Asia-Pacific Chiropractic Journal

The Leg Length Check and its importance to the complete practice of Chiropractic

Gilbert Weiner

Abstract

Objective: To discuss the Leg length check as practiced by Chiropractors; its techniques, rationale, clinical value, physiological and neurophysiological roots and ramifications.

Background: In the process of performing various Chiropractic workshops, we have found that a significant portion of attendees did not uniformly incorporate complete leg length checks in their protocols. Furthermore, even those that did employ leg length tests in their protocols did not fully employ all the variations, nor did they comprehend the physiological and neurophysiological rational as to the entirety of what or why these tests reveal the findings that they do, and how that information is crucial to the treatment of the patient

Methods: An investigative meta-research study was undertaken perusing the existing published research both domestic and foreign, Chiropractic, Osteopathic, Allopathic, and Physiotherapeutic, to be as comprehensive as possible. This in order to illustrate all manner and variation (to our knowledge) of leg length check tests. The goal is to attempt to explain what those tests demonstrate, why and how they demonstrate their findings through spinal, fascial, osseous, and neurological reflex factors.

Conclusion: This study has attempted to explain the importance of proper procedures, the protocols, and the possible findings related to leg length checks. There was a presentation to explain how those findings can be physiologically justified. Factors such as fascia, muscle, spinal structure, osseous growth, and neurological reflexes were substantially discussed. It is our sincere hope that upon reading this study practitioners will come away with a new respect for this tool, making leg length checks a pivotal procedure in their office protocols, and comprehend the benefit of the information gleaned from these tests. It is recommended that further studies are needed to further corroborate these findings and those studies should include proper examiner training and patient population selection.

Indexing terms: Chiropractic; Subluxation; leg length; Derifield; neurological postural reflexes; dural torque; fascia; Lovett Brother; DeJarnette; SOT; Sacro Occipital Technique; Osseous growth factors.

Introduction

Through this paper it is the hope that it will be evident that every Chiropractor should be initiating his or her examination with a posture

> *… leg length checks are a pivotal procedure in the Chiropractic clinic and reveal much more about the patient than a simplistic 'short leg'…'*

analysis, pelvic posture, and leg check. This includes a leg length measurement usually performed with the patient in the prone position, as is customarily referred to as the Derifield Leg Length Check. (1, 2) To be clear a leg length check could be performed with the patient in the supine position as seen in SOT Cat 2, but this will be discussed later on.

In the past the investigational studies carried out concerning the Derifield leg test and leg length tests in general were many times corrupted one way or another. There are some that do validate the test and others that run the gamut from inconclusive to not valid. Many times, the outcome of the study depends on the author’s personal or professional bias. Some have been performed utilising non-Chiropractic personnel. Sometimes there appears to have been no attempt to correctly train the examiners or standardise the procedures or observations. In almost all studies with questionable outcomes, there is no attempt to normalise the posture prior to the analysis. There are those that do not fully mention the leg length nuances and there are no indications as to what structural or physiological variants they are considering when filtering the participating population.

The Analysis

The posture analysis and a proper leg length check can give a world of valuable information as to what is going on with each particular patient. Our personal preference is to begin with the Derifield leg check (AKA Derifield, d-Thompson Leg Check). In this leg test, for example, the patient is laying prone, the Chiropractor observes the level of the medial malleoli (Figure 1). We have observed that many doctors are measuring to the heel level of the patient’s shoes (heels). This is not a valid measure, although, it is very important to observe the pattern of how that patient is wearing down the heels of the shoes. That gives tremendous input into understanding heel strike and rotation. It is imperative during a leg length check to make sure that the legs/knees are in a natural anatomical position (check the popliteal fossa orientation). (Figure 2) The popliteal fossa should be facing the posterior without any lateral or medial rotation. If there appears to be rotation in the presentation of the popliteal fossa, then make sure the femur and hips are in the proper position. If after repositioning, the popliteal fossa continues to present in a non-anatomical position, hip pathology and or femur pathology must be investigated.

