potentials at each site were calculated. Proprietary software incorporated into the ProScan 2000 EMG scanner compares the readings of a patient being examined with the normative data. This information can be incorporated into a printed report, and/or stored on a hard disk. In the analysis of paraspinal EMG potentials, two parameters are considered: amplitude (signal intensity) and symmetry (comparison of the left side to the right).

**PAIN AND PARASPINAL EMG ACTIVITY**

The relationship between altered paraspinal EMG potentials and pain has been explored by several investigators. Price et al reported that abnormal patterns of EMG activity were associated with areas of pain and tenderness in the back. It was suggested that these changes may have resulted from attempts by the patient to relieve pain by altering position.

Muscle tension backache is thought to be due to a "vicious cycle" of pain producing spasm, and spasm producing pain. Calliet states that increased involuntary muscle activity is an etiologic factor in chronic pain. Price et al suggested that splinting and tensing of muscles causes diminished blood flow resulting in ischemic pain. Muscle spasm appears to be a "common denominator" in a variety of myogenic pain syndromes including fibrositis, myalgis, and myofascial pain syndrome. Muscle spasm is accompanied by elevated EMG levels.

Although elevated potentials associated with spasm may be seen in patients with back pain, other investigators have found that symmetry of EMG potentials may also be clinically significant. Wolf et al reported that low back pain may result in low or asymmetrical EMG potentials, as well as elevated readings. Triano and Luttges described four types of EMG patterns considering both amplitude and symmetry. Kent and Hyde described low amplitude symmetrical readings and high amplitude asymmetrical readings in patients presenting for chiropractic care.

EMG CHANGES FOLLOWING ADJUSTMENT OR MANIPULATION

Ellestad et al studied the effect of manipulation on surface electrode electromyographic potentials in patients with low back pain and pain free controls. 20 subjects with low back pain of at least 2 weeks but no longer than six months duration were examined. The pain was localized in the erector spinae musculature between L-2 and S-1. 20 controls who denied any low back symptoms within the six months preceding the study were also examined.

Active EMG electrodes were placed 2 cm lateral to the spinous processes of L-3 and L-5. One electrode was placed on side of the spinous process of each level. A ground electrode was also applied to each patient. EMG recordings were made with each subject standing, prone, and in active lumbar extension.

High velocity low amplitude techniques were applied to 10 pain patients and 10 pain free subjects. The remaining 20 patients and controls received no care. The paraspinal EMG activity of those individuals receiving manipulation was significantly reduced. Further, the reduction in EMG potentials were noted as well in the pain free group, albeit to a lesser degree. No significant changes in paraspinal EMG activity were observed in the non-treatment groups.

Shambaugh conducted a pilot study where surface electrodes were used to measure paraspinal EMG activity before and after chiropractic adjustment. Shambaugh concluded, "Results of this study show that significant changes in muscle electrical activity occur as a consequence of adjusting."

**PARASPINAL EMG SCANNING AND VERTEBRAL SUBLUXATION**

Paraspinal EMG scanning may be useful in documenting the muscular dysfunction of the vertebral subluxation complex and monitoring the muscular responses of a patient to a course of chiropractic care. Traditional chiropractic philosophy defines the vertebral subluxation in terms of four criteria:

1. Loss of juxtaposition of a vertebra with the one above, the one below, or both
2. Occlusion of an opening
3. Impingement of nerve
4. Interference with the transmission of mental impulses.

A contemporary definition of the vertebral subluxation complex proposes at least five components:

1. Spinal Kinesiopathology
2. Neuropathology
3. Myopathology
4. Histopathology
5. Bio-chemical Changes/Pathology

Both definitions incorporate biomechanical and pathophysiological manifestations.

A number of procedures have been utilized in chiropractic practice to detect and evaluate vertebral subluxations:

A. To detect biomechanical changes

1. Postural analysis
2. Static palpation
3. Motion palpation
4. Static radiograph
5. Functional radiograph
6. Computed tomography
7. Magnetic resonance imaging

B. To detect neurophysiological changes

1. Orthopedic examination
2. Neurological examination
    a. Reflexes
    b. Muscle strength tests
    c. Dermatome examination
    d. Functional leg checks
3. Thermography
4. Electromyography.

The reliability of these procedures vary greatly. Some techniques, while potentially valuable to individual practitioners do not exhibit acceptable levels of test-retest reliability. The reliability of others may depend on the skill of the examiner and the protocols employed.

For decades, chiropractors were taught to explore the paravertebral muscles for "taut and tender" fibres surrounding areas of vertebral subluxation. Useful as such techniques may be in clinical

practice, they are subject to charges of subjectivity. It has been proposed that surface electrode EMG scanning may be used to monitor patient progress under chiropractic care, to determine the severity of myospasm, and to quantify muscular activity.

**INDICATIONS**

Gentempo and Kent published specific indications for paraspinal EMG scanning in chiropractic practice. The test is indicated if any three of the following are present:

1. Palpable paraspinal muscle spasm.

2. Palpable asymmetry of the paraspinal muscles.

3. Asymmetrical range(s) of motion.

4. Paraspinal muscle tenderness (pain on pressure).

5. Paraspinal pain reported by patient.

6. History of trauma to the spine.

7. Diagnosis of nerve root irritation evidenced by abnormal neurological examination findings.

8. Clinical presentation of an antalgic gait or lean.

9. Diminished or asymmetrical paraspinal muscle strength demonstrated by manual or electronic muscle testing.

10. Thermographic evidence of paraspinal muscle dysfunction.

**CONCLUSION**

Surface electrode paraspinal EMG scanning is an accepted clinical tool to evaluate the changes in paraspinal muscle activity frequently encountered in chiropractic. It is a means of quantifying palpation findings, and as a tool in single patient time series case studies. Longitudinal studies to determine patient response to chiropractic care represent another potential area for clinical research. Further, paraspinal EMG scanning appears useful in detecting areas of muscle spasm. Like any diagnostic tool, paraspinal EMG scan data must be correlated with other clinical findings, and cannot be relied upon as the sole basis for a chiropractic diagnosis.

**OTHER INSTRUMENT MEASURES**

Several other types of examining instruments are in use within the chiropractic profession. As none of these are widespread, only the fundamentals of their use will be described.

1. Non-invasive vascular measures

   Both plethysmography and doppler ultrasonic measures allow objective evaluation of vascular disorders by quantifying segmental limb blood pressures, velocities or pulse wave forms.

Doppler ultrasound:

Doppler ultrasound is the most simple and versatile method available for screening examinations of suspected vascular disease of the peripheral vessels; however, doppler spectral analysis (Duplex scanning) is more accurate for cerebrovascular and visceral arterial disease.

