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CLINICALEXPOSITION

Proprioception in Chiropractic:

Measuring tone with Chiropractic Neuro-Physiology

Scott Cuthbert

Narrative: Proprioceptors (mechanoreceptors) are found in the muscles, skin, tendons, ligaments and joints. Afferent fibres from mechanoreceptors converge segmentally on the dorsal horn of the spinal cord.

Proprioceptive testing for chiropractors should be performed on any patient who complains of disturbed balance or if there is a suspicion that equilibrium disturbances exist in the patient. Because postural and proprioceptive functions are so automatic they are often taken for granted even in the clinical setting.

If the patient walks onto the examination table, the doctor then looks for pain and its cause. But the cause of the problem may be discovered only when testing the patient while proprioception is active, or while the patient is moving. This tendency toward lack of awareness of the proprioceptive integrity in our patients is especially true if only a mild dysfunction exists that does not obviously interfere with gait and stability during locomotion. One of the more difficult tasks of the physician is to recognise not only the existence, but also the significance of slightly disordered postural mechanisms.

This paper focuses on the diagnosis and adequate Chiropractic treatment of an essential neuromuscular problem in human beings and expands the concept that a breakdown in proprioceptive communication may have a role to play in dysfunction and disease. Part of this discussion will be the traditional chiropractic hypothesis that irritation and dysfunction within the somatic structures (and other soft tissues) of the body might be a contributory factor to neural 'confusion' and hence homeostatic imbalance and physiological disorganisation.

Indexing Terms: Chiropractic; AK; Applied Kinesiology; proprioception; tone.

Introduction

Proprioception from mechanoreceptors, equilibrium, and balance are at the core of human functioning. It is the first system to be developed in utero and is myelinated at birth, providing the foetus with a sense of direction and orientation inside the womb. It is in place at the very beginning of human life in order to help cope with the problems of gravity, which we will encounter in its full force when we are born, and these problems with gravity will not cease to challenge us until we die.

The term proprioception was derived by Sherrington (1906) from the Latin *proprius* to refer to the organism's perception of sensations that originate in receptors that are stimulated by its own movement. Sherrington realised that proprioception was the human being's '*sixth sense*', and identified the muscle spindles, mechanoreceptors in joints, tendons and vestibular receptors as the primary sources of proprioceptive inputs. (1)

> *... the muscle spindle is the eye of the body. Knowledgable isolation and testing is able to reveal much about the clinical processes occurring within the patient. Proprioception is vital to normal daily functioning and the tests described here are essential to the practice of Chiropractic ...'*

On Proprioception

The mechanoreceptors feed into the nervous system our information about movement, tension and pressure. The mechanoreceptors are present in all vertebrates and in all tissues in which active or passive movements occur. These include the skeletal muscles, bones, joints, ligaments and tendons and their associated capsules and sheaths; the skin; the internal ear; the eyes; the digestive tract; the respiratory, cardiovascular and genitourinary system.

It is '*the awesome human ensemble*', and any system of diagnosis that can determine perturbations and abnormalities in these specific functions will give the physician a mighty ability to '*read the needs*' of patients. Without an ability to '*read*' proprioceptive dysfunctions in our human patients leaves the chiropractic clinician in a tenuous position.

In general, mobility involves skeletal muscle and bone to provide the power and fulcrum; metabolic processes to provide energy for power; blood circulation to distribute the energy source; external and internal respiratory processes to support metabolism; and visual, vestibular, kinaesthetic, proprioceptive, auditory and olfactory senses to provide information as to where to go and how things are going when the organism is in motion. The applied kinesiology Chiropractic method provides numerous methods for the diagnosis and treatment in each of these specific areas of body function. (2, 3, 4, 5)

Soft tissue damage leading to sensory disturbances into the nervous system is a primary finding in chiropractic and Applied Kinesiology (AK) manual muscle testing (MMT) evaluation. Many receptors and their axons have a lower tensile strength when compared to the tissues in which they are embedded. Physical trauma to tissues and nerve trunks can damage the mechanoreceptors and their axons resulting in specific and localised proprioceptive losses and measurable muscle inhibitions.

Proprioceptive changes in musculoskeletal injuries often manifest as diminished acuity in position and movement sense and have been demonstrated in the literature for patients with ankle, knee, shoulder, temporomandibular, lower back, neck and whiplash injuries. Disuse of muscles and joints, scarring, and trauma to muscles, ligaments, and joints, contraction and stiffness in the connective tissues surrounding the muscles and the presence of oedema and inflammation are all proposed as factors able to compromise sensory feedback into the nervous system by bombarding the afferent mechanisms with altered feedback. (6)

Body posture and balance are adversely influenced by dysfunctions affecting the central nervous system, the peripheral nervous system, the eyes, the ears, and the musculoskeletal system where proprioceptive and mechanoreceptor sensory organs lie. Defects in any of these tissues lead to diminished postural function and increased instability, and eventually to trauma from falling. There is evidence that multiple factors can adversely affect the postural mechanism and that these factors are cumulative. (7)

One of the causes of the Chiropractic subluxation may be found in faulty proprioceptive mechanisms. But simply palpating and popping spinal and other articular joints without assessing the factors of faulty proprioception is insufficient to the Chiropractic physicians' promise for patients.

Proprioceptive testing should be performed on any patient who complains of disturbed balance or if there is a suspicion that equilibrium disturbances exist. Because postural and proprioceptive functions are so automatic, they are often taken for granted even in the clinical setting. If the patient walks onto the examination table, the doctor then looks for pain and its cause. But the cause of the problem may be discovered only when testing the patient while proprioception is going on, or while the patient is moving. This tendency toward lack of

awareness of the proprioceptive integrity in our patients is especially true if only a mild dysfunction exists that does not obviously interfere with gait and stability during locomotion.

One of the more difficult tasks of the physician is to recognise not only the existence, but also the significance of slightly disordered postural mechanisms.

If muscle proprioceptors are signalling improperly, they will send incorrect messages through the afferent sensory nerves into the spinal cord and cerebellum. When the CNS responds to this aberrant afferent information, the motor response and signals will be incorrect producing improper motor movement, tension, timing, and posture. As a result, some muscles will be hypertonic and others will be hypotonic. This results in structural misalignment of the body, uncoordinated movement, and pain.

The proprioceptive, visual, auditory, and vestibular perceptual systems influence most of the motor mechanisms. In both listening and looking, motor functions become increasingly involved in enhancing the function of the auditory and visual mechanisms. The head will turn so that sound and light are received as effectively as possible.

It is no longer appropriate to think of isolated sensory modalities in relation to proprioceptive function. That is not the way the brain functions. It functions as a whole. Our global view of integrated biomechanics and neurophysiology is one of the major differences between chiropractic (and especially applied kinesiology) practice and that of many of the other manipulative and medical professions.

These proprioceptive systems integrate and overlap with one another. The eyes reinforce what the skin perceives and that which the joints of the hand and arm are moving toward. The different proprioceptive senses therefore enrich and verify one another, creating a multi-sensory perception of our environment. We use this multi-sensory perceptive field of tensile simultaneity to interact effectively with the world. When the input from these sensory systems conflicts or a discrepancy exists between any of the sensory perceptions, it may affect the individual's ability to interact with their environment. This has been referred to as the holographic theory of brain function. (8, 9, 10)

McPartland, Brodeur and Hallgren (11) summarise that reduced proprioceptive input from inhibited or atrophied muscles results in chronic pain and poor postural stability because of a lack of proprioceptive inhibition of nociceptors at the dorsal horn in the spinal cord. It is the authors' contention that clinically, for neuromusculoskeletal conditions at least, inhibitions of muscle function during the MMT can be a vital sign, an indicator of the numerous underlying factors making up the constellation of dysfunctions contributing to patients dis-ease and/or disease, and useful in making a more definitive diagnosis for a broader range of patient disorders.

Rome & McKibben (12) observe that the ICD- 9 (*International Classification of Diseases, from the World Health Organisation*) expanded from 14,315 to 69,101 in the ICD-10, being an indication that the identification of symptoms and 'functional disorders' is broadening.

The AK MMT examination system has significantly addressed the problem of not having provided a meaningful functional neurological assessment of the motor system by its inclusion of not only the nervous system, but also the vascular and lymphatic systems, nutrition, acupuncture, cerebrospinal fluid function and many other controlling or disturbing factors that influence health and neuromusculoskeletal function. (8, 9, 10)

Muscle tone also reflects certain conditions of the brain stem, especially how the brain stem is processing and directing its afferent input. In particular the function of the cranial nerves can be evaluated using applied kinesiology testing procedures. The cranial nerves, together with the cranial connective tissue, operate as a continuum and are powerfully linked to vital organs (eyes, ears, cerebrum, cerebellum, brainstem) and pain-sensitive structures (e.g., cranial nerves and

dura mater), and injury or impaired physiology or motion to these structures can make cranial nerve tissue dysfunctional. The function of cranial nerves III, IV, and VI can be evaluated using applied kinesiology's ocular lock, 13 eyes-into-distortion, and oculo-basic testing procedures. (2, 3, 4, 5, 8, 9, 10) The function of cranial nerve XI is evaluated by the well-known MMTs of the sternocleidomastoid and upper trapezius muscles. Numerous other cranial nerve tests are described in the AK and neurological literature. (9)

An example would be the reflexes in the semicircular canals of the temporal bone and in the extraocular muscles of the eye and how they affect muscles other than those of the eyes and head, especially those of the limbs and neck, and provide an indirect route for influencing global muscle function. Improved function of the upper trapezius, sternocleidomastoid, and extraocular muscles is a consistent outcome from proper cranial treatment using applied kinesiology chiropractic procedures. Proper contraction of the upper trapezius and sternocleidomastoid muscles are necessary to hold the head up and stabilise it. Without the proper function of these and the other neck flexor and extensor muscles, lasting correction of cervico-cranial syndromes is unlikely. This muscle contraction elicits a proprioceptive flow that adds its influence to the direct influence of the improved ocular and vestibular functions achieved by cranial treatment to these areas. The entire sensorimotor response becomes self-supportive through proprioceptive facilitation.

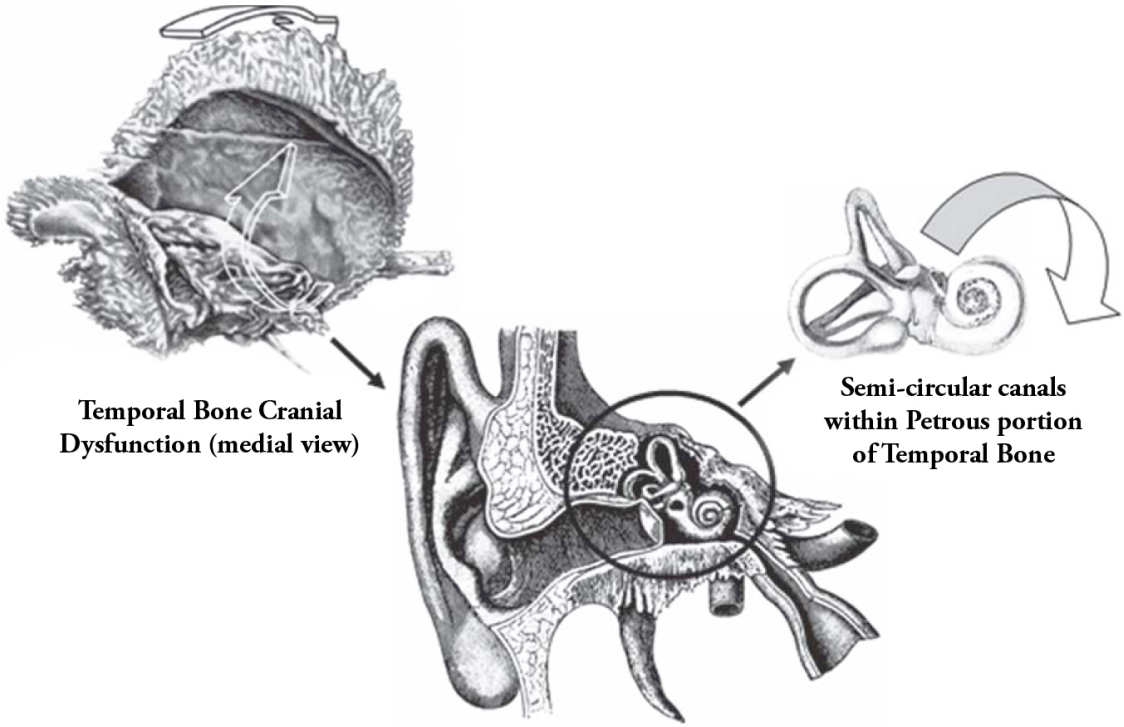
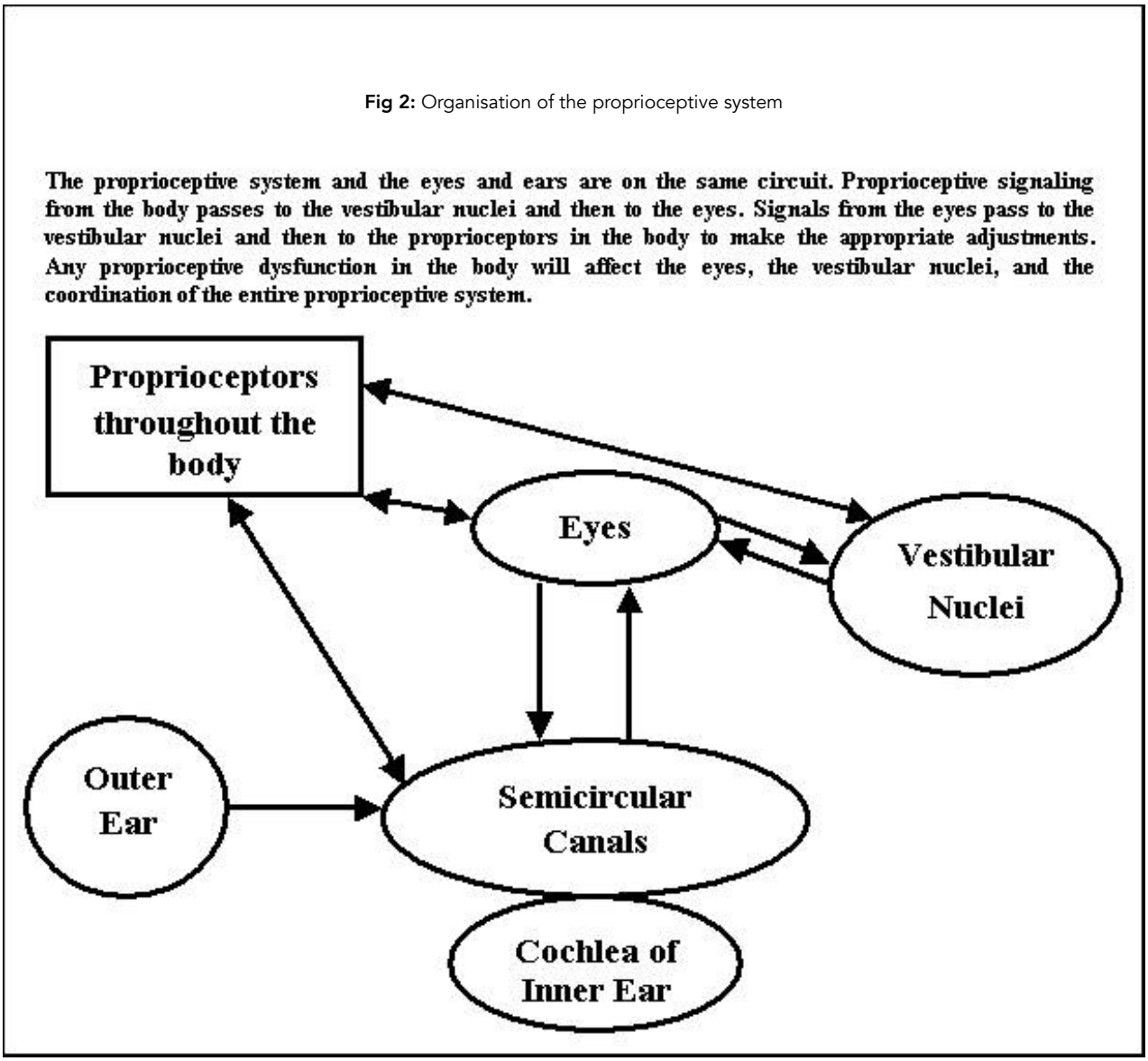