Figure 1: Aligning the medial malleoli

Figure 2: Aligning the popliteal fossae

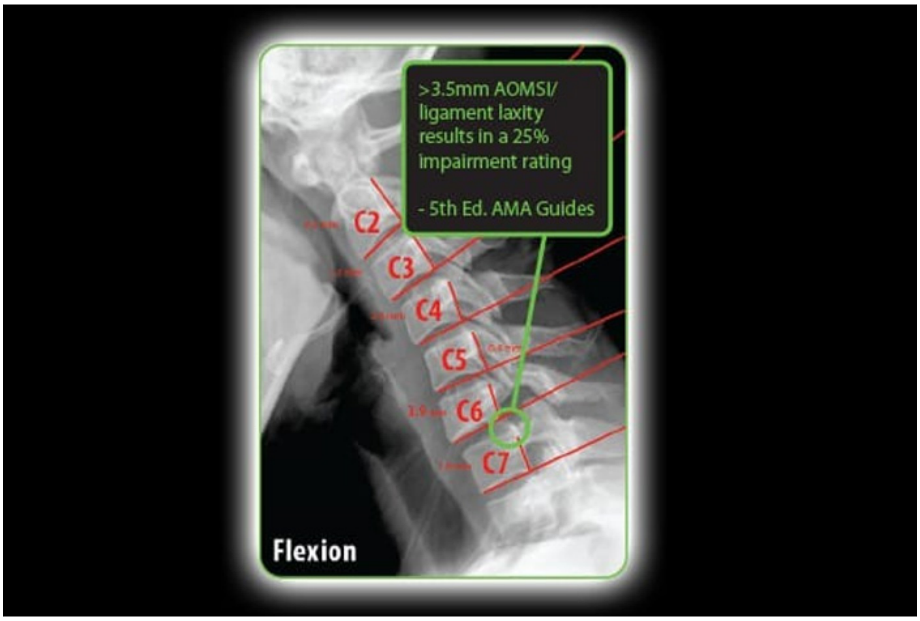
Observing the proper popliteal fossa orientation, the notation is made reporting if the leg is short, for example, 'Left Short'. The patient is then asked to rotate their head to one side, the right first, for example. If now, with the rotation of the face to the right, the legs length is then found to be equal or switched in length it is considered an RCS, Right Cervical Syndrome. The primary structural insult is to be found in the cervical spine or occiput. This process is repeated with rotation of the face to the left side. If the legs only become equal or the short leg becomes long now, it is considered a LCS (left Cervical Syndrome) and again a primary cervical spine / occiput issue. It is possible to have leg length changes with both right and left rotation; this is considered to be BCS (bilateral cervical syndrome, Double Cervical Lock). When a BCS is present one should then question the patient concerning any automobile collisions they may have had. The BCS has a high correlation to whiplash. (3)

Bilateral cervical syndrome and concussion frequently co-occur because the forces responsible for a concussion, especially whiplash, also damage neck tissues.

Spinal ligamental injuries are also highly correlated to spinal intersegmental instability. This leads to overlapping symptoms such as headaches, dizziness, cognitive fog, and balance issues. The neck's connection to the brain means cervical problems can mimic or worsen post-concussion symptoms, necessitating thorough neck assessment alongside brain injury evaluation for effective recovery. (4)

Generally speaking, one should always obtain radiographic studies of the patient when clinically indicated, it is always advantageous to include cervical lateral and flexion / extension views. This allows for an assessment of Alteration of Motion Segment Integrity (AOMSI). This is defined by AMA Guidelines as 'translation': Movement of one vertebra over another exceeding 3.5 mm in the cervical spine or 4.5 mm in the lumbar spine; and / or Angular Motion: A difference in rotation between adjacent segments of 11° or more. The significance is that it is often one of the key factors in the classification as a severe injury comparable to a spinal fracture or fusion, frequently resulting in a 25% whole-person impairment rating. (Figure 3) The AMA Guidelines 6e states that '*AOMSI is always due to trauma, especially acceleration flexion extension injury as forceful neck movement from impacts like car crashes, revealing spinal instability (hypermobility) from damaged ligaments. AOMSI does not occur due to degenerative change only trauma. AOMSI, unlike simple strains do not heal well*' (5)

Figure 3: An example impairment rating



This finding from a simple leg length check may be extremely beneficial for the patient. This because many states use the Discovery Rule, which delays the start of the personal injury statute of limitations (the deadline to sue after a car crash) until the victim discovers, or reasonably should have discovered, their injury and its link to the accident, rather than just the date of the collision. States like California, Illinois, Pennsylvania, Ohio, Oregon, Arizona, Indiana, Massachusetts, New Jersey, Alaska, and Arkansas recognise this rule, though its application can vary. The rule states that '*it's crucial in cases with delayed symptoms, like some whiplash or internal injuries, to ensure fairness when harm isn't immediately obvious*'. This is crucial since every state also has a legal Statute of Limitations (SOL) for personal injury claims from car accidents, setting deadlines from as short as 1 year (Tennessee) to 6 years (Maine, North Dakota), with many states at 2 or 3 years. Some states have rules allowing the clock to start when you discover the injury, as just stated as the discovery rule. This isn't automatic and requires strong medical proof linking it to the crash.