For lower extremity claudication, doppler will identify significant occlusive arterial disease with a high degree of reproducibility. Special procedures of value include the ankle/arm index and lower extremity, multi-segmental pressure analysis. The latter examines for a pressure gradient greater than 3 mm Hg across appropriate intervals (200). Hemodynamic deficit may be further evaluated using hyperemia procedures.

## IV. RECOMMENDATIONS

All recommendations are made based upon the assumption that the operator/examiner is appropriately trained, versed in the technical issues affecting the qualities of safety, validity, discriminability, accuracy, precision and reliability of the measures. Standardized test protocols and periodic instrument calibration is important to ensure clinical utility of the information. Interpretation should be made by the attending clinician in all cases.

### Perceptual Measurements

A. Questionnaires as Instruments

Questionnaire instruments are safe and effective. Several instruments have been fully validated, are widely used and well established. Their use is supported by both Class I (modified to the discipline of measurement) and Class II evidence.

16.1.1 **Rating**: Established
Strength **Level** Type A.

B. Screening Questionnaire

Their use is safe and effective, supported by Class II and III evidence.

16.2.1 **Rating**: Established
Strength Type C.

C. Algometer (pain pressure threshold)

Manually applying pressure into the spinal and paraspinal tissues to produce tenderness in support of vertebral subluxation and other malpositioned articulations and structures analysis has been used nearly since the chiropractic profession began. A Pressure Pain Threshold meter yields a measurement when the recipient feels a change from pressure to tenderness as it produces mechanical irritation of the deep somatic structures. Fisher has shown that pressure pain thresholds are highly symmetrical. Reliability coefficients were shown to be 0.71 to 0.97 by Reeves et al. It has been shown to be very useful in measuring change in paraspinal tissue tenderness following spinal adjustments.

16.3.1. **Rating**: Established
Evidence: E, L, C

### FUNCTIONAL MEASUREMENTS: SPINAL KINESIOPATHOLOGY

A. Measurement of position/Clinical Anthropometric (Posture)

1. Electrogoniometry (e.g., Metrecom)

The electrogoniometer (EGM) - EGM is a computerinterfaced, electromechanical device which quantifies the location of points in three dimensional space and then calculates various numerical descriptors of postural alignment. The EGM has been found to be reliable and valid in measuring lines in inanimate objects and found to be more reliable than the manual goniometer for measuring joint range-of-motion. The EGM has been found to be accurate and reliable in determining leg lengths. Adams et al found that the intra and inter-examiner reliability of the EGM for plumb line postural analysis was very high for specific and general postural measurements. Wagnon reports that the instrument is reliable for measuring skeletal-muscular parameters, subject only to the skill of the operator in locating anatomical landmarks.

16.4.1 **Rating**: Established
Evidence: E, L, C

2. Inclinometry

An inclinometer is a hand-held device that uses the constant vertical component of gravity as a reference and yields a measure of motion when held against the area being motion tested. Accuracy has been shown to be within 3 to 5 degrees.

16.4.2. **Rating**: Established
Evidence: E, L, C

3. Goniometry

A goniometer is a large protractor that may be held in the proximity of the area being motion tested to provide a means by which to determine degrees of motion. A 10-15 degree of accuracy is common. Due to its lack of accuracy and reliability, the Goniometer has been largely replaced by the Inclinometer.

16.4.3. **Rating**: Established
Evidence: E, L, C

4. Optically Based Systems

Optically based systems are established for evaluating specific gait abnormalities or risky positions related to work tasks. They are safe and effective when evaluated by specially trained personnel and are supported by Class II evidence.

16.4.4. **Rating**: Established
Strength Type B

B. Muscle strength testing

Many chiropractic techniques utilize manual muscle testing for evaluation of vertebral subluxation. These techniques typically use manual muscle testing for the purpose of vertebral subluxation and other malpositioned articulations and structures analysis and are typically limited to gross bilateral differences in patient resistance or a virtually total lack of resistance that is easily detectable by the experienced practitioner. Manual and mechanized muscle testing may also be used to demonstrate subtle changes in muscle strength as a result of

nerve function.

1. Manual - Manual evaluation of muscle strength gives only an approximation of capability. One reference indicates that a difference of 35% in muscle strength must exist to be detected by manual testing.

16.5.1. **Rating**: Established
Evidence: E, L

2. Hand-held (Dynamometer) - The dynamometer is a hand-held device which produces greater reliability and accuracy than manual testing.

6.5.2. **Rating**: Established
Evidence: E, L

3. Modular - Isometric (e.g., Dynatron 2000, myo-logic), Isokinetic, Isoinertial.

16.5.3. **Rating**: Established
Evidence: E, L

**Physiologic and Electrophysiologic Measurements**

A Temperature reading devices

Highly significant temperature changes have been noted in spinal and paraspinal tissues following a chiropractic adjustment. Hand-held thermographic devices "have been evaluated and shown to have moderate to excellent inter-examiner reliability over short time durations."

Early chiropractic investigators recognized three basic physiological concepts that underlie the value of cutaneous thermography:

- the body is segmented into "dermatomes";
- side-to-side skin temperatures are generally symmetrical unless dysfunction exists; and
- any anomalous deviation from a gradually increasing paraspinal skin temperature from S-2 to C-1 may be indicative of the vertebral subluxation and other malpositioned articulations and structures or other dysfunction.

1. Thermocouple: The use of thermocouple instrumentation in chiropractic practice is well established.
2. 
   a. Single-channel (e.g., chirometer)

   b. Dual-channel (e.g., Neurocalograph (NCGH), Thermoscribe, Analograph)

   The dual probe devices give a bilateral comparative temperature reading of the paraspinal tissues. However, the instrument requires skin contact.

16.6.1. **Rating**: Established
Evidence: E, L

2. Infrared Thermography

Infrared instruments detect and record changes in temperature rapidly and require no skin contact, and are relevant to chiropractic practice.

1. Single-channel (dermathermagraph) double-channel (e.g., Accolade, Tytron C-2000, VT 2000)

16.6.2. **Rating**: Established
Evidence: E, L

B. Multi(channel (e.g., Visitherm II)

16.7.1 **Rating**: Established
Evidence: E, L

C. Cryogenic-cooled detector thermal imaging cameras (Inframetrics, Agema, Mikron)

"A thermogram provides a graphic representation of neural fiber irritation by demonstrating a change in the thermal regions, innervated by that particular nerve."