Fig 1: It is suggested here that temporal bone cranial dysfunctions may change the angulation of the semicircular canals and the movement of fluids through the vestibular mechanism. They may also change the shape of and the tension within the jugular foramina, disturbing cranial nerve XI to the SCM and *Upper Trapezius* muscles. This disturbance may also restrict the elasticity of the *tentorium cerebelli*, and increase tension on the cranial membranes throughout the skull. Under these conditions the cranial nerves are subject to adverse mechanical influences of various kinds, including compression, stretch, angulation, torsion, and oedema

Central to the AK concept of neurological organisation is the consideration that the senses of seeing, hearing, smelling, tasting, and feeling, are not simple, specific sensations but rather are sensory systems that are closely interrelated among themselves and intimately linked with motor functions.

Fig 2: Organisation of the proprioceptive system



Sperry has described the primary function of the brain as '*essentially the transforming of sensory patterns into patterns of motor coordination*'. He feels that perception merges into movement so that it cannot be said where one ends and the other begins. In relationship to AK evaluation and treatment methods, Sperry points out that '*Motor adjustment, rather than stimulus patterns or the contents of subjective experience, figures predominantly as a proper frame of reference for understanding the organisation, meaning, and significance of brain excitation*'. (14) The primary function of the brain is to translate sensory impulses into meaningful information and to organise an appropriate motor response. The sensory portion of this equation as far as movement is concerned is proprioception, the focus of this essay.

The proprioceptive tests described in this paper are also used in the medical and neurological evaluation of the cerebellum. (15)

Proprioception's importance to chiropractic

For voluntary movements to be well timed, accurate, and painless, they require coordinated tactile, visual, and proprioceptive information about the movement in progress. Locomotion should be a stable cycle generated by sensory links between the musculoskeletal system, the nervous system and the environment. (16) Without adequate sensation, ongoing function is limited and poorly controlled. Voluntary movement depends upon integration of the motor and sensory systems. The MMT allows a physician to evaluate this interaction with a method

distinctly tailored to monitor it. Sensory information is necessary for the control of movement and is used to correct errors through feedback and feed-forward mechanisms. (17) Any problem or confusion within the sensory system may affect the guidance systems for movement, leading to inefficient muscular activity for any task required.

The manual muscle test is an individual, real-time, and dynamic process that holds its own unique value. Other more 'high tech' and 'laboratory' methods of assessment bring with them their own flaws. Gracovetsky (18) points out that X-ray and other imaging techniques cannot distinguish between the spine of a living patient and a cadaver; his point being that they provide information about structure and only loose assumptions about consequent function based on that structure. The MMT (combined with the AK sensorimotor challenge and therapy localisation procedures) connects function to structure immediately and convincingly for both clinician and patient.

Muscle strength and the biomechanical relations of joints will affect an individual's ability to respond in an appropriate, efficient, effective and timely manner to perturbations in posture. (19) Proprioceptive flow, determined by MMT and proprioceptive challenges of the body, helps set the hypothalamic balance which, in turn, acts on the autonomic nervous system and exerts a tonic excitatory influence on the cortex. Through this route, according to Gellhorn, increased proprioception can result in a more positive emotional state. (20)

Posture is the product of an integrated orchestration between the sensory and motor systems. (21) Peripheral sensory systems provide an internal representation of the outside world. Diseases or dysfunctions affecting sensory systems, central nervous control systems, motor systems or the structural elements of the body (that have tissue continuity with all the others), can lead to progressive failure of the postural mechanisms that will manifest as postural embarrassment, subluxation, and failure on proprioceptive testing.

Figs 3: Proprioception

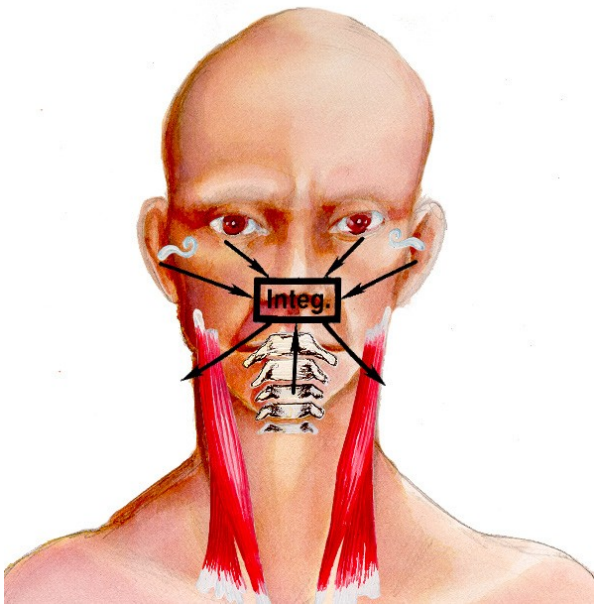


Fig 3a: 'Proprioceptive Balance' (Equal inputs from all proprioceptive sources)

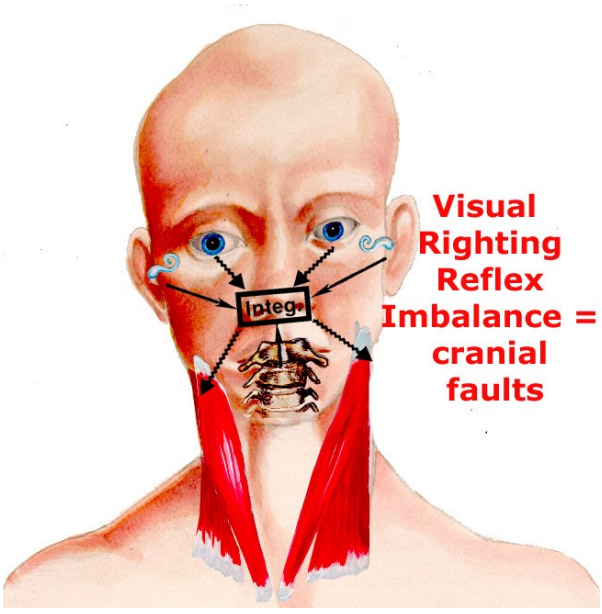


Fig 3b: 'Ocular-visual Equilibrium Disturbance' (a Visual Right Reflex Imbalance)

Figs 4: Proprioception

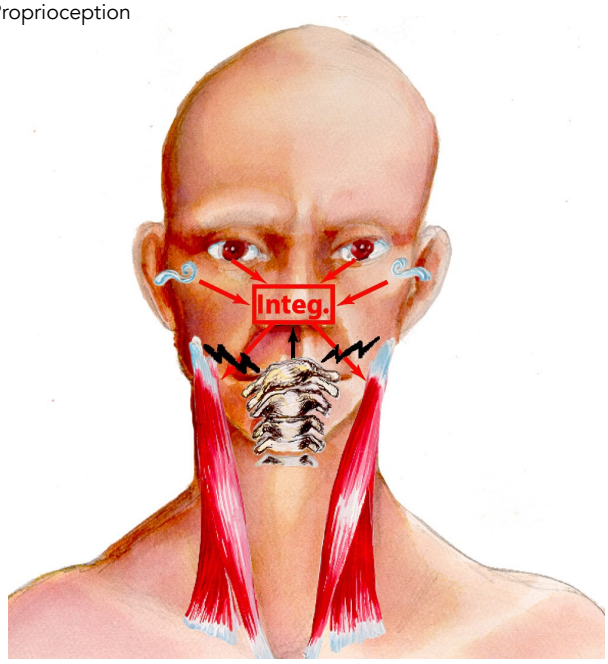


Fig 4a: Upper Cervical Disturbance

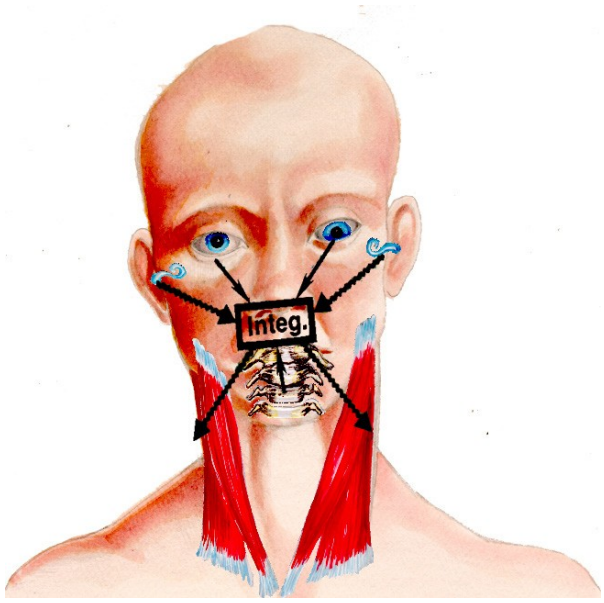
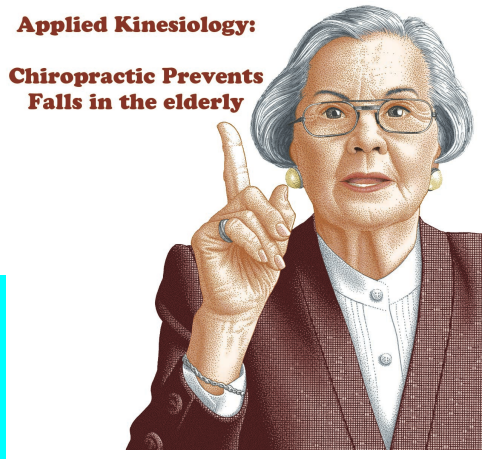


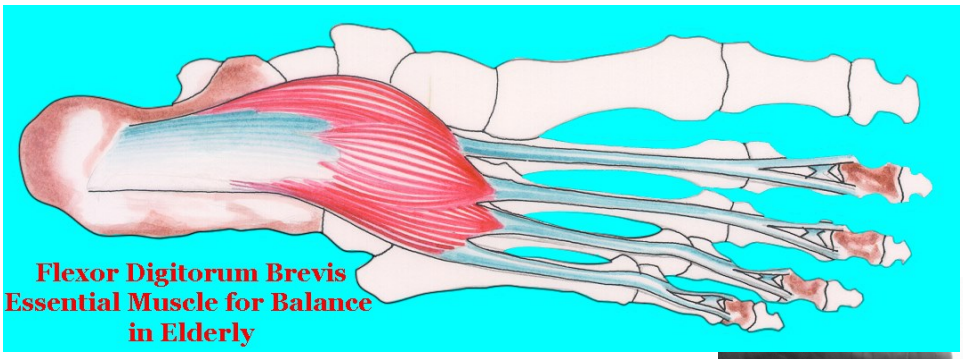
Fig 4b: Vestibular & Labryrinthine Equilibrium Disturbance

Figs 3, 4: Proprioceptive Integration.