Common Timeframes by State:

- 1 Year: Tennessee.
- 2 Years: Many states, including Florida (recently reduced from 4 years), Texas, Arizona, California, New Jersey, Ohio, etc.
- 3 Years: States like New York, Michigan, Arkansas, Colorado, etc.
- 4 Years: Nebraska, Utah, Wyoming (Missouri is 5 years).
- Up to 6 Years: Maine, North Dakota. (6)

One can appreciate the impact that the proper utilisation of the Derifield Leg Length Test may have on the patient's case, health, condition, and recovery. The initial thought is that there are subluxations in the cervical region causing the leg change. But, how and why? We must understand that there probably are subluxations present, but are they the only provocative stimuli?

Continuing the examination

Continuing in our Derifield examination the knees/ legs are flexed to 90° and the leg lengths are again reported. (Figure 4) If the short leg remains short it is considered a sacral problem and noted as a '-D' (Derifield negative). However, if the short leg measures as long or equal in length it is noted as a '+D' (Derifield positive) or an Ilium problem.

Figure 4: With knees at 90°

At this point we are beginning to appreciate where the primary cause of the imbalance might be. Remember, it is not impossible to have multiple conditions overlapping (comorbidities). We continue in our leg length examination by flexing the knees in the prone position approximating the heels to the gluteal muscle as far as they comfortably move. This is also known as the Webster technique leg test. (7) (Figure 5)

Figure 5: Webster technique leg test

As the heel approaches the gluteal area, we should remember that the natural maximum flexion of the knee joint itself is ~ 150° (Figure 6)

Figure 6: Knee ROM

As the heel approximates the gluteal area while prone, at some point, usually near the 150° point in your knee range of motion (ROM), the hip joint must move into extension, and the ilium must flex anteriorly and superiorly (as noted from the perspective of the PSIS). The Ilium motion we observe as the hip extends, the ipsilateral (same side) ileum rotates anteriorly and superiorly at the sacroiliac (SI) joint. This is part of the normal kinesiological chain

Anterior rotation is part of the normal, coupled movement of the pelvis and spine, allowing for the full range of motion at the hip joint and maintaining stability of the sacroiliac joint. A restriction in this movement can be indicative of sacroiliac joint dysfunction (SIJD), although most times the patient appreciates the discomfort at the knee. This occurs since we are pushing the knee joint past the normal range of motion exerting pressure on the knee joint. So here, if we observe this movement blocked we must assume that the ipsilateral ilium is limited in mobility perhaps by the sacrum. Some practitioners might prefer to make this adjustment at this time before moving on then retest.

The next test we apply is for bilateral lateral motion of the lower extremities into abduction of the lower legs with the concomitant simultaneous medial rotation of both femurs. (Figure 7)

Figure 7: Medial rotation of both femurs

This leg check will provide information concerning the psoas maj., psoas min. and iliacus muscles as well as the femur head / acetabular joint itself. (Figure 8) These muscles will control medial and lateral rotation of the femur.

There will be imbalance in this muscle complex noted when, in the most common condition, one side is hypertonic and the opposite side hypotonic. The hypertonic psoas group will maintain the ipsilateral ileum in a fixed AS position, and limit femoral rotation. The hypotonic psoas group will allow for instability of the ilium / hip/ femur complex and allow for excessive femur rotation, observed in Figure 7 on the right leg.

As we examine the prone or supine patient we will find a foot eversion as well on the side of the weak psoas. Here, we see the foot eversion in the supine position. (Figure 9) and prone in Figure 9a. When on observation we should see symmetrical foot patterns (Figure 10)