16.8.1 **Rating**: Established
Evidence: E, L

D. Current Perception Threshold Devices (e.g., neurometer)

The current perception threshold device is a variable constant current sine wave stimulator proposed as a simple non-invasive and quantitative measure of peripheral nerve function. The neurometer has been shown to be appropriate for rapid screening for neural dysfunction.

16.9.1 **Rating**: Established
Evidence: E, L

E. Electroencephalography (EEG)

Standard EEG and computerized EEG, also known as brain mapping, have been shown to be useful in chiropractic patient management and document the effectiveness of chiropractic care..

16.10.1. **Rating**: Established
Evidence: E, L

F. Tissue compliance measurements

The tissue compliance instruments measure soft tissue consistency or compliance. Caution should be used in interpreting pre- and post-adjustment readings based on information which has shown that 26% of readings taken ten minutes following initial testing were significantly different without any intervention. A bilateral difference of greater than 2mm at 2 kg is significant and suggests pathological asymmetry.

16.11.1. **Rating**: Established
Evidence: E, L

2. Surface electromyography (EMG) is the technique of collecting and recording the electrical activity of the muscles.

Surface EMG, also known as "scanning" or "kinesiologic" EMG, employs a self-contained, hand-held electrode assembly connected to a computerized system that measures electrical potentials associated with the muscle in question. Electrodes are placed over the muscle in question. It enables scanning of paraspinal muscles over several vertebral levels. Very good test-retest reliability has been shown due to ease of duplicating protocols for longitudinal studies. Protocols and normative data for paraspinal EMG scanning in the chiropractic practice have been suggested by Kent & Gentempo. The same authors have found that Surface EMG potentials are substantially higher in children than in adults. Gentempo reported that "electromyographic findings were consistent with the clinical and radiographic manifestations of subluxation and myospasm." Significant changes in surface EMG potentials have been shown after a chiropractic adjustment.

16.11.2 **Rating**: Established
Evidence: E, L, C

H. Surface Electrodiagnostic procedures (NCV, F-Wave, H-Reflex, SSEP)

Surface electrodiagnostic procedures (NCV, F-wave, H-reflex, SSEP) are established procedures effective for examination of peripheral nerve disorders and are supported by Class I and Class II evidence. Somatosensory evoked potentials are established for limited applications to peripheral nerve disorders and lesions affecting the long sensory tracks of the spinal cord.

16.12.1. **Rating**: Established
Strength Type A

I. Other Instrument Measures

1. Spirometry

Pulmonary function testing is established as a method to assess effect of severe scoliosis and the differential diagnosis of lung disease. These uses are backed by Class I and Class II evidence. The procedures are safe and effective when performed by appropriately trained personnel.

16.13.1. **Rating**: Established
Strength Type A

## V. COMMENTS

Instrumentation has been used in chiropractic nearly since its inception in 1895. Many advances in the accuracy and usefulness of the instruments have taken place. The use of instrumentation provides a scientific basis for analysis and outcome assessment in chiropractic practice. Due to advances that have been made in instrumentation germane to the analysis of vertebral subluxation the past decade, it is anticipated that the contents of this chapter will require periodic updating.

## VI. REFERENCES

Adams A, Lopez D, Wild S, Lawless P, Loucks J: Intra- and Inter-examiner reliability of plumb line posture analysis measurements using a three dimensional electrogoniometer. *Res for* 1988, 4(3):60-72.

Agarwal A, Lloyd EN, Dovey P: Thermography of the spine and sacroiliac joints in spondylitis. *Rheum Phys Med* 1970, 10:349.

Ahern DK, Follick MJ, Council JR, Laser-Wolston N: Reliability of lumbar paravertebral EMG assessment in chronic low back pain. *Arch Phys Med Rehabil* 1986, 67:762.

Ahern DK, Follick MJ, Council JR, Laser-Wolston N, Litchman H: Comparison of lumbar paravertebral EMG patterns in chronic low back pain patients and non-patient controls. *Pain* 1988; 34:153.

Albanese AA: Calcium nutrition in the elderly: maintaining bone health to minimize fracture risk. *Postgrad Med* 1978, 63:167.

Andersson G, Jonsson B, Ortengren R: Myoelectric activity in individual lumbar erector spinae muscles in sitting. A study with surface and wire electrodes. *Scand J Rehab Med* 1974 Supl; 3:91.

Ayoub MA: Ergonomic deficiencies: I. Pin at work. *I Occup Med* 1990, 32:52.

Ayoub MA: *Design of a pre-employment screening program*, In: Kvalseth TO (ed). *Ergonomics of workstation design*, London: Butterworths, 1983. 152-8.

Ayres SM: *Pulmonary function studies*. In: Holman CW, Muschenheim C (eds): *Bronchopulmonary diseases and related disorders*, Hagerstown: Harper & Row, 1972.

Baillie AH, Biagioni PA, Forsyth A, Garioch JJ: Thermographic assessment of patch-test responses. *Br J Dermatol* 1990, 122:351.

Baltzopoulos V, Brodie DA: Isokinetic dynamometry applications and limitations. *Sports Med* 1989, 8:101.

Barbee, JA, Nron, BJ: *Reliability and validity of the metrecom for measuring inanimate objects.* Presented at the 1988 CPA/APTA Joint Annual Meeting, Las Vegas, NV June 1988.

Barlow DH, Hayes S, Nelson R: *The Scientist Practitioner: Research and Accountability in Clinical and Educational Settings*, New York: Pergamon Press, 1984, 112-124.

Basmajian JV: *Muscles alive*, Baltimore: Williams and Wilkins Co., 1979.

Beasley WC: Influence of method on estimates of normal knee extensor force among normal and postpolio children. *Phys Ther* 1956.

Beimborn DS, Morrissey MC: A review of the literature related to trunk muscle performance. *Spine* 1988, 13:655.

Bergofsky EH, Turino GM, Fishman AP: Cardiorespiratory failure in kyphoscoliosis. *Medicine* 1959, 38:263.

Bergstrom E, Courtis G: An inter- and intra-examiner reliability study of motion palpation in lateral flexion in the seated position. *Euro J Chiro* 1986, 34:121.

Bjure J, Grimby G, Kasalicky J, Lindh N, Nachemson A: Respiratory impairment and airway closure in patients with untreated idiopathic scoliosis. *Thorax* 1970, 25:451.

Bohannan RW: Hand-held dynamometry; stability of muscle strength over multiple measurements. *Clinical Biomech* 1986, 2:74.