All of the muscular and tendinous and osteoarticular mechanoreceptors play an important role in proprioception. Other proprioceptive receptors include the oculomotor, baroreceptor, plantar, and vestibular receptors throughout the body. The postural and proprioceptive systems are so complex that many of its connections are still unknown. The localisation of the tissues causing proprioceptive dysfunction can be determined using applied kinesiology manual muscle testing, challenge and therapy localisation methods. (9)



Even the evaluation and correction of the strength in the flexor muscles in the feet is important to proprioceptive efficacy for human beings, as weakness of these muscles have been correlated with a higher prevalence of falls in the elderly. (22)



Figs 5, 6: *Flexor digitorum brevis* location and MMT

For an instance, the response of the *tibialis anterior* muscle to a proprioceptive technique used in applied kinesiology was investigated by Perot et al (23) during manual muscle testing using a graphical registration of both mechanical and electromyographic parameters.

Experiments were conducted blind on ten subjects. Each subject was tested with MMT and EMG ten times, five times as a reference, and five times after proprioceptive techniques to inhibit the muscle. Results indicated that after treatment an inhibition was easily registered. The reliability of the proposed procedure is mostly dependent upon satisfactory subject-examiner coordination that is also necessary in standard manual muscle testing.

The recovery of tissues in which the receptors are embedded is also important for proprioception. Naturally occurring healing using chiropractic hands-on methods lads to normalisation of the tissue's properties and consequently to better detection of movement by the receptors embedded in them.

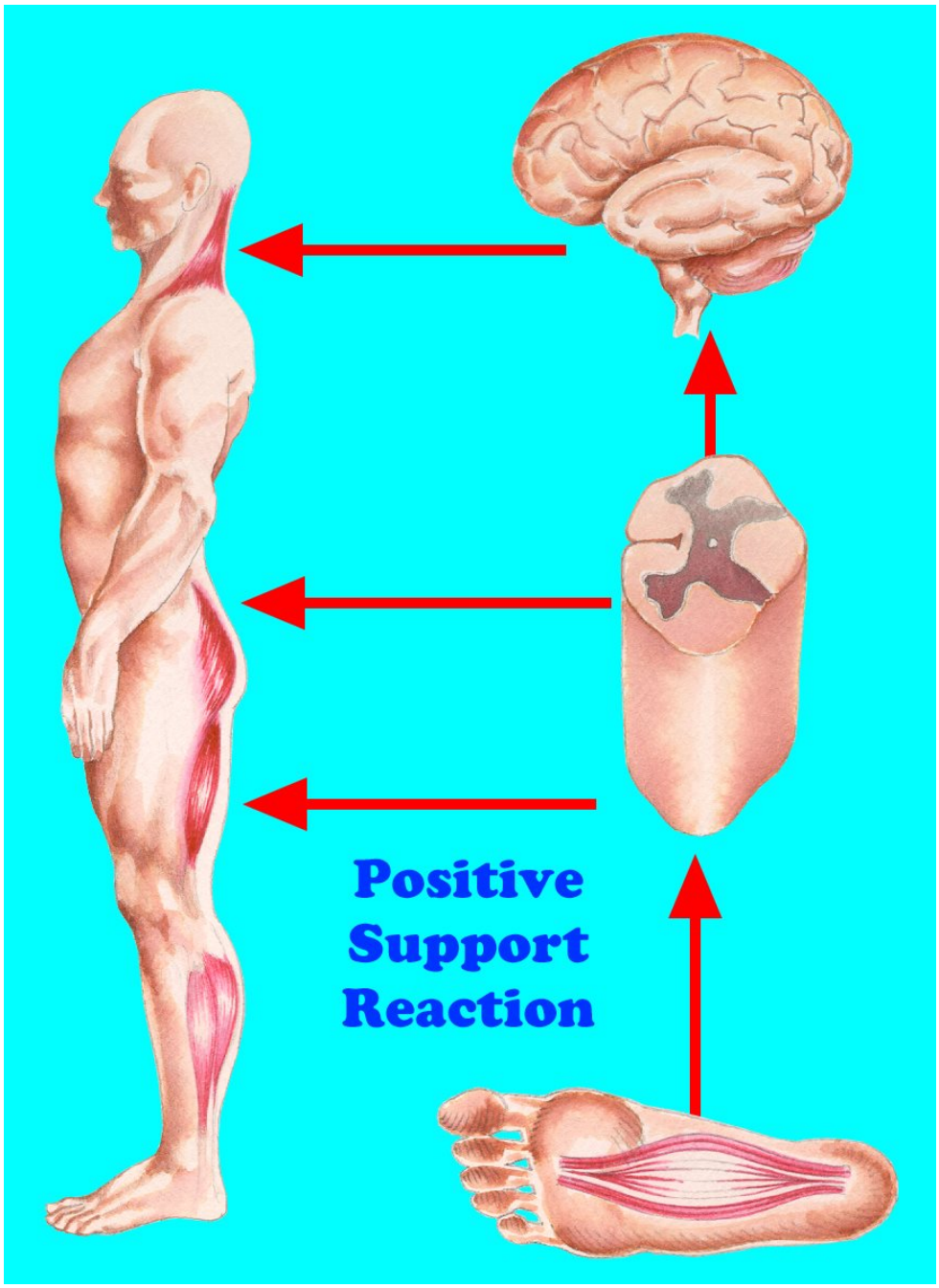
Figs 7, 8: Tibialis anterior muscle, location and MMT

A literature search reported that '*In virtually all studies that included strength testing, muscle weakness was a consistent risk factor for falls in the elderly … We conclude that muscle weakness is an important risk factor for falls that is potentially amenable to therapeutic intervention …*'. (24)

Proprioceptive information from the articulations and intrinsic muscles of the foot, mediated through the central nervous system, provides control for facilitation and inhibition of the neck flexor muscles when walking. This model proposes that the afferent supply from the ligaments, tendons, muscles, fascia, and skin of the foot can be disturbed by entrapment in the tarsal tunnel, creating information to be sent to the central nervous system that is not in keeping with the

current actions of the foot. For this reason, the neck flexors, or any other associated muscle in the gait system for that matter, may be inappropriately inhibited; they immediately regain normal function when the tarsal tunnel entrapment is corrected. (10)

Fig 9: Overview of inputs for proprioception



Proprioceptive training

Prevention of ankle sprains depends on proper organisation of the muscles supporting the ankle and foot. Often the cause of the sprain in the first place is poor muscle control when an inversion force is applied to the foot while walking or running. A significant amount of research has shown ankle sprains to be associated with muscle imbalances, most particularly weakness of the dorsiflexors and invertors of the foot. Chronic ankle sprains have been associated with

arthrogenic muscle weakness. The arthrogenic weakness of these ankle muscles can produce inhibition of the *peroneals* and the *hip abductors*. (25)

Disorganisation present before or developed from the current injury must be corrected before function is returned to normal. Clinical experience has shown that foot subluxations are a common cause of neurologic disorganisation throughout the body, apparently because improper stimulation to the joint proprioceptors of the foot causes dysponesis. AK examination and correction are the prerequisites to proprioceptive training. The training procedures are enhanced when there are no foot/ankle subluxations or fixations and the muscles perform correctly in an chiropractic AK examination.

The need for proprioceptive training is indicated by decreased ability to stand on one foot with stability. This often decreases following ankle sprain. Functional instability of the foot is usually due in the first place to motor incoordination consequent upon articular de-afferentation. In particular, the mechanoreceptors in the human foot and ankle (among other receptors) control the instantaneous and qualitatively precise contractions of the calf muscles that must occur if the foot is to remain stable on uneven ground. (10)

An objective method of evaluating stability, called stabilometry recording, has been described by Lopez- Rodriguez et al. (26) When there is instability on one foot standing, as indicated by stabilometry recording, there is a significantly higher risk of sustaining an ankle injury than when there are normal stabilometric values. Manipulation of the *talocrural* joint improved the stabilometric values and distribution of weight on the feet in these patients. Further evidence of this was determined by Tropp et al. (27) they studied one-legged stability standing in a control group and applied that information to 127 soccer players. The soccer players showing an abnormal stabilometric value ran a significantly higher risk ($p < 0.001$) of sustaining an ankle injury during the following season compared to players with normal values. Players with a history of previous ankle joint injury, but a normal stabilometric value, did not run a higher risk compared to players without previous injury.

Freeman et al. (28) evaluated patients who had recent sprains of the foot and ankle by a modified Romberg test, comparing stability when standing on the injured extremity with the uninjured one. This is the same test described in this essay, called the *Freeman-Wyke One-Leg Standing test*. Freeman found that 34% of their patients had an objective or subjective proprioceptive deficit. No deficit was detected in 16%. The remainder were unstable, but the cause could not be determined because of pain or stiffness. Thus in at least 34%, and at most 84% of the patients studied, there was instability due to proprioceptive deficit. They attribute this deficit to causing the symptom of the foot '*giving way*'.

Fig 10: Use of a 'balance board'

Use of the balance board

If instability continues after muscles have been tested and corrected by applied kinesiology techniques, the patient can be trained on unstable surfaces such as a balance board, or rocker and wobble boards, and ankle disk. (Figure 10)

The balance board is about 15"/38cm square; at the bottom, a 2"/5cm board is centred to balance on. Several boards with higher balancing points can be used for increasing exercise levels. The ankle disk has a spherical undersurface so that it tips in any direction. The balance board is generally used first. Balancing anterior to posterior exercises the muscles and develops proprioception in flexion and extension. Lateral balancing effectively improves action of inversion and eversion. First both ankles are exercised together. Balancing is done to bring the edge of the board close to the floor, but to control it from touching the floor by muscle action. Movement of the board is then reversed to bring the opposite edge of the board close to the floor before stopping action. As control is optimised, one ankle at a time can be exercised on the board.

With exercise on the ankle disk, there is greater proprioceptive and muscle demand. This activity exercises one ankle at a time. First the ankle is moved in circumduction both clockwise and counterclockwise, keeping the edge of the disk in contact with the floor. As proficiency is obtained, the movement is done to just keep the edge of the disk from touching the floor.

Exercise with the balancing board or an ankle disk is done for about ten minutes per day. After optimal function is obtained the exercise can be reduced to about five minutes per day, three times a week to maintain performance.

The inversion sprain in athletic competition is most common. It may be reduced by a conditioning program to strengthen the peroneal muscles, and by teaching the players to land with a relatively wide-based stance. The latter places the foot slightly lateral to the falling center of gravity, making an inversion stress on the ankle unlikely.

Janda's model

The work of Vladimir Janda (with its emphasis on treating muscle imbalance, and particularly muscle inhibition, with physiotherapy) has become popular. Morris and Page have presented the Janda approach (particularly using the rocker and wobble board apparatus) comprehensively. (29, 30, 31)

It should be noted that in Janda's model of the diagnosis and treatment of muscle imbalances, *Sherrington's Law* of reciprocal innervation operates primarily in one direction: muscle hypertonicity/tightness/spasm generates inhibition in its antagonists and so spasm is treated first. For this reason, muscle spasm and tightness are considered the etiological factors of articular dysfunction. In Janda's approach hypertonic muscles are treated with physiotherapeutic means such as massage, stretching, proprioceptive neuromuscular facilitation, electrotherapy and other methods that do not usually include manipulative therapy. (29, 30, 31) In Janda's classic text on the MMT (now out of print), there is no mention of spinal or other joint manipulation options for the muscle inhibitions found; nor were correlations ever observed between muscle inhibitions found on examination and cranial, meridian, nutritional, or psychological treatments.

In Janda's model the inhibited (weak) muscles are treated with exercise, rocker boards, wobble boards, balance shoes, and mini-trampolines among others. The principles of this physical therapy approach to muscular imbalances were based on the work of Bobath and Bobath who developed physiotherapy programs for children with cerebral palsy. (32)

Muscle imbalance as conceived by Janda was mainly embraced by the physiotherapy community, though in recent years it has lost some of its popularity to the concept of core function and motor control. (33) One common reason for the decline in interest in muscle imbalance in the physiotherapy and manual medicine communities is that, as with nearly all

clinical entities, to find a textbook patient showing the muscle imbalance syndromes described by Janda is less common than finding only a partial case. This makes the diagnosis of muscle imbalance syndromes confusing. Further, the approach to diagnosing a muscle imbalance (for practical purposes) is based primarily on subjective assessment, such as the visual observation of standing posture. Based on this visual diagnostic method the prescription of treatment preferred by Janda, corrective stretching, corrective mobilisation, corrective exercises and other nutrition and life style advice, may be somewhat non-specific. Additionally, aside from subjective symptomatology, progress is difficult to gauge with this subjective approach.