Bolecek C, Steiner C, Guzelsu N: *Evaluation of conservative treatment of low-back pain via electromyography and pain quantification*. In: *Electromyographic Kinesiology Excerpta Medica*, New York: 1990, 191-194.
Boline P, Keating J, Brist J, Denver G: Inter-examiner reliability of palpatory evaluations of the lumbar spine. *Am J Chiro Med* 1988, 1(1):5.

Brand W, Gizoni C: Moire contouragraphy and infrared thermography: changes resulting from chiropractic adjustments. *J Manip Physio Ther* 1982, 113-116.

Braunwald E, Isselbacher KJ, Petersdorf RG, Wilson JD, Martin JB, Fauci AS (eds): *Harrison's principles of internal medicine*, New York: McGraw-Hill, 1987.

Brown WF: *The physiological and technical basis of electromyography*, Boston: Butterworth, 1984.

Brown WF RW: Hand-held dynamometry; stability of muscle strength over multiple measurements. *Clinical Biomech* 1986, 2:74.

Bullock-Saxton J, Janda V, Bullock M: Reflex activation of gluteal muscles in walking: an approach to restoration of muscle function patients with low back pain. *Spine* 1993, 18(6):704.

Busse EW: How mind, body, and environment influence nutrition in the elderly. *Postgrad Med* 1978, 63:118.

Byl NN, Richards S, Asturias J: Intrareter and interrater reliability of strength measurements of the biceps and deltoid using a hand held dynamometer. *J Orthop Sports Phys Ther* 1988, 9:399.

Caliendo MA, Sanjur D. Wright J, Cummings G: Nutritional status of preschool children. *J Am Diet Assoc* 1977, 71:20.

Calliet R: *Soft tissue pain and disability*, Philadelphia: F A Davis, 1977.

Calliet R: *Low back pain syndrome,* ed 3. Philadelphia: F A Davis, 1977.

Cassidy J, Potter G: Motion examination of the lumbar spine. 1979, 2 (3):151.

Chafetz N, Wexler CI, Kaiser JA: Neuromuscular thermography of the lumbar spine with CT correlation. *Spine* 1988, 13:922.

Chaffin D: Ergonomics guide for the assessment of human static strength. *AM Ind Hyg Assoc J* July 1975, 505-511.

Chaffin DB, Anderson GBJ: *Occupational 1987*, New York: Biomechanics, Wiley Interscience Publishers, 1988, 117-122.

Chang L, Abernathy N, O'Rourke D, Dittberner N, Robinson C: The evaluation of posterior thoracic temperatures by telethermography, thermoocouple, thermistor and liquid crystal thermography. *Therm* 1985, 1:95-101.
Christiansen J, Gerow G: *Thermography*, Baltimore: Williams & Wilkins, 1990.

Cobb CR, DeVries HA, Urban RT, Luekens CA, Bragg RJ: Electrical activity in muscle pain. *Am J Phys Med* 1975, 54(2):80

Coggins WN: *Basic Techniques and Systems of Body Mechanics*, Florrissant: Elco, 1975.

Cohen HL, Brumlik JD: *Manual of Electroneuromyography*, 2nd ed, Hagerstown: Harper & Row, 1976.

Collins GA, Cohen MJ, Neliboff BD, Shandler SL: Comparative analysis of paraspinal and frontalis EMG, heart rate and skin conductance in chronic low back pain. *Scand J Rehabil Med* 1982, 14:39.

Cooper P, Randall WC, Hartzman AB: Vascular convection of heat from active muscle to overlying skin. *J Appl Physiol* 1959, 14:207.

Cram J: *Clinical EMG: Muscle scanning for surface electrodes*, Seattle: Biofeedback Institute of Seattle, 1986.

Cram Jr, Lloyd J, Cahn TS: The reliability of EMG muscle scanning. *Int J Psychosomatics* 1994, 41:41.

Davis D: Respiratory manifestations of dorsal spine radiculitis stimulating cardiac arrythmia. *Ann Intern Med* 1950, 32:954.

DeBois EF: *The mechanism of heat loss and temperature regulation*, Stanford: Stanford University Press, 1937.

Desmedt J (ed): *New developments in electro-myography and clinical neurophysiology*, New York: S. Karger, 1973.

Deyo R: Measuring the functional status of patients with low-back pain. *Chiropractic Technique* 1990, 2930:127-136.

Diakow PR: Thermographic imaging of myofascial trigger points. *Manip Physiol Ther* 1988, 11:114.

Dolan P, Mannion AF, Adams MA: Fatigue of the erector spinae muscles. A quantitative assessment using frequency banding of the surface electromyography signal. *Spine* 1995; 20(2):149.

Donaldson S, Donaldson M: Multi-channel EMG assessment and treatment tecxhniques. In Cram J (ed) *Clinical EMG for Surface Recordings: Volume 2*. Clinical Resources. Nevada City, CA 1990.

Dotson, LR, Luithens CA: *A comparison between a standard manual goniometer and the metrecom skeletal analysis system*, Presented at the South Florida Physical Therapy Association Meeting, North Miami Beach, FL; April, 1988.

Dowling JJ, Kennedy SR: *The quantitative assessment of EMC cross talk in human soleus and gastrocnemius muscles*, Thirteenth annual meeting of the American Society of Biomechanics. Vermont, August, 1989.

Duensing F, Becker P, Rittmeyer K: Thermographic findings in lumba disc protrusions. *Arch Psychiatr Nervenkr* 1973, 217:53.

Dye AA: *The evolution of chiropractic*, Prentice Hall, 1939.

Ebrall, PS: A chiropractic screening health questionnaire: A pilot study concerned with quality standard of practice. *J Aust Chiropractor's Assoc* 1990; 20:122-8.

Ebrall PS, Iggo A, Hobson P, Farrant G: Preliminary report: the thermal characteristics of spinal levels identified as having differential temperature by contact thermocouple measurement (Nervo-scope). *Chiropractic Journal of Australia* 1994; 24(4):139.

Edwards R, Hyde S: Methods of measuring muscle strength and fatigue. *Physiotherapy* 1977, 63:51.

Eisen A, Schomer D, Melmed C: An electrophysiological method for examining lumbosacral root compression. *Can J Neurol Sci* 1977, 4:117.

Ellestad S, Nagle R, Boesler D, Kilmore M: Electromyographic and skin resistance responses to osteopathic manipulative treatment of low back pain. *JAOA* 1988, 88(8) 1991.

Feldman F, Nickoloff: Normal thermographic standards for the cervical spine and upper extremities. *Skeletal Radiol* 1984, 12:235-249.

Figar S, Krausova L: A plethysmographic study of the effects of chiropractic treatment in vertebrogenic syndromes. *ACTA Univ Caro Med (Suppl)* 1965, 21:84.