The visual diagnosis of a specific muscle's problem is difficult. The different elements within the chain of events of any particular movement that a patient undergoes in front of the examiner occur within a fraction of a second, too rapidly to be accessed separately in the absence of laboratory tools. Dananberg makes this clear in the failure of the great toe to move in the 100 msec time-frame it must during the stance phase. (34) Visual detection of this muscular impairment is essentially impossible.

> Therefore, what is actually observed by the examiner is the grand total of how rapidly and smoothly a person can change between two activities.

For these reasons it is strongly urged that to evaluate any muscle imbalance, clinical measurement tools, including but not limited to the MMT, dynamometers, and digital cameras should be used.

Tape and support

Tape and support are used at the ankle for two purposes:

1. to provide compression and support for the injured ankle, and
2. to prevent injury of the normal ankle.

Tape should be applied to the ankle over skin that has been prepared with a tape adherent tincture; tape adhesion has been improved considerably. Some believe the more complicated woven or basket-weave strapping lasts no longer than simpler types.

There is controversy regarding the use of support to prevent ankle injuries. It seems obvious that ankle support muscles, especially the peroneus group and the tibialis posterior, must be functioning normally and there should be no extended pronation. Simultaneous electromyography and stop-action movies show the *peroneus brevis* and *longus* and the *tibialis posterior* to be the most important stabilising muscles. (35) Langer offers a useful test to determine if the *tibialis posterior* muscle is injured: ff patients feel pain or an increase in pain when shifting their weight to the affected foot and rising up onto their toes, then it is likely that this muscle is dysfunctional.

The plasticity of the nervous system allows us to compensate for degenerative changes in any one system, but there is a limit beyond which failure of the postural motor system must occur. It is at this point of breakdown and multi-sensory system failure that we begin to treat many of our patients in the Chiropractic clinical setting.

A single event, such as pain signals arising from damaged tissue, can have widespread influence throughout the rest of the nervous system and the consequences of the reaction to that event can cascade through many levels of function and behaviour. (16) Clinically we find that even though the tissue injury may have been to a small, discreet area, it is possible to observe reactive and compensatory changes throughout the body.

It is well accepted that alterations in the function of the sensory system may impede postural stability. For example, distortions in the proprioceptive information from diseased joints such as an arthritic knee or spondylitic vertebrae will affect the individual's perception of position. (17) Diseases affecting cutaneous afferent fibres, such as in diabetic neuropathy or scarring, may interfere with information about motion coming from the soles of the feet. (18)

> It is an accepted biological fact that appropriate muscle tone and tension are necessary for skeletal structures to be stable, and any condition that alters the tone of the muscles leads to instability in the structure during activity. Dysfunctions can appear at any level of the controlling system of muscles, on the sensory or the motor side.

There are many pathological processes affecting the neural control of movement (such as CVA, MS, traumatic denervation, Parkinson's disease, among many others). These are beyond the scope of this paper. What will be discussed are other reasons for muscle action to be inappropriate or inefficient. These 'less serious' conditions are placed, in applied kinesiology's chiropractic epistemology, under the umbrella term functional disorders.

'*Functional*' implies that the underlying neural tissue is not diseased but that the information being processed is not optimal for the patient's functional life and can be improved to more homeostatic patterns.

Proprioceptive problems in children

Many children with learning disabilities and developmental delay will also have subtle balance and coordination impairments, which can be discovered by stressing multiple sensory and proprioceptive systems at once. Discovering and correcting these postural and muscle imbalances in children improves their motor, sensory, and integrative capacities enabling them to learn, to move, and to function physically and mentally in a more satisfactory manner.

Asking the seated child to '*look up over your head and close your eyes*' will often cause a child with proprioceptive dysfunction and neurologic disorganisation to fall backwards. *Hautant's test* will be positive in such a child. During *Freeman Wyke* testing, TL to the appropriate sensory receptor area producing the proprioceptive dysfunction will improve the child's balance.

Another test involves sitting the child at a table and giving him a task, such as drawing a house or adding numbers. Once the child is involved in the task, suddenly call his name or make a distracting sound. Often, the child will lose his balance in the chair. This is similar to an exaggerated startle response. The many behavioural and postural clues to be looked for in children with proprioceptive and learning disabilities have been written about extensively. (39, 40, 41, 42, 43)

Cuthbert and Barras showed that *Developmental Delay Syndromes* (DDS) were also linked to motor nerve impairments (determined by the MMT). DDS encompass a group of malfunctions including dyspraxia, dyslexia, learning disabilities, and attention-deficit hyperactivity disorder.

Psychometric testing evaluating cognitive function in 157 children with DDS showed good improvements after AK chiropractic treatment to this cohort of children. (43)

An important narrative literature review by Pauli was published about these AK chiropractic concepts and the clinical research papers were reviewed regarding the treatment of children with DDS. Ferrari and Wainwright, two clinicians whose work comes from AK, have written a book on the chiropractic treatment of dyslexia and learning disabilities, which includes numerous case reports. (44, 45)

Postural instability in children may contribute to various learning and behaviour problems, including attention deficit disorder and complex developmental disorders. Many children who fall within these categories will demonstrate significant posture and balance dysfunctions when carefully tested. More often than not, the postural deficit is related to a biomechanical dysfunction, which can be corrected with the proper chiropractic adjustment.

The concept of and diagnosis for neurological disorganisation explains these phenomena and points toward the therapy needed. These children frequently have related problems in a variety of areas including psychosocial, motor, and intellectual skills. Neurological disorganisation theory attempts to explain the relationship between these neuro-anatomical (sensory and motor) and behavioural deficits within the nervous system when they cannot be attributed to frank neurological damage or abnormalities (e.g. cerebral palsy, mental retardation, traumatic brain injury, peripheral sensory loss).

Apraxia, for example, is a disorder of the sensory portion of the nervous system interfering with the ability to plan and execute skilled or non-habitual motor tasks. Usually, there is some inability to relate the sequence of the motions to each other. In the classic descriptions of the 'switching' phenomenon observed in patients with neurologic disorganisation in applied kinesiology settings, the patients frequently confuse their left from their right, up from down, they reverse the instructions given to them, and so on. They will also frequently fail a number of the tests for proprioceptive function described here.

Another movement disorder, ataxia, involving the timing of movement may also be evident upon close examination of the patient. Patients with ataxia may walk with a wide-based gait and have trouble maintaining balance. In the cases we are speaking about here, this is not due to frank cerebellar or basal ganglia pathologies, but to distorted feedback to the cerebellum from joint and muscle proprioceptor dysfunctions.

To make the AK hypothesis clear, it is proposed that the abnormalities in postural mechanisms seen in learning disabled children are often reflected in poor 'tonic' afferent flow from the muscle spindles and that the postural responses can be helped toward normalisation by activating the tonic afferents using specific chiropractic adjustive treatment. The concepts of Melillo and Leisman are congruent with this approach in the treatment of children with developmental delay syndromes. (46)

Muscle spindle function is one of the most powerful reasons any person with neurological dysfunctions needs to be assessed by a chiropractic applied kinesiologist. Muscle spindles produce a great deal of the activity going on within the human brain.

When the muscle is moved, spindle impulses travel to sensory areas of the cerebral cortex via Clarke's column, the dorsal spinocerebellar tract (DSCT), Nucleus Z, and the thalamus. Correcting this aberration between brain cell and tissue cell is a mighty form of chiropractic neurological therapy.

Fig 11: Positive feedback relating proprioception to learning

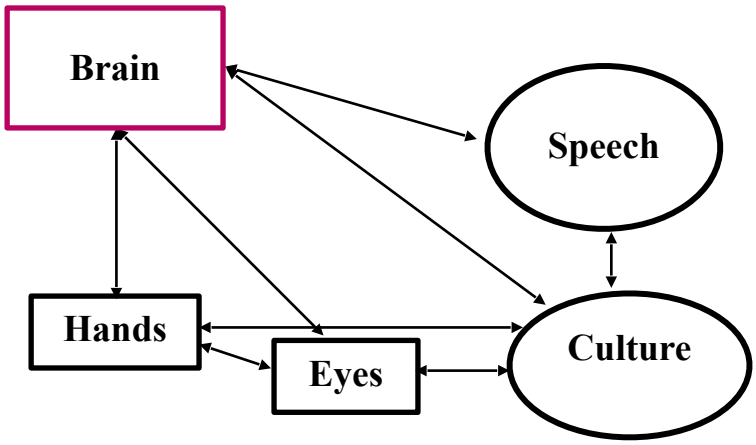


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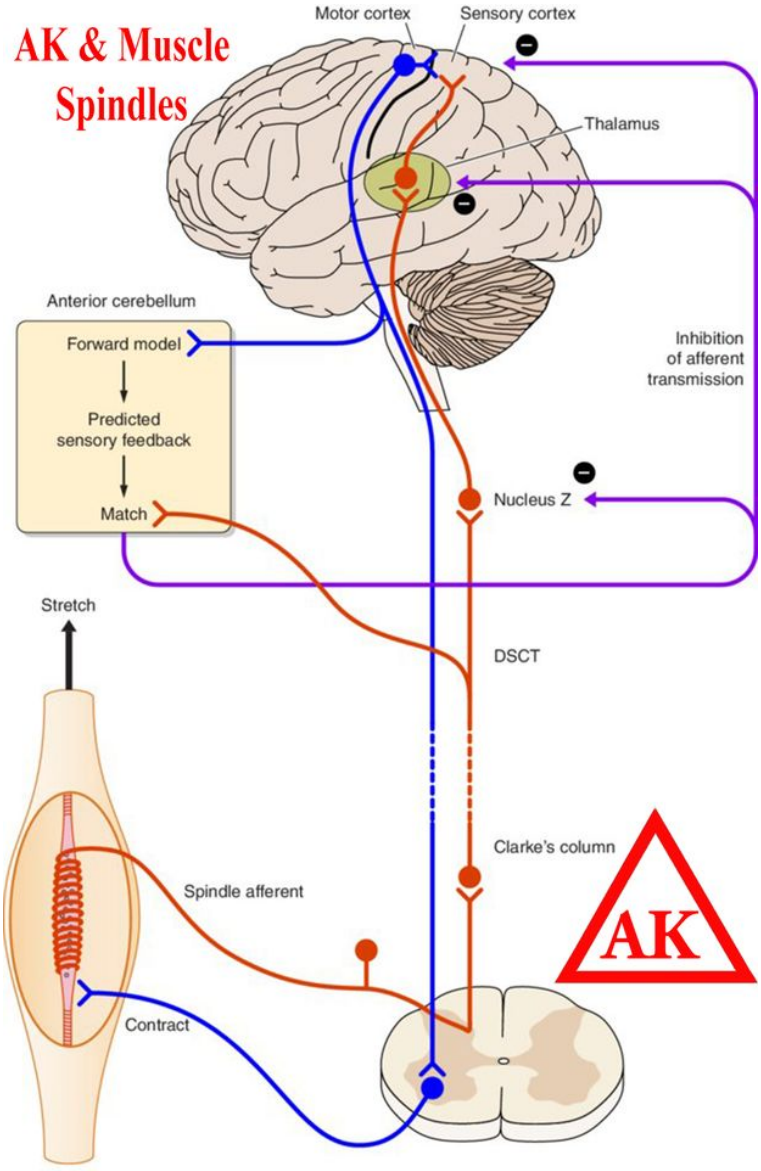
Fig 12: Thalamus connectivity



In general, hypotonicity on MMT may indicate a paucity of sensory flow upon which normal execution of postural reflexes is dependent. Kinesthesia has been found to be positively related to muscle tone in learning disabled children. This relationship may be demonstrated with the proprioceptive tests described in this paper.

> Kinesthesia is another proprioceptive function that can be tested. With the vision occluded, the patient attempts to place his finger on a point at which his finger previously had been placed by the examiner.

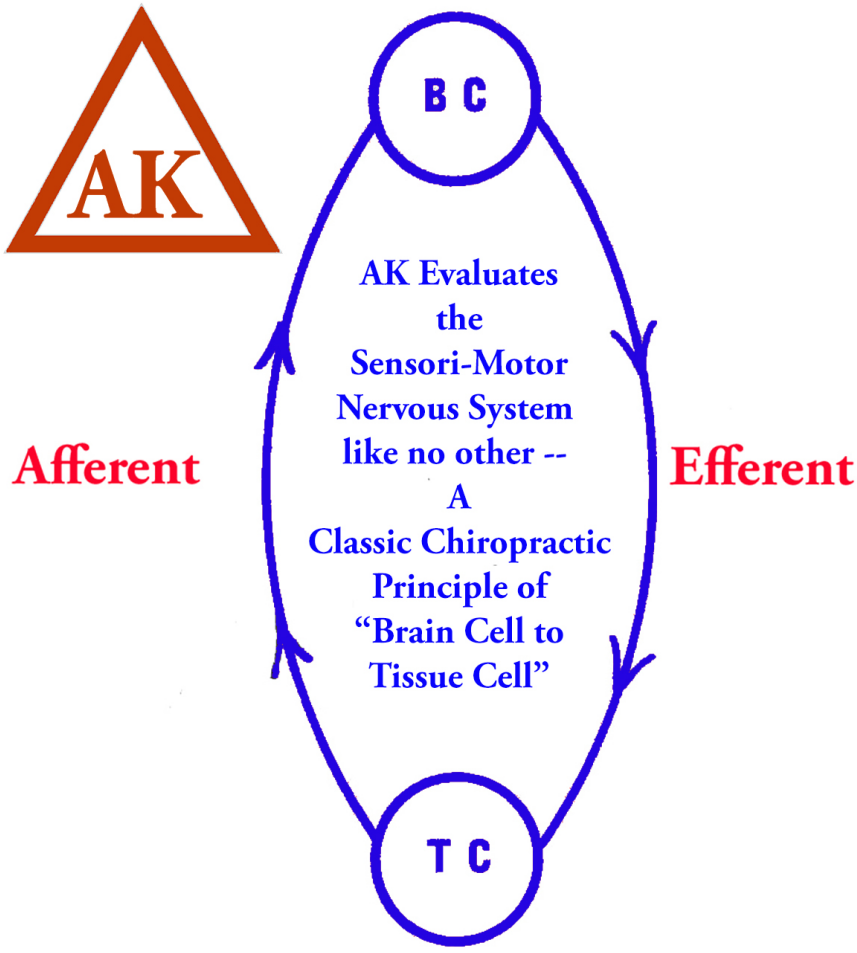
Neurological disorganisation theory was developed to explain an observed relationship between

a. deficits in interpreting sensory or postural information from the body and the environment, and
b. deficits in academic or neuromotor learning in some individuals who demonstrate learning disabilities or clumsiness or movement aberrations of various kinds.