Figar S, Krausova L, Levit K: Plethysmographic examination following treatment of vertebrogenic disorders by manipulation. *ACTA Neurove* 1967, 29:618.

Fisher AA: Pressure algometry over normal muscles: Standard values, validity and reproducibility of pressure threshold. *Pain Vol* 1, 115-126, 1989.

Fisher AA: Pressure threshold meter: Its use for quantification of tenderspots. *Arch Pys Med Rehab*, Vol 67 #11, 836-838, 1986.

Fisher AA: Tissue compliance meter for objective documentation of soft tissue consistency and pathology. *Arch Phys Med Rehabil* 1987, 68:122-25.

Fisher AA: Clinical use of tissue compliance meter for documentation of soft tissue pathology. *Clin J Pain* 1987, 3:23-30.

Fisk JW: *A Practical Guide to Management of the Painful Neck and Back: Diagnosis, Manipulation, Exercises*, Prevention. Springfield: Charles C. Thomas, 1977, 10.

Frank GC, Voors AW, Schilling PE, Berenson GS: Dietary studies of rural school children in a cardiovascular survey. *J Am Diet Assoc* 1977, 71:31.

Freedman S: *Design of respiratory circuits and spirometry*. In: Laszk G, Sudlow MF (eds): *Measurement in clinical respiratory physiology,* London: Academic Press, 1983.

Freeman MO: *Rubbing Plate: Summary of Device and Mechanics of Use*, Portland, OR.

Frese E, Brown N, Norton B: Clinical reliability of manual muscle testing. Middle trapezius and gluteus medius muscles. *Phys Ther* 1987, 67(7): 1072-1076.

Fronk A, Coel N, Bernstein E: The importance of combined multisegmental pressure and doppler flow velocity studies in the diagnosis of peripheral arterial occlusive disease. *J Surg* 1978, 84: 840-847.

Fuhrer MJ: Effects of stimulus site on the pattern of skin conductance responses evoked from spinal manipulation. *J Neurol Neurosurg Psychiatr* 1975, 38:749.

Gemmell H, Jacobson B, Heng B: Effectiveness of toftness sacral apex adiustment in correcting fixation of the sacroiliac joint. A preliminary report. *Am J Chiro Med* 1990, 3(1):5-8.

Gemmell H, Jacobson B, Edwards S, Heng R: Interexaminer reliability of the electromagnetic radiation receiver for determining lumbar spinal joint dysfunction in subjects with low back pain. *J Manip Phys Ther* 1990, 13(3):134-37

Gentempo P, Kent C: Establishing medical necessity for paraspinal EMG scanning. *Journal of Chiropractic Research and Clinical Investigation* 1990; (3)1:22.

Gerow G, Callton N, Meyer JJ, Demchak JJ, Christiansen J: Thermographic evaluation of rats with complete sciatic nerve transection. *J Manip Physiol Ther* 1990, 13:257.

Gillette RG: A speculative arguement for the coactivation of diverse somatic receptor populations by forceful chiropractic adjustments. *Man Med* 1987, 3:1.

Giroux B, Lamontagne M: Comparisons between surface electrodes and intramuscular wire electrodes in isometric and dynamic conditions. *Electromyogr Clin Neurophysiol* 1990, 30:397.

Gleim GW, Nicholas JA, Webb JN: Isokinetic evaluation following leg injuries. *Phys Sportsmed* 1978, 68:74.

Goldman SR: A structural approach to bronchial asthma. *Bull Euro Chiropr Union* 1972, 21:66.

Gomez T, Beach G, Cooke C, Hrudey W, Goyert P: Normative database for trunk range of motion, strength, velocity, and endurance with the isostation B-200 lumbar dynamometer. *Spine* 1991, 16:15.

Gonella C, Paris S, Kutner M: Reliability in evaluating passive intervertebral motion. *Phys Ther* 1982, 62(4):436.

Goodman PH, Murphy MG, Siltanen GL, Kelley NP, Rucker L: Normal temperature asymmetry of the back and extremities by computer-assisted infrared imaging. *Therm* 1986, 1:195-202.

Green J, Coyle M, Becker C, Reilly A: Abnormal thermographic findings in asymptomatic volunteers. *Therm* 1986, 2:13-15.

Halberg F: Chronobiology. *Annu Rev Physiol* 1969, 31:675.

Haldeman S: The electrodiagnostic evaluation of nerve root function. *Spine* 1984, 9(1):42-48.

Hazard RG, Bendix A, Fenwick JW: Disability exaggeration as a predictor of functional restoration outcomes for patients with chronic low-back pain. *Spine* 1983, 8:141.

Hazard RG, Fenwick JW, Kalish SM, Redmond J, Reeves V, Reid S, Frymoyer JW: Functional restoration with behavioral support. A one-year prospective study of patients with chronic low-back pain. *Spine* 1989, 14:157.

Hazard RG, Reid S, Fenwick J, Reeves V: Isokinetic trunk and lifting strength measurements: Variability as an indicator of effort. *Spine* 1988, 13:54.

Head MK, Weeks RJ, Girbbs E: Major nutrients in the type A lunch. *J Am Diet Assoc* 1973, 63:620.

Herzog W, Bigg B, Real L, Olsson E: Asymmetries in ground reaction force patterns in normal human gait. *Med Sci Sports Exerc* 1989, 21(1):110-114.

Hildebrandt RW: *Chiropractic Spinography: a Manual of Technology and Interpretation*, Des Plaines: Hilmark Publication, 1977.

Hill FW: The phytogenesis and clinical import of the sacroiliac mechanism. *J Can Chiropr Assoc* 1965, 9:9.

Hoppenfeld S: *Scoliosis: A manual of concept and treatment*, Philadelphia: Lippincott, 1967.

Houdas Y, Guieu JD: Environmental factors affecting skin temperatures. *Bibl Radiol* 1974, 6:157.

Hoyt WH, Hunt HH, DePauw MA et al: Electromyographic assessment of low back pain syndrome. *JAOA* 1981, 80:728.

Hsieh CY, Phillips RB: Reliability of manual muscle testing with a computerized dynanometer. *Transactions of the PCCR*, June 1988.

Hubbard JE, Hoyt C: Pain evaluation by electronic infrared thermography: correlations with symptoms, EMG, Myelogram and CT scan. *Therm* 1985, 1:26-35.

Huskisson EC, Berry H, Browett J, Wykeham Balme H: Measurement of inflammation. *Ann Rheum Dis* 1973, 32:99.

Illi FW: The phylogenesis and clinical import of the sacroiliac mechanism. *J Can Chiropr Assoc* 1965, 9:9.

Jabre JF, Hackett ER: *EMG manual*, Springfield: Thomas, 1983.

Jacobs I, Bell DG, Pope J: Comparison of isokinetic and isomertial lifting tests as predictors of maximal lifting capacity. *Europ J Appl Physiol Occup Physiol* 1988, 57:146.

Jalovaara P, Niinimaki T, Vanharanta H: Pocket-size, portable surface EMG device in the differentiation of low back pain patients. *Eur Spine J* 1995, 4:(4):210.

Jamison JR: Dietary intervention in the clinical prevention of ischemic heart disease. *J Manip Physiol Ther* 1990, 31:247.

Jamison JR: Dietary control of mild essential hypertension. *J Manip Physiol Ther* 1987, 10:101.

Jansen R, Nansel D, Siosberg N: Normal paraspinal tissue compliance: the reliability of a new clinical and experimental instrument. *Manip Physiol Ther* 1990, (13)5:243-146.

Jiang BC, Smith JL, Ayoub MM: Psychophysical modelling of manual materials-handling capacities using isoinertial strength variables. *Hum Factors* 1986, 28:691.

Jiang BC, Smith JL, Ayoub NM: Psychophysical modelling for combined manual materials-handling activities. *Ergonomics* 1986, 29:1173.

Jones CH: Physical aspects of thermography in relation to clinical techniques. *Bible Radiol* 1974, 6:1.

Jones A, Wolf S: EMG Biofeedback training during movement. *Phys Ther* 1980, 60, 1:58.

Jowsey J: Osteoporosis. *Postgrad Med* 1976, 60:75.

Jull G, Bullock M: A motion profile of the lumbar spine in an aging population assessed by manual examination. *Physiotherapy Practice* 1987, 3:70.

Kannus P: Ratio of hamstring to quadriceps femoris muscles' strength in the anterior cruciate ligament insufficient knee. Relationship to long-term recovery. *Phys Ther* 1988, 68:961.

Karpman HL, Knebel A, Semel CJ, Cooper J: Clinical studies in thermography: II. Application of thermography in evaluating musculoligamentous injuries of the spine - a preliminary report. *Arch Environ Health* 1970, 20:412.

Katems JJ, et al: Constant current sine wave transcutaneous nerve stimulation for evaluation of peripheral neuropathy. *Arch Phys Med Rehabil* 1987, 68:210-213.

Katems JJ, et al: Current perception threshold: Repeatability and comparison with nerve conduction in evaluation of carpal tunnel syndrome. *Trans Am Soc Artif Int Organs* 1989, 35:280-284.

Keating J: *Inter-examiner reliability of motion palpation of the lumbar spine: a review of the quantitative literature*, Proceedings of the Scientific Symposium on Spinal Biomechanics. International Chiropractors Association. May 19-21, 1989.

Kent C, Gentempo P: Protocols and normative data for paraspinal EMG scanning in chriorpactic practice. *Journal of Chiropractic Research and Clinical Investigation* Oct 1990, 6(3):64.

Kent C, Gentempo P: Dynamic paraspinal surface EMG: a chiroprctic protocol. *Chiropractic Research Journal* 1993 2(4):40.

Kent C, Gentempo P: Normative data for paraspinal surface electromyographic scanning using a 25-500 Hz bandpass. *Journal of Vertebral Subluxation Research* 1996; 1(1):43.

Khalil TM, Goldberg XL, Asfour SS, Moty EA, Rosomoff RS, Rosomoff HL: Acceptable maximum effort (AME) a psychophysical measure of strength in back pain patients. *Spine* 1987, 12:372.

Kibler WB, Chandler TJ, Uhl T, Maddux RE: A musculoskeletal approach to the preparticipation physical examination. Preventing injury and improving performance, *Am J Sports Med* 1989, 17:525.

Kieffer JD: Laboratory procedures in the low-back syndrome. *ACA J Chiropr* 1965, 2:17.

Kimura J: *Electrodiagnosis in diseases of nerve and muscle*, Philadelphia: FA Davis, 1985.

Kohrs NB, O'Neil R, Preston A, Eklund D, Abrahams O: Nutritional status of elderly residents in Missouri. *Am J Clin*

*Nutri* 1978, 31:2186.

Komi P, Buskirk E: Reproducibility of electromyographic measurements with inserted wire electrodes and surface electrodes. *Electromyography* 1970, 10:357.

Kravitz E, Moore ME, Glaros A: Paralumbar muscle activity in chronic low back pain. *Arch Phys Med Rehabil* 1981, 62:172.

Kritchevsky D: How aging affects cholesterol metabolism. *Postgrad Med* 1978, 63:133.

Kroemer K: Testing individual capability to lift materials. Repeatability of a dynamic test compared with static testing. *J Safety Res* 1985, 16:1.

Kroemer KHE: An isoinertial technique to assess individual capacity. *Hum Factors* 1983, 25:493.

Kvalseth TO (ed.): *Ergonomics of Workstation Design,* London: Butterworths, 1983.

Kyneur JS, Bolton SP: Chiropractic instrumenttion: an update for the >90s. *Chiropractic Journal of Australia* (Sept 1991) 21(3):82.

Lakomy HKA, Williams C: Measurement of isokinetic concentric and eccentric muscle imbalance. *Int J Sports Med (Suppl)* 1984, 5:40.

Langrana NA, Lee CK, Alexander H, Mayott CW: Quantitative assessment of back strength using isokinetic testing. *Spine* 1984, 9:287.

Lilienfeld A, Jacob M, Willis M: Study of the reproducibility of muscle testing and certain other aspects of muscle scoring.

Lofland KR, Mumby PB, Cassisi JE, et al: Assessment of lumbar EMG during static and dynamic activity in pain-free normals: implications for muscle scanning protocols. *Biofeedback and Self-Regulation* 1995; 20(1):3.

Love R, Brodeur R: Inter-and intra-examiner of reliability of motion palpation for the thoracolumbar spine. *JMPT* 1987; 10(1)1.

Ludin HP: *Electromyography in practice*, Stuttgart: George Thieme Veriag, 1980.

Masson EA, VBeves A, Fernando D, Boulton AJM: Current perception threshold: a new quick and reproducible method for the assessment of peripheral neuropathy in diabetes mellitus. *Diabetologia* 1989, 32:724-728.

Mayer TG, Smit SS, Keeley J, Hooney V: Quantification of Lumbar function. Part 2: Sagittal plane trunk strength in chronic low-back pain patient. *Spine* 1985, 10:765.