Learning here can be used in a very broad sense to include both academic learning, as well as behaviour change and adaptive motor behaviours.

The theory hypothesises that the correction of sensory and motor impairments will improve the ability of the CNS to process and organise sensory input and motor output, and, through this process, enhances conceptual and motor learning.

Fig 13: The sensorimotor nervous loop



Applied Kinesiology (AK) Evaluation and Treatment

Applied Kinesiology (AK) is a method of chiropractic founded by George J. Goodheart, Jr., a chiropractic physician practicing near Detroit, Michigan. It is a popular diagnostic and therapeutic system used by nearly 1 million health care practitioners around the world today. In a survey specifically made by the National Board of Chiropractic, 37.2% of the respondents stated that they used applied kinesiology (AK) in their practices, and the use of AK in other countries is even higher. (47, 48)

AK employs manual muscle testing (MMT) as a major part of evaluating patients in conjunction with standard natural health care evaluations and diagnostic modalities. Successive diagnostic and therapeutic procedures were developed for the objective testing (manual muscle tests, or MMT) of subluxations, neurolymphatic reflexes, neurovascular reflexes and cerebrospinal fluid flow from ideas originally described by the chiropractic profession, Frank Chapman DO, Terrance J Bennett DC, and William G Sutherland DO, respectively.

Later, influenced by the writings of Felix Mann MD, Goodheart incorporated acupuncture meridian therapy into the AK system. Additionally, the vertebral challenge method (1972) (49) and therapy localisation technique (1974) (50) were added. The correlation of nutritional influences on muscle physiology has also been extensively studied. The myofascial ideas of Fulford, Jones, and Travell are also an important part of the AK system. (51, 52, 53, 54, 55) The work of Major B DeJarnette, DO, DC, and founder of the *Sacro-Occipital Technique* (SOT), is also an important part of AK's diagnostic and therapeutic procedures. (56, 57, 58, 59)

> During an AK examination what the doctor is looking for are patterns of inhibition (weakness) and facilitation (strength) in the nervous system.

MMT evaluates the anterior horn motor neurons to a muscle, and a treatment that improves the facilitation (strength) of a muscle also improves the function on the final common pathway to muscles in the anterior horn motor neurons of the spinal cord, as well as the motor portion of the cranial nerves.

- Facilitation (strength on MMT) refers to the increasing ability of neurons to fire.
- Inhibition (weakness on MMT) refers to the decreasing ability of neurons to fire. Muscles that are inhibited generally do not perform well.

Muscles that are facilitated generally do respond well to challenges of all kinds. The overall 'tone' of the nervous system is thought to be evaluated and treated using these methods. (60)

Since 1964, the AK community of physicians worldwide (members of the *International College of Applied Kinesiology*) has continued to test various therapeutic approaches using manual muscle testing as a clinical parameter for the measurement of physiologic response and the restoration of normal muscle function and tone.

AK is an established diagnostic and therapeutic chiropractic technique that has support within the chiropractic, dental, biofeedback, acupuncture, veterinary, and other health care modalities. (61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 82, 84, 85)

Even with the wide popularity that manual muscle testing has achieved among chiropractors and other physicians in the United States and around the world, few practitioners are familiar

with the laboratory research underlying AK manual muscle testing procedures. (8, 9, 10) AK uses a method of diagnosis with specific methods of manual muscle testing to guide treatment and to validate the effectiveness of care rendered to the patient.

As with most chiropractic techniques the research is ongoing; however, there is mounting evidence published in this Journal of its clinical effectiveness. Continuing studies are warranted.

Proprioceptive Testing in Applied Kinesiology

Sensory ability: assessment and challenge

Since equilibrium reactions are subtle, sometimes even virtually unobservable when they involve little or no motion, eliciting them and observing their response requires special skill. It is particularly easy to overlook the importance of equilibrium reactions in the supine or prone position. Arguments for activating postural mechanisms in our patients in the prone, supine, sitting, standing, and moving positions have been given elsewhere in the AK literature (PRYT testing, E-I-D, ocular lock, oculo-basic, and gait testing, etc.). (8, 9, 10)

The physician who evaluates proprioceptive function in his patient must have some understanding of the status of the sensory receptor system in the patient he is attempting to help and, most importantly, where any dysfunction may lie. Many aspects of proprioceptive dysfunction can be evaluated objectively using manual muscle testing and other assessment procedures developed in applied kinesiology.

Fig 14: Symptoms in patients that suggest a need for proprioceptive evaluation and treatment:

a) Poor posture – stooping (especially when reading or writing)
b) True vertigo with a sense of directional imbalance triggered by movements of the head and neck.
c) Hypotonic muscles
d) Hypertonic muscles – stiff, jerky movements
e) Poor sense of balance
f) Dislike of heights, fear of falling
g) Constant fidgeting or moving
h) Motion sickness (gets car sick)
i) Problems with awareness, memory, or language
j) Inner ear problems
k) Oculomotor dysfunctions
l) Visual problems
m) Reading difficulties
n) Poor depth perception
o) Dislike of sporting activities, P.E. classes, running, etc.
p) Poor organisational skills

The most commonly employed methods for evaluation of the cerebellum and the vestibular system rely on the contribution of the body's proprioceptors for eliciting the equilibrium reactions that help maintain balance. Methods used to test the integrity of the vestibular,

equilibrium, ocular, mechanoreceptor, and kinesthetic systems (all connected to the integrative function of the cerebellum), indicate the role that these systems assume in total body function.

The inseparability of proprioceptive and somatic functions has been discussed already. In addition to overt manifestations of proprioceptive imbalances, the AK method of proprioceptive testing is sensitive to the presence of abnormalities in somatic functions that are commonly undetected by the usual neurological evaluation. The existence of such factors as fine aberrations in mobility; impaired ability to converge the eyes at near point, with or without the presence of frank concomitant strabismus or nystagmus; mixed dominance; one-leg standing imbalance with visual righting reflexes removed; positive *Hautant's* testing; and other tests of cerebellar function; gait testing, all of these tests identify the vulnerability of the individual to stress in environmental situations and postural challenges usually considered to be routine for most people.

Because of the importance of proprioception to the overall function of the human organism, direct clinical measurement of this factor in our patient's functional ensemble is desirable. Before measurements can be meaningful however, they must be directed to the right things and even in science, finding these things is the major achievement; the identification of something that has objective or physical reality and distinctness is even more important than its quantification.

Freeman Wyke One-Leg Standing Test

Goodheart introduced the *Freeman-Wyke one-leg standing test* into AK in 1989. (58) This test calls for organisation of balance between flexor and extensor neuromuscular mechanisms, particularly the facilitatory and inhibitory factors mediated by the reticular system. Such organisation involves the integration of

1. the alpha motor efferents from the larger anterior horn cells of the spinal cord which provide the prime stimulus to muscle contraction
2. the finer gamma efferents which innervate the neuromuscular spindles of the muscle fibres and regulate muscle tone, and
3. the muscle afferents which provide the proprioceptive sensory feedback which is essential for the regulation of motor functions.

Goodheart, citing the work of numerous physiologists, pointed out repeatedly that there is a high density of proprioceptive fibres in the upper cervical spine. More than 40% of the sensors relaying proprioceptive information are found in the cervical region. The suboccipital area is critically important to proprioception, and it is the area most frequently faulted in proprioceptive examination and treatment. This fact is consistent with the rule that the more refined the function of the muscle, the greater number of muscle spindles per unit weight of the muscle.

Grostic, Sweat, and other upper cervical chiropractic researchers have shown that joint dysfunctions of even less than 1mm can disturb cerebellar function, muscle function, body posture, leg length inequalities, and nociception. (86, 87)

The Freeman Wyke One-Leg Standing test is a functional neurological evaluation that requires the integrated function of various proprioceptors all over the body, the integration of the right and left sides of the brain and spinal cord, and their related centres in the brain. These complex types of challenges are an important part of the differential diagnostic information that a physician using AK methods can employ to determine dysfunction in the sensory-motor-postural-proprioceptive systems.

In the *Freeman Wyke* test, the perception of verticality acts on the postural mechanisms to help keep the body upright. The reflex is easily observed by comparing standing balance with eyes open and closed. This close interrelationship between the visual righting reflexes found in the *Freeman Wyke test*, and the effect of ocular muscle function on muscle testing outcomes

throughout the body found in ocular lock testing, provides the basis for the assumption in AK that activating and normalising ocular and somatosensory and postural mechanisms, especially in the supine, prone, sitting and standing positions, will provide a fundamental, natural, and optimum approach to improving neurologic organisation, extraocular and body-wide muscle control, and proprioceptive facilitation.

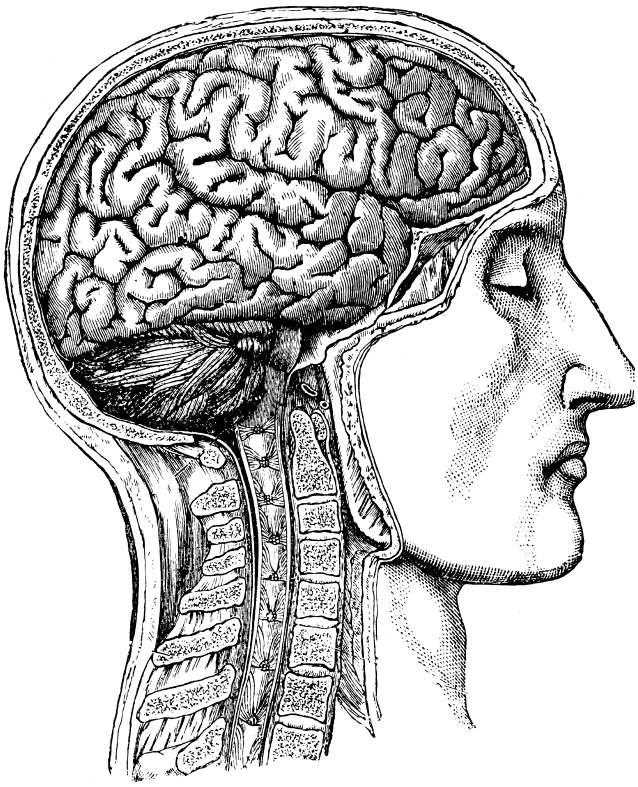


Fig 15: More than 40% of the sensors relaying proprioceptive information to the brain are found in the cervical region. The suboccipital area is critically important to proprioception, and it is the area most frequently faulted in proprioceptive examination and treatment. (89)

This test can be used to demonstrate the importance of proprioception to our patients and it demonstrates how effective our treatments can be. This test is useful in effective treatment and patient management: we demonstrate to the patient after treatment that movement of the neck and postural function no longer provokes imbalance, dizziness, or vertigo. Older patients especially appreciate this demonstrable, very evident change in their balance before and after treatment. It is an excellent evaluation tool, and shows how much you can do to immediately change such a critical body function.

The standing deviations of the patient on one leg standing may also help assay the relative degree of neural integration of the two cerebral hemispheres, relating to which leg and to which side of the body the patient deviates. Carrick's method of blind spot mapping in order to determine the side of manipulation relates to this factor. (88)

Tests of standing balance should not be the sole criterion for evaluation of degree of integration of postural mechanisms. There is a fairly high natural variability in standing balance

(especially among young children and older adults), and most patients have a large amount of practice balancing in the biped position.

Postural stability and adequate bilateral motor function required in the *Freeman Wyke test* depends upon two adequately coordinated extremities. If dysfunction in the foot, ankle, knee, acetabulum, or lumbosacral area exists in either extremity the two sides of the body cannot be expected to be well coordinated. The method used in AK to discover where this dysfunction exists is therapy localisation and challenge.

Fig 16: Variations of the Freeman Wyke one-leg standing test

Freeman Wyke one-leg standing test with eyes open. [Proprioceptive problems should be suspected in the patient's ankle and leg if instability appears in these areas during testing. Hautant's test may be employed with this type of patient.]	*Freeman Wyke* one-leg standing test producing postural imbalance with eyes closed.	*Freeman Wyke* one-leg standing test with eyes closed, and simultaneous therapy localisation to the cervical spine improves balance. TL to the sacro-iliac joints will also improve postural balance if proprioceptive dysfunction originates there.