Mayer TG, Gatchel RJ, Kishino N, Keeley J, Mayer H, Capra P, Mooney V: A prospective short-term study of chronic low-back pain patients utilizing novel objective functional measurement. *Pain* 1986, 25:53.

McNeil T, Warwick D, Anderson G, Schultz A: Trunk strengths in attempted flexion, extension, and lateral bending in healthy subjects and patients with low-back disorders. *Spine* 1980, 5:529.

Meyer JJ, Anderson AV, Berk RJ: The flexion-rexlaxation phenomenon: does it exist in the cervical spine? *Proceedings of the 1990 International Conference on Spinal Manipulation.* FCER, Arlinton VA.

Miller-Brown H, Mellenthin N, Miller R: Quantifying human muscle strength, endurance, and fatigue. *Arch Phys Med Rehab* 1986, 76:530.

Miller D: Comparison of electromyographic activity in the lumbar paraspinal muscles of subjects with and without chronic back pain. *Phys Ther* 1985, 65, 9:1357.

Mills GH, Davies GX, Getty CJ, Conway J: The evaluation of liquid crystal thermography in the investigation of nerve root compression due to lumbosacral lateral spinal stenosis. *Spine* 1986, 11:427.

Mira AJ, Markely K, Greer RB III: A critical analysis of quadriceps function after femoral shaft fracture in adults. *J Bone Joint* Surg 1980, 62A:61.

Mitchell FL, Pruzzo NL: Investigation of voluntary and primary respiratory mechanism. *J Am Osteopath Assoc* 1971, 70:1109.

Munroe HN, Young VR: Protein metabolism in the elderly: observations relating to dietary needs. *Postgrad Med* 1978, 63:143.

Niebuhr BR, Marion R: Detecting sincerity of efforts when measuring grip strength. *Am J Phys Med* 1987, 66:16.

Nunn KD, Mayhew JL: Comparison of three methods of assessing strength imbalances at the knee. *J Orthop Sports Phys Ther* 1988, 10:134.

O'Donovan D: The possible significance of scoliosis of the spine in the causation of asthma and allied allergic conditions. *Am Allergy* 1951, 9:184.

Palmer DD: *The Science, Art, and Philosophy of Chiropractic*, 1910.

Palmer BJ: *Precise posture spinograph comparative graphs*, Davenport, IA: Palmer School of Chiropractic Press, 1938.

Parnianpour M, Li F, Mordin M, Kahanovitz N: A database of isoinertia strength test against three resistance levels in sagittal, frontal, and transverse planes in normal male subjects. *Spine* 1989, 14:409.

Peneff AL, Nansel DD, Jansen RD, Cooperstein R: Inter and intra-examiner reliability with respect to the detection of right left joint play asymmetries in the cervical spine. *Transactions of the PCCR* June 1988.

Perelman RB, Adler D, Humphreys N: *Reflex sympathetic dystrophy. A thermographic evaluation*, Acad. Neuromuscular Therm Clin Proceedings. Orlando, FL, Sept 1986.

Plaugher G, Lopes N, Melch P, Cremats E: The Inter- and intra-examiner reliability of a paraspinal skin temperature differential instrument. *J Manip Physiol Ther* 14(6)361-367.

Pochaczevsky R: Thermography in posttraumatic pain. *Am J Sport Med* 1987, 15:243.

Pollock ML, Leggett SH, Graves JE, Jones A, Fulton M, Cirulli J: Effect of resistance training on lumbar extension strength. *Am J Sports Med* 1989, 17:624.

Price JP, Clare MH, Ewerhardt RH: Studies in low backache with persistent muscle spasm. *Arch Phys Med Rehabil* 1948; 19:703.

Prodromas C, Andriacohi T, Galante J: A relationship between gait and clinical changes following high tibial Osteotomy. *JBJS* 1985, 657(8):1188-1196.

Purse FN: Manipulative therapy of upper respiratory infections in children. *J Am Osteopath Assoc* 1966, 65:964.

Quigley F, Paris L, Duncan H: A comparison of doppler ankle pressure and skin perfusion pressure in subjects with and without diabetes. *Clin Physiology* 1991, 11:21-25.

Raskin N: *Thermography in low-back diseases. Medical thermography: theory and clinical applications,* Los Angeles: Brentwood, 1976.

Reeves J, Jaeger B, Graff-Radford S: Reliability of the pressure algometer as a measure of myofascial trigger point sensitivity. *Pain* 1986, 24:313-21.

Reinberg: Circadian changes in the temperature of human beings. *Bibl Radiol* 1975, 6:128.

Rendell MS, et al: A comparison of nerve conduction velocities and current perception thresholds as correlates of clinical severity of diabetic sensory neuropathy. *J Neural Neurosurg Psychiatry* 1989, 52:502-511.

Roaf R: *Scoliosis*, Baltimore: Williams & Wilkins, 1966.

Roland M, Morris R: A study of the natural history of back pain. Part I, development of a reliable and sensitive measure of disability in low-back pain. *Spine* 1983, 8:141.

Ruch TC, Patton HD, Woodbury JW, Towe AL: *Neurophysiology*, Philadelphia: Saunders, 1965.

Sapega AA: Muscle performance evaluation in orthopaedic practice. *J Bone Joint Surg* 1990, 72A:1562.

Saraniti AJ, Gleim GW, Melvin N, Nicholas JA: The relationship between subjective and objective measurements of strength. *J Orthop Sports Phys Ther* 1980, 2:15.

Sawyer CE: *Nutritional disorders*. In: Lawrence D (ed): *Fundamentals of chiropractic diagnosis and management*, Baltimore: Williams & Wilkins, 1991.

Schafer RE (ed): *Basic Chiropractic Procedural Manual*, Des Moines: American Chiropractic Association, 1977.

Scneider HA, Anderson CE, Coursin DB: *Nutritional support of medical practice*, Hagerstown: Harper & Row, 1977.

Seeds RH, Levene JA, Goldberg HM: Abnormal patient data for the isostation B100. *J Orthop Sports Phys Ther* 1988, 10:121.

Shambaugh P: Changes in electrical activity in muscles resulting from chiropractic adjustment: a pilot study. *JMPT* Dec 1987, 10 (6):300.

Sherman RA, Barja RH, Bruno GM: Thermographic correlates of chronic pain: analysis of 125 patients incorporating evaluations by a blind panel. *Arch Phys Med Rehabil* 1987, 68:273.

Silverman JL, Rodriguez AA, Agre JC: Reliability of hand-held dynamometer in neck strength testing. *Arch Phys Med Rehabil (Suppl)* 1989, 70-94.

Sims LS, Morris PM: Nutritional status of preschoolers. *J Am Diet Assoc* 1974, 64:492.

Sisson JA: *Handbook of clinical pathology*, Philadelphia: JB Lippincott, 1976.

Smith GA, Nelson RC, Sadoff SJ, Dadoff AM: Assessing sincerity of effort in maximal grip strength tests. *Am J Phys Med Rehabil* 1989, 68:73.

So YT, Aminoff NJ, Olney RK: The role of thermography in the evaluation of lumbosacral radiculopathy. *Neurology* 1989, 39:1154.

Spector B, Eilbert L, Finando S, Fukuda F: Video Integrated Measurement System. *J Manip Physiol Ther* 5(2):55-61, 1982.

Spector B: Surface electromyography as a model for the development of standardized procedures and reliability testing. *JMPT* 1979, 2(4):214.

Stephenson RW: *Chiropractic Textbook*, Davenport, IA: Palmer School of Chiropractic, 1927.

Stewart MS, Riffle DW, Boone WR: Computer-aided pattern analysis of temperature differentials. *JMPT* 1989; 12(5):345.

Stoddard A: *Manual of Osteopathic practice*, New York: Harper & Row, 1969.

Suter E, Herzog W, Conway PJ, Zhang YT: Reflex response associated with manipulative treatment of the thoracic spine. *JNMSS* 1994; 2(3):124.

Thompson J, Erickson R, Offord K: EMG muscle scanning: stability of hand-held electrodes. *Biofeedback Self Regul* 1979, 14(1):55.
Thorstensson A, Arvidson A: Trunk muscle strength and low back pain. *Scand J Rehabil Med* 1982, 14:69.

Triano J, Baker J, McGregor M, Torres B: Optimizing measures on maximum voluntary contraction. *Spine Rehab* (Submitted 1991).

Triano J, Skogsbergh D, Kowalski N: *The use of instrumentation by chiropractors*. In: Haldeman, S (ed) *Modern Developments in the Principles and Practice of Chiropractic*, Appleton-Lange, 1992.

Triano JJ, Luttges M: Myoelectric paraspinal response to spinal loads: potential for monitoring low back pain. *JMPT* 1985, 8, 3:137.

Triano JJ, Schultz AB: Correlation of objective measure of trunk motion and muscle function with low-back disability ratings. *Spine* 1987, 12:561.

Triano JJ, Humphreys CR: Patient monitoring in the conservative management of cervical radiculopathy. *J Manip Physiol Ther* 1987, 10:94.

Trott PH, Maitand GD, Gerrard B: The neurocalometer: a survey to assess its value as a diagnostic instrument. *Med J Aus* 1972, 1:464.

Uematsu, S, Hendler U, Hungerford, et al: Thermography and electromyography in the differential diagnosis of chronic pain syndromes and reflex sympathetic dystrophy. *Electro Clin Neurophysiol* 1981, 21:165-182.

Uematsu S: Quantification of thermal asymmetry. Part 1: Normal values and reproducibility. *J Neurosurg* 1988, 69, 552-555.

Vallfors B: Acute, subacute and chronic low-back pain. Clinical symptoms, absenteeism and working environment. *Scand J Rehabil Med (suppl)* 1985, 185:1.

Vernon H: Applying research-based assessments of pain and loss of function to the issue of developing standards of care in chiropractic. *Chiropractic Technique* 1990, 2(3): 121-126.

Vernon H, Aker P, Burns S, Viljakanen S, Short L: Pressure pain threshold evaluation of the effect of a spinal manipulation in the treatment of chronic neck pain. *J Manip Physiol Ther* 1990, 13(1):13.

Vernon H, Gitelman R: Pressure algometry and tissue compliance measures in the treatment of chronic headache by spinal manipulation: a single case/single treatment report. *J Canad Chiro Assoc* 1990, 34(3):141-144.

Vernon H, Grice A: The four quadrant weight scale: a technical and procedural review. *J Manip Physiol Ther* 1984, 3:165.

Wallace H, Wallace J, Resh R: Advances in paraspinal thermographic analysis. *Chiropractic Research Journal* 1993; 2(3):39.

Walshe FMR: *Diseases of the nervous system described for practitioners and students*, 10th ed. Baltimore: Williams and Wilkins, 1963.

Walther DS: *Applied kinesiology - the advanced approach in chiropractic*, Pueblo Systems, D.D., 1976.

Watkins MP, Harris BA, Kozlowski BA: Isokinetic testing in patients with herniparesis. A pilot study. *Phys Ther* 1984, 64:184.

Weber B, Smith JP, Briscoe WA, Friedman SA, King TX: Pulmonary function in asymptomatic adolescents with idiopathic scoliosis. *Am Rev Respir Dis* 1975, 111:389.

Whatmore GB, Kohi DR: Dysponesis: a neurophysiologic factor in functional disorders. *Behav Sci* 1968;13(2):102.

Wickes DJ: *Cardiovascular disorder in ambulatory patients*, In: Lawrence D (ed): *Fundamentals of chiropractic diagnosis and management*, Baltimore: Williams & Wilkins, 1991.

Wickes D: *Laboratory evaluation*. In: Cox JM: *Low-back pain mechanism, diagnosis and treatment*, 5th ed. Baltimore: Williams & Wilkins, 1990.

Wilbourn A, Aminoff N: AAEE minimomograph #32: The electrophysiologic examination in patients with radiculophathies.

Williams M, Stutzman L: Strength variation through the range of joint motion. *Phys Ther Rev* 1959, 39:145.

Wolf SL, Nacht M, Kelly JL: EMG feedback training during dynamic movement for low back pain patients. *Behavior Therapy* 1982, 13:395.

*Work Practices Guide for Manual Lifting*. Niosh technical report; USDHHS 1981, #81-122.

Wright J, Cruickshank J, Kontis S, et al.: Aortic compliance measured by non-invasive doppler ultrasound: description of a method and its reproducibility. *Clin Sci* 1990, 78:463-468.

Wyatt MP, Edwards AM: Comparison of quadriceps and hamstring torque values during isokinetic exercise. *J Orthop Sports Phys Ther* 3:48.

Ziegler EE, O'Donnel AM, Stearns G, Nelson SE, Burmeister LF, Formon SJ: Nitrogen balance studies with normal children. *Am J Clin Nurm* 1977, 30-939.

Zusman M: Spinal manipulative therapy: review of some proposed mechanism, and a new hypothesis. *Aust J Physiother* 1986, 32:89.