The patient is asked to stand upon one foot in front of the doctor, to find their balance if they can, and then to close their eyes. If they lose their balance, the test is positive. Upon asking the patient to therapy localise (26) to the cervical spine, they may immediately improve their balance.

Therapy localisation (TL) has been scientifically measured and confirmed in the scientific literature. One of the fundamental 'diagnostic advantages' of the AK practitioner is gaining more and more scientific proof. A recent report demonstrates that even with the subjects (n=36) and the examiner being blinded, therapy localisation was specific for the joint and myotomes innervating the middle deltoid muscle. Good intra-examiner reliability on testing this muscle was also observed. (90, 91) Therapy localisation proposes a change in muscle function when a patient's hand is placed over an area of suspected dysfunction. Therapy localisation has also shown strong sensitivity and specificity to the *ileocecal valve* producing weakness in MMT, correlated with the presence of low back pain in patients with a sensitivity of 87% with this condition and a specificity of 97% lacking low back pain. (92)

Fig 18: Disorders demonstrated with TL:

- Subluxations
- Reflex points
  - Neurolymphatic
  - Neurovascular
  - Stress receptors
    - Proprioceptors
    - Origin and Insertion of muscles
    - Myofascial trigger points
    - Meridian points
    - Cranial faults

Therapy localisation to the TMJ and/or the sacroiliac joints may also improve your patients' balance. Even the insalivation of a particular nutrient, when needed by the patient, may improve *Freeman Wyke One-Leg Standing testing* (cf. case history below). Subsequent specific challenge and palpation to these areas will find subluxations and other problems present. Therapy localisation is difficult for detecting knee and foot or ankle dysfunction during the *Freeman-Wyke test*, and the physician can contact these areas very gently to observe for an improvement in postural balance during the test.

Hautant's Test

In many patients who are dizzy, have vertigo, or are prone to postural embarrassment, the *Freeman Wyke one-leg standing test* is difficult to perform. Many patients have pronated feet, weak ankles, or other foot problems that make one-leg standing tests impossible to perform. Patients who are obese or who are simply too 'proprioceptively disorganised' cannot perform this test well either. I have found another proprioceptive test to be simpler and as demonstrative to the doctor and the patient of their problem with proprioception.

Hautant's Test will usually confirm the findings of the *Freeman Wyke one-leg standing test. Hautant's test* has the patient seated during the testing, so that she feels safe even if dizzy. The patient is seated and the eyes are open, with both arms stretched out in front of them. The patient should point their fingers at the doctor's thumbs.

The patient then closes their eyes in the neutral position while the doctor watches the hands and trunk for a few seconds to see whether the patient's hands deviate to one side in relation to the doctor's own fingers. After examination in the neutral position, the test is repeated in different head positions: rotated right, rotated left, extended back, flexed forward.

While the patient changes position the doctor holds the patient's hands in the neutral position to prevent deviation of the patient's fingers due to synkinesis of the arms (synkinesis: an unintentional movement accompanying an intentional movement). Drifting of the arms, deviation of the hands, vertigo, blurred vision are positive findings.

An advantage to the *Hautant's test* is that the patient feels safe even if they are dizzy because they are seated, and deviation is not caused by nervousness, foot or ankle dysfunctions, or the common postural faults seen in the feeble, the elderly, or the very young. This is often the case in *Romberg's test* or the *Freeman Wyke one-leg standing test* scenarios.

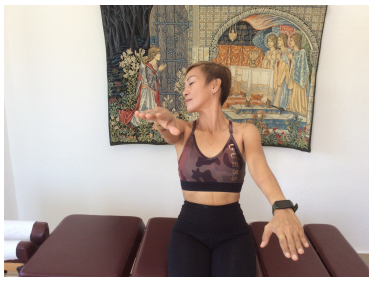
Certain positions of the head will create deviation of the hands that are pointing at the doctor's thumbs, and certain positions will abolish the deviation. In this test any deviation that takes place when the patient turns her head is the result of the head position relative to the trunk. The cervical spine can be diagnosed as the primary suspect if the test is positive.

In fact, I have found that this test gives useful information as to the subluxation present in the neck. Positions that cause or increase deviation, and those that abolish deviation can indicate (via body-language analysis) the subluxation positions to examine for during challenge testing of the cervical spine. (8, 49) Diagnosis is corroborated (or reversed) if the deviation disappears (or persists) after treatment. If the *Freeman Wyke test* can be performed, I have found that correcting the factors causing it to be positive will also correct the factors creating positive testing in *Hautant's test*.

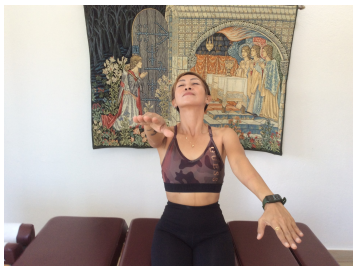
If the test remains positive after clearing the cervical spine of subluxations and soft tissue problems, then a disturbance to the *labyrinth* should be suspected, leading us into the cranial evaluation and treatment of the patient. As we know, it is not only by afferent stimuli from the joints and muscles that the cervical spine may cause disturbances of equilibrium; proprioceptive disturbances can also come from intracranial structures, including the *labyrinth of the inner ear* inside the *petrous portion* of the *temporal bone*; the *vertebral artery* may also be disturbed and must be evaluated in cases where treatment to the cervical spine do not correct the *Freeman Wyke*, *Hautant's*, and other cerebellar and proprioceptive tests.

Fig 19: *Hautant's* test, and *DeKleyn's* Test

Hautant's test unsteady in neutral position. (Patient's hands drift to her left and inferiorly in each of these photographs.)



Hautant's test unsteady with head rotation. (Doctor's thumbs – target of patient's fingers – not pictured.)



Hautant's unsteady with head extension (or flexion).
(More than 40% of the sensory receptors relaying proprioceptive information are found in the cervical region) (64)

DeKleyn's test for vertebral artery involvement. During rotation of the neck, the output of the vertebral artery on the side opposite the rotation is reduced. At maximal rotation, the carotid output is also diminished. Rotation combined with extension of the neck reduces output of the contralateral vertebral artery by approximately 30%. Normally, this creates automatic circulatory compensation in a patient who has no trauma or arthritis in the neck. It is much more difficult in a patient with cervical subluxation, arthritis, and abnormal muscular/ligamentous/dural tension. Many studies have shown that the vertebral arteries play a primary role in vascularising the cerebellum as well as the primary autonomic centres in the brainstem. Hypo-perfusion through the vertebral arteries in turn reduces flow through its collaterals ultimately affecting blood supply to tissues throughout the brain.

Differential diagnosis

The importance of differential diagnosis in cases of proprioceptive disturbance should be obvious after this discussion.

All of the sensory organs that we treat in chiropractic with AK are a source of specialised proprioceptive inputs.

But, many of the clinical assessments used by other methods of proprioceptive diagnosis do not enable the physician to differentiate between the proprioceptive, the visual, the vestibular, or the mechanoreceptor contributions to postural control and motor performance. The tests discussed here allow us to determine precisely where the proprioceptive dysfunction lies. This complex problem of proprioceptive differential diagnosis involves neurology, orthopaedics, otorhinolaryngology and ophthalmology.

Applied kinesiology's proprioceptive treatment method:

the motor system's contribution to the sensory and proprioceptive system

The chiropractic objective in treating proprioceptive disorders is to increase the brain's capacity to integrate proprioceptive sensation from the body's receptors by developing the motor responses that aid this mechanism. This will allow the patient to gradually self-induce proprioceptive stimulation, thereby potentiating this portion of the sensory system on a daily basis. It must be reiterated that the recovery of the tissues in which the receptors are embedded is very important for proprioception. (93)

Many of these proprioceptive receptors are embedded in the muscles and connective tissues surrounding the joints of the body, and it is thought within chiropractic applied kinesiology that alteration in muscle or connective tissue 'tone' may interfere with these feedback mechanisms.

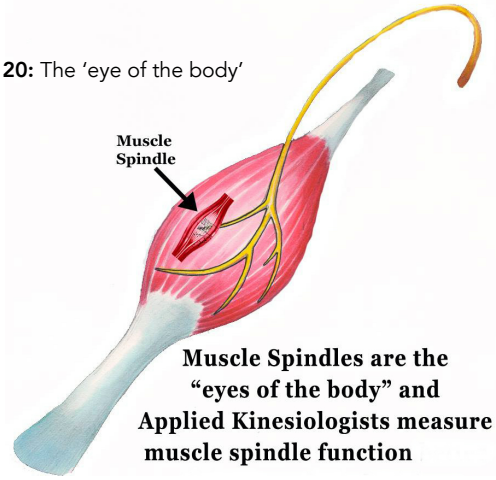
Treatment that leads to better processing of information at the sensory receptor, spinal cord, or higher level, should also reduce the neural consequences of proprioceptive dysfunction. Normalising tissue tone, signalling, and circulation should help to normalise signals that are entering the nervous system, and so gradually allow the nervous system to shift back to normal.

Adequate muscle contraction, especially against resistance, provides one of the major means by which proprioceptive input to the central nervous system is enhanced, and the major source of resistance is the force of gravity acting upon a segment of the body. Improvement of muscle strength (a consistent outcome of applied kinesiology therapy) thereby improves the proprioceptive pathways into the nervous system.

By normalising the muscle spindle activity or Golgi tendon organ activity of muscles in the clinic, the physician can enable a more normal pattern of muscle response during implementation of an activity. The majority of the AK armamentarium is directed toward the therapeutic evaluation and treatment of this kind of dysfunction.

All of the motor challenges and corrections described in this paper stimulate proprioception; if properly done, dramatically improves the recovery of sensory function that is so essential to recovering control of movement for injured patients.

Fig 20: The 'eye of the body'



Case Histories

C.G. (b. 1941)

Initial examination May 29, 2022. After several days of neck pain and stiffness, dramatic dizziness occurred with all body motions. Going from a seated position to standing produced instant dizziness. Patient had a feeling of instability and fear of falling; neck motion caused dizziness; had blurred vision when getting out of a chair.

On examination there was a positive *Freeman-Wyke* test on the right foot only; *Hautant's test* was positive with right head rotation and cervical extension, with the hands deviating to the left and inferiorly. *Romberg's test* was positive; finger-to-nose test was right finger over left by one inch.

Numerous muscles in the body were strengthened by an upper cervical fixation correction. SCM muscles weak bilaterally; strengthened with cranial dysfunction corrections. After sacroiliac, spinal, and cranial corrections that strengthened all the hypotonic muscles in her body on MMT, the patient passed the *Freeman Wyke* test on her right foot and said she '*feels more normal*'. *Hautant's test* still showed slight deviation to the left on right head rotation.

On follow up exam May 31, 2022, patient's balance was much better. Only a slight dizziness now with certain positions of the head. Finger-to-finger and finger-to-nose tests accurate. *Wyke* testing remained imbalanced with eyes closed on the right foot; *Hautant's* test normal. Cranial dysfunctions now negative; spinal and sacral corrections correct proprioceptive testing. Recurrence of imbalance problem with getting out of a chair in August, 2001. Treatment of *Adrenal Stress Disorder* corrects this. No return of proprioceptive or equilibrium problems in the past 2 ½ years. Patient seen on a monthly basis.

L.C. (b. 1961)

Initial examination on May 14, 2021. For the previous week the patient had dizziness and black outs. Neck pain, headaches, low back tension; digestive problems, insomnia, nightmares; on medication for pain; plantar fasciitis; low blood pressure; varicosities. On examination there was imbalance on the right foot during *Freeman Wyke* testing, and TL to the cervical spine improved balance. *Hautant's* test showed deviation to the right, which improved on head rotation to the right as well as flexion of the neck. *Ocular lock* positive. Upper cervical subluxation corrected.

Extensive findings of hypotonic muscles on MMT. *Freeman Wyke* testing improved, but *Hautant's* still positive. Negative findings in the neck and cranium leads to treatment of neuromuscular spindle cells in the TMJ. This corrects *Hautant's* test.

On follow up exam May 18, 2021 patient had only one dizzy spell, but no black outs. Treated frequently for two weeks for numerous pain and visceral disorders. No recurrence of dizziness and blackouts in the past 2½ years.

T.D. (b. 1968)

Initial examination on July 17, 2023. This 55-year-old former New York City resident lived 3 blocks from the *World Trade Center* on September 11th 2001. He has suffered physically and psychologically since that time; adverse environmental exposures; business and personal misfortunes. Positive *Freeman Wyke* and *Hautant's* tests. Correction of cranial and cervical, pelvic and spinal dysfunctions improved proprioceptive testing. Curiously in this case, with the insalivation of *Ashwagandha*, there was immediate improvement on *Freeman Wyke* testing.

On the initial test, there was unsteadiness of the right ankle during the testing that was obvious to the examiner. The posterior tibial muscle on the right foot was also weak; curiously, the proprioceptive testing and posterior tibial weakness were both corrected by adrenal nutritional support.

On follow up exam the patient believed an enormous load had been lifted from him. Proprioceptive testing was now negative, with marked improvement on MMT. The patient was seen 3 times before he moved back to New York City (now living in Brooklyn).

P.Q. (b. 2016)

Initial examination on December 13, 2022. This 6-year-old child had problems with movement, clumsiness, and reading. She was forced to read slowly and with her finger; she trips and falls constantly; bumps into things; avoids physical competition and running; is mixed dominant. Difficult birth process due to delayed cervical dilation by her mother. Has had 18 sinus infections in her life; antibiotics used throughout her life.

She did not go through a crawling stage; went immediately from scuttling on the floor to walking. *Freeman Wyke* test positive on right foot; TL to cervical spine improved balance on her right foot but caused imbalance to commence when standing on her left foot. She wobbles on her feet as she stands; she sits during the consultation on her own foot; touches things around her constantly. Near pointing is slightly off with her left hand. *Hautant's* test had deviation with all movements of the neck. Ocular lock is positive in both upper quadrants. Weakening of indicator muscles with reading. Numerous problems in feet, pelvis, spine, jaw, and cranium are corrected. Uvula deviation corrected by Universal cranial dysfunction correction. After treatment *Hautant's* test and *Freeman Wyke* are corrected.

On follow up examination December 19, 2022, mother reports that her child seems to be moving better and more confidently. Her habit of reading with her finger along the line of text has disappeared. *Ocular lock* testing and *Hautant's* still positive, but improved. Patient treated 4 times before all proprioceptive tests remained negative. Has progressed during the past year from being a very average student to being one of the best in her class. This case is still in progress.

L.P. (b. 1997)

Initial examination on July 14, 2003. This 6-year-old girl has cystic fibrosis; Trisomy X; a gastric-tube is still in place for feeding; she has an 'oral aversion' due to her first 3 years of life on a Naso-gastric tube. Projectile vomiting and reflux problem until she was 4 yoa. Patient grinds teeth at night; clumsy; hyperactive; adrenal stress disorder; tires easily; ADHD distractibility; if she cannot see her teacher or mother, she cannot hear them when spoken to; tactile aversions; on antibiotics most of her life in order to control cystic fibrosis.

Finger-to-finger, finger-to-nose, near-pointing, *Freeman Wyke*, and *Hautant's* testing are all positive; mixed dominance; during *ocular lock* testing the child was unable to find my finger in certain fields of gaze. Large sutural dysfunctions are found, especially in the *occipito-parietal*, *occipito-mastoid* sutures. Foot, pelvic, upper cervical, TMJ, and cranial dysfunctions corrected. K-27 testing remained positive.

On follow up examination August 1, 2003 patient's mother notices that she is moving more confidently. The child is more graceful and confident in her running, and her arms and head no longer flop about wildly as she scampers about. School is beginning now and the child is reading better than expected. This child did not respond as fully to manipulative therapy as desired, and so cross-crawl patterning was given. This improved her physical and mental performance further. On second day of cross-crawl therapy, (94) her mother was able to begin reducing dosage of Ritalin™.

These are all complicated cases and are interesting for many reasons. The same physical dysfunctions that were creating these patients' pain and discomforts were also the problems creating their proprioceptive and equilibrium disorders. As long as some underlying disturbance; in the feet, the jaw, the viscera, the cranium, and especially the upper cervical area, remained uncorrected, with its consequent faulty proprioceptive and movement disorders, relapses would

occur. Examination and treatment of the entire system has proven to be necessary in complicated cases.

The interrelationships between proprioceptive testing and treatment, postural problems, the Chiropractic subluxation, hypotonicity on MMT, cranial dysfunctions and other related factors found on AK evaluation may seem complex and tangled, but they are all causative factors that must be recognised and managed in our problem patients.

It is not believed that new anatomical pathways are developed with the improvements in muscle function found after AK therapy, but that already existing neuronal connections, which are lying more or less dormant, are used with greater ease and frequency and consequently become more important in directing behaviour. Eccles has expressed the situation clearly: '*Frequency of synaptic use leads to an enduring enhancement of synaptic function and prolonged disuse has a deleterious effect on the potency of synapses*'. (95)

Neuronal connections change as a consequence of experience. For a neuron, experience consists of either receiving or emitting an impulse. Therapy consists of correcting the sensory input problems in the patient that are transmitting aberrant experience into their CNS; corrections specifically planned, using the applied kinesiology differential diagnostic methods, to control sensory input and elicit output will bring about more normal function, especially at the brain stem level.

The objective is to simultaneously increase the brain's capacity to integrate optic, vestibular, and somatosensory (proprioceptor and mechanoreceptor) stimuli by developing the motor responses that aid integration and to gradually increase self-induced muscular, ocular, and vestibular (proprioceptive) stimulation.

Conclusion

The method of evaluation presented in this paper cannot stand alone, and constitutes just a part of how applied kinesiologists evaluate body function, health and disease.

It is only when the ideas presented throughout the applied kinesiology teachings have been put together that one can appreciate the overall nature of the applied kinesiology chiropractic perspective on health and disease.

This point is made as applied kinesiologists feel that to resolve locomotor and biomechanical problems, many areas of the body must be explored in order to achieve long lasting symptom relief.

Scott Cuthbert
BA, DC
Chiropractor, Dumaguete City
Associate Editor
cranialdc@hotmail.com

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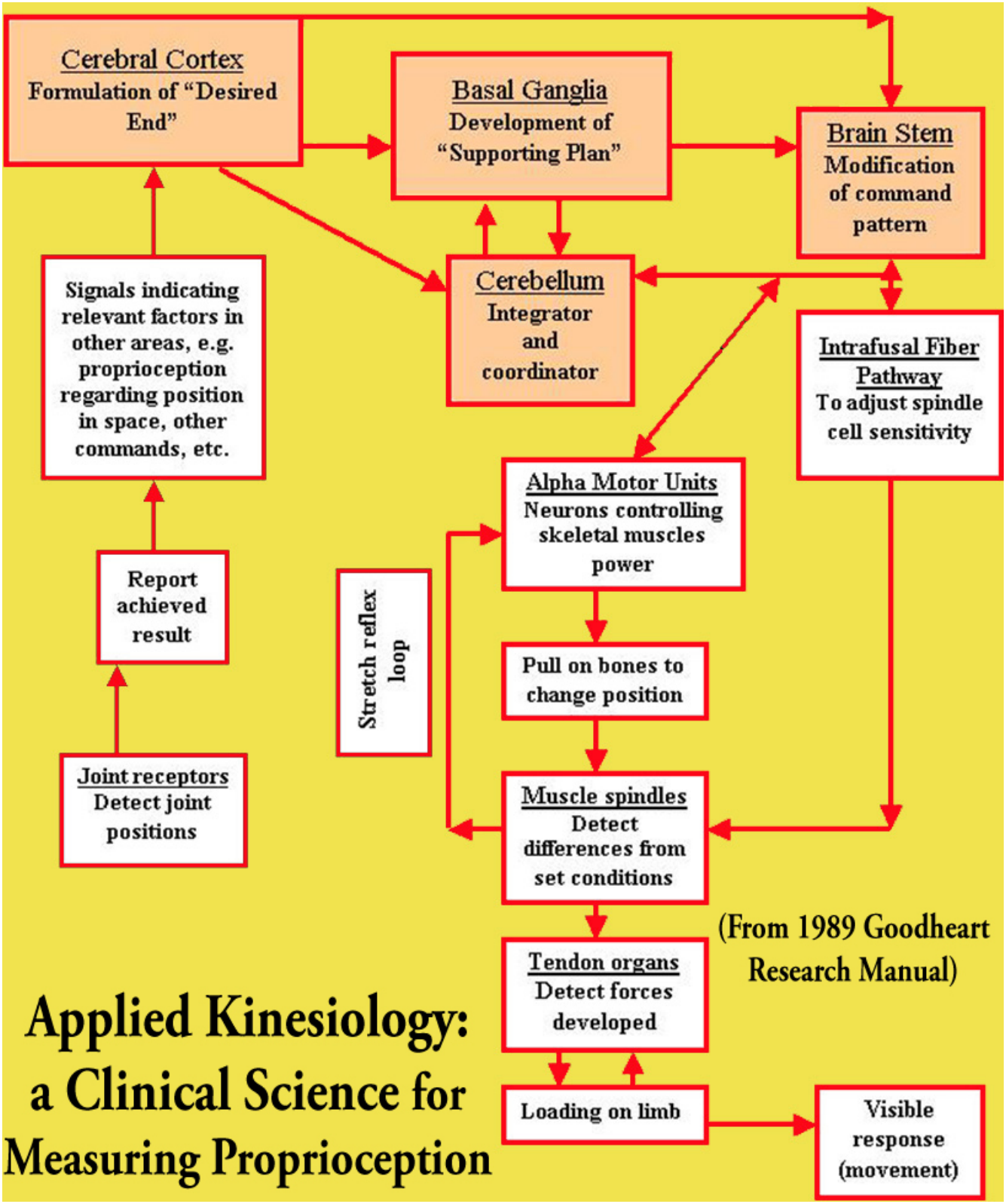
Fig 21: Schematic representation of pathways and feedback loops discussed in this paper



About the author

Scott Cuthbert, DC practices in the Philippines and is Associate Editor with the *Journal*. He has served on the Board of Directors of the *International College of Applied Kinesiology USA*. He is the author of three textbooks on applied kinesiology (in addition to 15 papers cited by *Index Medicus*, and over 50 peer-reviewed research papers) on applied kinesiology approaches to functional health problems.

As this Clinical paper demonstrates Dr Cuthbert practices chiropractic with Mastery of the AK approach with a deep understanding of its history of development. This paper contains photographs taken and compiled by Scott Cuthbert, BA, DC.

References

1. Sherrington, Charles S. The Integrative Action of the Nervous System. New Haven: Yale University Press, 1906.
2. Goodheart, G.J. Applied Kinesiology Workshop Procedure Manuals, (Detroit, MI: Privately published, 1964-1999)
3. Walther, D.S., Applied Kinesiology, Vol. I, Vol. II. (Systems DC, Pueblo, CO, 1981 & 1983)
4. Walther, D.S., Applied Kinesiology, Synopsis, 2nd Edition. (Systems DC, Pueblo, CO, 2000)
5. Leaf D, Applied Kinesiology Flowchart Manual, 3rd ed., privately published, Plymouth, MA, 1995.
6. Malenka, R.C. Synaptic plasticity. Mucking up movements. Nature, 372, 218-219, 1994.
7. Wolfson, L., Whipple, R, Derby, C A et al. A dynamic posturography study of balance in health elderly. Neurology 1992;42: 2069-2075.
8. Cuthbert SC, Walther DS. Whiplash Dynamics and Manual Muscle Testing. Amazon Kindle, 2018. Available at: https://www.amazon.com/stores/Scott%20Cuthbert/author/B00B6T8I6W.
9. Cuthbert S, Walther DS, et al. Applied Kinesiology Essentials: The Missing Link in Health Care. Available at: https://www.amazon.com/stores/Scott%20Cuthbert/author/B00B6T8I6W
10. Cuthbert S, Walther DS, et al. Applied Kinesiology: Clinical Techniques for Lower Body Dysfunctions, 2018. Available at: https://www.amazon.com/stores/Scott%20Cuthbert/author/B00B6T8I6W.
11. McPartland, J.M., R.R. Brodeur, and R.C. Hallgren. 1997. Chronic neck pain, standing balance, and suboccipital muscle atrophy – a pilot study. J Manipulative Physiol Ther 20(1):24-29.
12. Rome PL, McKibbin M. Towards defining unclassified symptoms: eclectic conditions presenting in two chiropractic clinics. Chiropr J Aust. 2011;41(3):83-94.
13. Ocular Lock is a testing procedure used in applied kinesiology to discover neurologic disorganization in the nervous system. It demonstrates the failure of the eyes to work together on a binocular basis through the cardinal positions of gaze. This is usually not gross pathology of cranial nerves III, IV, and VI; rather it is poor functional organization. When the eyes are turned in a specific direction, a previously strong indicator muscle will weaken. The eyes must work together as a team so that each eye is directed to the same fixation point on a page, somewhat like two spotlights highlighting a dancer at the center of the stage. This is called convergence. The focus of the eyes must also be quickly adjusted from one distance or angle to another, and this is called accommodation. The eyes must be able to track or scan along the horizon or a line of print smoothly and evenly, so that the brain can receive a flow of sequentially correct visual information. This is called tracking. Eye motion and position are integrated with proprioceptors throughout the body, as well as those of the vestibular apparatus and head-on-neck reflexes. When a dysfunction of the eye muscles or cranial nerves III, IV, or VI exists, the ocular lock finding will be positive.
14. Sperry, R. W. Neurology and the mind-brain problem. American Scientist, 1952;40:291-312.
15. Evans, R.C. Illustrated Essentials in Orthopedic Physical Assessment. Mosby, St. Louis, MO, 1994.
16. Winter, D.A., et al. Assessment of balance control in humans. Medical Progress through Technology, 16, 31-51, 1990.
17. McCloskey, D.I., Prochazka, A. The role of sensory information in the guidance of voluntary movement. Somatosensory and Motor Research, 11, 69-76,1994.
18. Gracovetsky S. The Spinal Engine. Springer-Verlag: Berlin; 1989.
19. Alexander, N. B, Shepard, N, Gu, MJ, Schultz, A. Postural control in young and elderly adults when stance is perturbed: kinematics. Journal of Gerontology, 1992; 47:M79-M87.
20. Gellhorn, E. Motion and emotion: the role of Proprioception in the physiology and pathology of the emotions. Psychological Review, 1964;71:457-472.
21. Holm, S., Indahl, A., Solomonow, M. Sensorimotor control of the spine, Journal of Electromyography and Kinesiology, 2002;12:3:219-234.

22. Hylton B, et al. Foot and ankle characteristics associated with impaired balance and functional ability in older people. J Gerontol A Biol Sci Med Sci. 2005 Dec;60(12):1546-52.

23. Perot et al., 1991; Perot C, Meldener R, Goubel F. Objective measurement of proprioceptive technique consequences on muscular maximal voluntary contraction during manual muscle testing. Agressologie. 1991;32(10 Spec No):471-4.

24. Corinne G, et al. A weak balance: the contribution of muscle weakness to postural instability and falls. Nat Clin Pract Neurol. 2008 Sep;4(9):504-15.

25. Zampagni ML, Corazza I, Molgora AP, Marcacci M. Can ankle imbalance be a risk factor for tensor fascia lata muscle weakness? J Electromyogr Kinesiol. 2009;19(4):651-9.

26. López-Rodríguez S, Fernández de-Las-Peñas C, Alburquerque- Sendín F, Rodríguez-Blanco C, Palomeque-del-Cerro L. Immediate effects of manipulation of the talocrural joint on stabilometry and baropodometry in patients with ankle sprain. J Manipulative Physiol Ther. 2007;30(3):186-92.

27. Tropp H, Askling C, Gillquist J. Prevention of ankle sprains. Am J Sports Med. 1985;13(4):259-62.

28. Freeman MAR. Instability of the foot after injuries to the lateral ligaments of the ankle. J Bone Joint Surg. [Br] 1965;47-(B): 669-77.

29. Cuthbert S. Best Practice Guidelines for Diagnosing Muscle Imbalance: Chiropractic versus Physiotherapy. Asia-Pac Chiropr J. 2022;3.1. Available at: apcj.net/papers-issue-3-1/#CuthbertBestPractice.

30. Page P, Frank CC, Lardner R. Assessment and treatment of muscle imbalance: The Janda Approach. Human Kinetics: Champaign, IL; 2010.

31. Morris CC. Low Back Syndromes: Integrated Clinical Management. McGraw-Hill: New York; 2006.

32. Bobath K, Bobath B: Facilitation of normal postural reactions and movement in treatment of cerebral palsy. Physiotherapy. 1964;50:246.

33. Wallden M. Rehabilitation and Re-education (movement) approaches. In: Naturopathic Physical Medicine. Ed. Chaitow L. Churchill-Livingstone: Edinburgh; 2007.

34. Dananberg H. Lower back pain as a gait-related repetitive motion injury. In: Vleeming A et al (Eds.) Movement, Stability and Low Back Pain. New York, NY: Churchill Livingstone;2007:253-264.

35. Langer P. Great Feet for Life: Footcare and Footwear for Healthy Aging. Fairview Press: Minneapolis, MN; 2007.

36. Lund, J.P., et al. The pain-adaptation model: a discussion of the relationship between chronic musculoskeletal pain and motor activity. Canadian Journal of Physiology and Pharmacology, 69, 683-694, 1991.

37. Barrett, D. S, Cobb, A G, Bentley, G. Joint proprioception in normal, osteoarthritic and replaced knees. Journal of Bone and Joint Surgery, 1991;73:53-56

38. Simoneau, G.G., et al. Postural instability in patients with diabetic sensory neuropathy. Diabetes Care 17:1411-1421, 1994

39. Doman, G. What To Do About Your Brain-Injured Child, The Gentle Revolution Press, Towson, MD, 2003.

40. Le Winn, E. B. Human Neurological Organization, Charles Thomas, Springfield, IL, 1969

41. Goddard, S. A. Teacher's Window Into the Child's Mind, Fern Ridge Press, Eugene, OR, 1995.

42. Delacato, C.H. The Diagnosis and Treatment of Speech and Reading Problems. Springfield, IL: Charles C. Thomas Publisher, 1963.

43. [Cuthbert S, Barras M. Developmental delay syndromes: psychometric testing before and after chiropractic treatment of 157 children. J Manipulative Physiol Ther. 2009 Oct;32(8):660-9.

44. Pauli Y. The Effects of Chiropractic Care on Individuals Suffering from Learning Disabilities and Dyslexia: A Review of the Literature. J Vertebral Subluxation Res 2007 Jan;15:1-12.

45. Ferrari CA, Wainwright RB. Breakthrough for dyslexia and learning disabilities. Florida: Exposition Press; 1984.

46. Melillo R, Leisman G. Neurobehavioral Disorders of Childhood: An Evolutionary Perspective 2010th Edition. Springer; 2010th edition (September 22, 2009).

47. Christensen, MG, Delle Morgan, DR. Job analysis of chiropractic: a project report, survey analysis, and summary of the practice of chiropractic within the United States. Greeley, CO: National Board of Chiropractic Examiners, 1993:78

48. Christensen, MG, Delle Morgan, DR. Job analysis of chiropractic in Australia and New Zealand: a project report, survey analysis, and summary of the practice of chiropractic within Australia and New Zealand. Greeley, CO: National Board of Chiropractic Examiners, 1994: 92:152.

49. Challenge is another essential diagnostic procedure used to determine the body's ability to cope with external stimuli, which can be physical, chemical, or mental. An example of a physical stimulus is pushing on an articulation and determining muscle strength change. Chemical stimulus occurs when one inhales potentially toxic chemicals or chews nutritional factors. Mental stimuli include thought processes, either pleasant or unpleasant to the individual. After an external stimulus is applied, muscle testing procedures are done to determine an improvement in or weakening of the muscle strength as a result of the stimulus.

50. Therapy localization is a diagnostic procedure in AK that consists of placing the patient's hand over areas of suspected involvement, then using muscle testing procedures to determine any change in strength. Placing the patient's hand on different locations stimulates nerve endings and/or possibly changes the patient's electromagnetic energy field. Therapy localization is strictly a diagnostic tool in AK that is to be combined with the other diagnostic findings to arrive at a final conclusion. It has no known therapeutic value.
51. Fulford, R.C., Touch of Life (Simon & Schuster, 1996).
52. Jones, L.H., Strain and Counterstrain (American Academy of Osteopathy, 1981).
53. Travell, J.G., & Simons, D.G., Myofascial Pain and Dysfunction – The Trigger Point Manual, Volume I & II. (Williams & Wilkins, 1992)
54. Travell, J.G., & Rinzler, S.H., The Myofascial Genesis of Pain, Postgraduate Medicine, May 1952 (Vol. II, No. 5)
55. Cuthbert, S. Applied Kinesiology and Myofascia. International Journal of Applied Kinesiology and Kinesiologic Medicine. 2002;13:34-39.
56. DeJarnette MB, Cranial Technique, self-published, Nebraska City, Nebraska, 1979-1980.
57. DeJarnette MB, Sacro Occipital Technique, self-published, Nebraska City, Nebraska, 1984.
58. Goodheart, GJ. Applied Kinesiology - The Beginning Digest Of Chiropractic Economics. 1989; 31(6): 15-23
59. Gin RH; Green BN George Goodheart, Jr., D.C., and a history of applied kinesiology. J Manipulative Physiol Ther, 1997 Jun, 20:5, 331-7
60. McDowall D, et al. Tone as a health concept: an analysis. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1744388117302529?fbclid=IwAR3XUdfBXySHzoQ1JOwnC3ja_qY_O3HW9IHxASFElmjOJJGliDcjEoSgmpo&via%3Dihub.
61. Goodheart GJ The Applied Kinesiology Technic Todays Chiro: Jul/Aug 1993; 22(93): 56-58
62. McCord KM Applied Kinesiology: An Historical Overview Dig Chiro Econ Sep/Oct 1991;34:20-27.
63. Haney V, Chronic Pediatric Migraine-Type Headaches Treated By Long-Term Inderol Prior To Chiropractic Care: A Case Report Proceedings of the National Conference on Chiropractic. 1993 Oct; 132-40
64. Perle S, Applied Kinesiology (AK) Chiropractic Technique. 1995 Aug; 7(3): 103-7
65. Lebeouf C. Patrick, K. The use of major and minor therapy forms in Australian chiropractic practice Journal Of The Australian Chiropractic Association. 1987; 17: 109-11
66. Mcdowall, D. A study of the results of Applied Kinesiology in a group of 123 Patients Journal Of The Australian Chiropractic Association. 1983 Aug; 13(2): 26-7
67. Goodheart G Applied kinesiology in dysfunction of the temporomandibular joint. Dent Clin North Am, 1983 Jul, 27:3, 613-30
68. Glassley DP Applied dental kinesiology: temporomandibular joint dysfunction. Basal Facts, 1983;5:2, 65-6
69. Walther DS Uses of applied kinesiology for dentists. Basal Facts, 1985;7:2, 133-41
70. Goodheart GJ Applied kinesiology and dentistry. Basal Facts, 1987;9:2, 69-73
71. Goodheart, G Posture: 30 years of observation and some logical chiropractic conclusions. Part II Digest Of Chiropractic Economics. 1987 Oct; 30(2): 34-41
72. Goodheart, G. Kinesiology and Dentistry Journal Of The American Society Of Psychosomatic Disease. 1976; 6: 16-18
73. Eversaul, G Biofeedback and kinesiology Journal of the American Society of Psychosomatic Disease. 1976; 6: 19-23
74. Froehle, R.; Ear Infection: A Retrospective Study Examining Improvement from Chiropractic Care and Analyzing for Influencing Factors Journal Of Manipulative And Physiological Therapeutics. 1996 Apr; 19(3): 169-177.
75. Santoro F, Maiorana C, Geirola R. [Neuromuscular relaxation and CCMDP. Rolfing and applied kinesiology.][Article in Italian] Dent Cadmos 1989 Nov 15;57(17):76-80
76. Omura Y. New simple early diagnostic methods using Omura's "Bi-Digital O-Ring Dysfunction Localization Method" and acupuncture organ representation points, and their applications to the "drug & food compatibility test" for individual organs and to auricular diagnosis of internal organs--Part I. Acupunct Electrother Res 1981;6(4):239-54
77. Meal G Applied Kinesiology: Muscle Response In Diagnosis, Therapy And Preventive Medicine Eur J Chiro: Jun 1986;34(2):107.
78. Tiekert, CG. Applied Kinesiology: it's use in veterinary diagnosis. Vet Med, 1981; 76: 1621-3.
79. Meal G Applied Kinesiology: Muscle Response In Diagnosis, Therapy And Preventive Medicine Eur J Chiro: Jun 1986;34(2): pg. 107.
80. Leisman, G, et al. Somatosensory evoked potential changes during muscle testing. International Journal of Neuroscience. 1989;45:143-151.
81. Schmitt, W., Yanuck, S. Expanding neurological examination using functional neurologic assessment, Part II: Neurologic basis of applied kinesiology. International Journal of Neuroscience, 1999;97:77-108.

82. Klinkoski B; Leboeuf C A review of the research papers published by the international College of Applied Kinesiology from 1981 to 1987. J Manipulative Physiol Ther, 1990 May, 13:4, pg. 190-4.
83. Williams L, Rosen Ms The Research Status of Applied Kinesiology, Part 2: An Annotated Bibliography of Applied Kinesiology Research Dig Chiro Econ May/Jun 1995;37:6: pg. 40-4.
84. Rosen Ms Research Status of Applied Kinesiology Part 1 Dig Chiro Econ: Sep/Oct 1994;37(2): pg. 17-23.
85. Goodheart, G. J. Applied Kinesiology 1989 Workshop Procedural Manual. Self-published;1989:90-104.
86. Grostic, J. F. Chiropractors Field Research Manual. Ann Arbor, MI: Private publication, 1946.
87. Sweat, R. W. Atlas Orthogonal Chiropractic Program. Atlanta, GA: Private publication, 1997.
88. Carrick, F. Changes In Brain Function After Manipulation Of The Cervical Spine J Manipulative Physiol Ther 1997;20(8):529-45
89. Guyton AC, Hall JE. Textbook of Medical Physiology, 11th ed. WB Saunders Co: Philadelphia; 2005.
90. Rosner AL et al. Reliability and Validity of Therapy Localization as Determined from Multiple Examiners and Instrumentation. Funct Neurol Rehabil Ergon; 2015 5(3): 365-386.
91. Rosner AL, Charles E. Therapy Localization in Applied Kinesiology: Validation by Means of Blinding in a Cohort Study. Funct Neurol Rehabil Ergon: 2016 6(2).
92. Pollard et al., 2006; Pollard HP, Bablis P, Bonello R. Can the ileocecal valve point predict low back pain using manual muscle testing? Chiropr Aust. 2006;36:58-62.
93. Leinonen V, et al. Lumbar paraspinal muscle function, perception of lumbar position, and postural control in disc herniation-related back pain. Spine (Phila Pa 1976). 2003 Apr 15;28(8):842-8.
94. Cross-crawl patterning is an exercise, developed from the ideas of Doman and Delacato, to assist in the repatterning of certain central nervous system dysfunctions.
95. Eccles, J. C. The effects of use and disuse on synaptic function. Brain Mechanisms and Learning. Oxford: Blackwell Scientific Publications, 1961.