Figure 8: relevant musculature

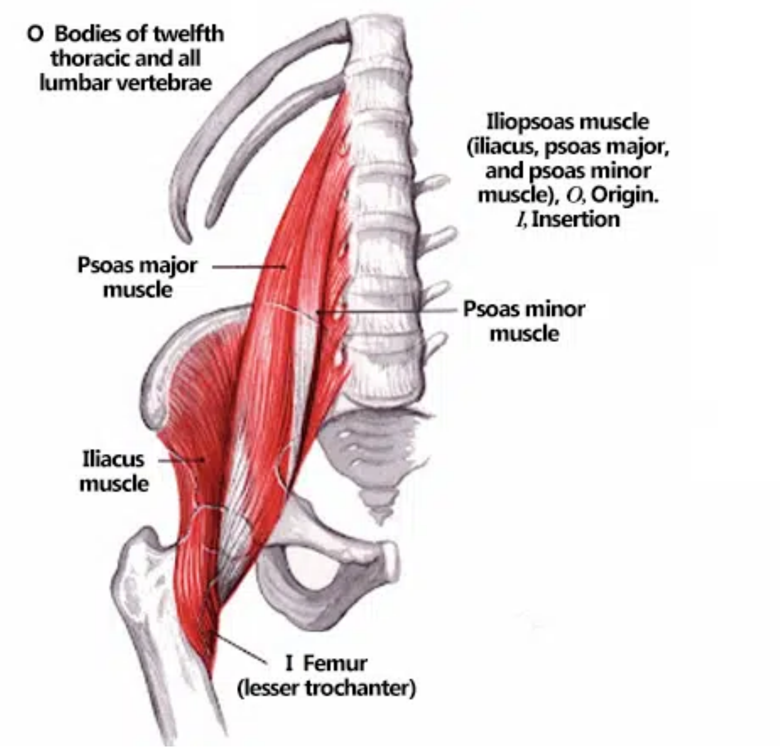


Figure 9a: R) foot eversion in the supine position

Figure 9b: R) foot eversion in the prone position

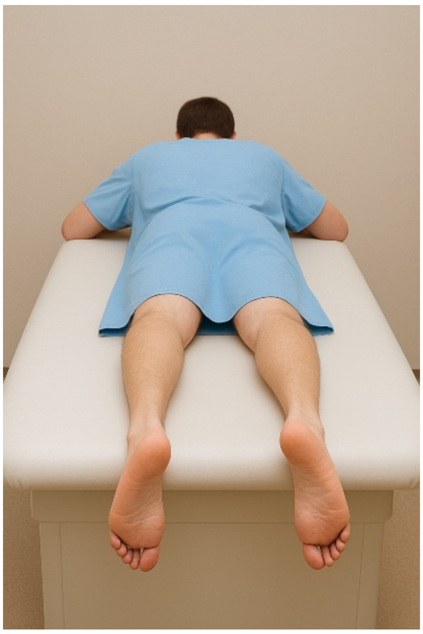


Figure 10: Observation of feet angles

There are times when the psoas muscle presents in bilateral hypo- or hyper tonus, it is rarer but does occur. We should observe the feet to present relaxed in the prone patient at 5 o'clock and 7 o'clock. In the supine observation the feet should present relaxed at 11 o'clock and 1 o'clock. Variation should be suspected as combinations of hypo and hypertonia. (Figure 10)

In the case of bilateral hypotonus of psoas, it is also important to observe the patient while supine. This is because we know that the patient laying on the table will have the table pushing back on the patient's body in both prone and supine. There are conditions where the ilium is locked and does not rock backwards as the table pushes against the ASIS the prone position (Figure 11) as well as when the ilium does not rock forwards as the table pushes against the PSIS in the supine position (Figure 12). This will supply important information as to the structural limitations of the patient. When we observe the bilateral psoas weakness, we should examine the patient's abdomen. Have the patient perform an abdominal crunch. If we observe an alteration in the abdominal midline known as 'tenting', (Figure 13) we can assume that there is a diastasis rectus (Figure 14) and possibly an umbilical hernia. This should be ruled out as this could be related to the psoas weakness.

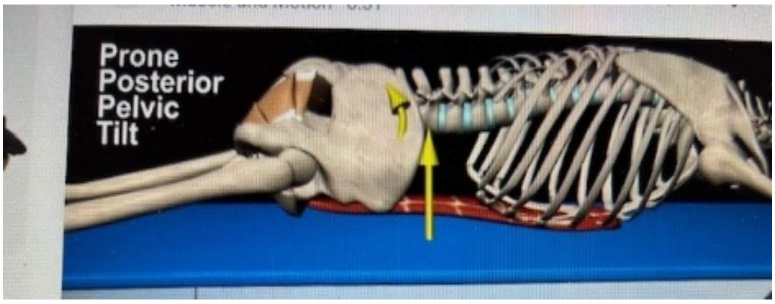


Figure 11: Table pushes against the ASIS the prone position

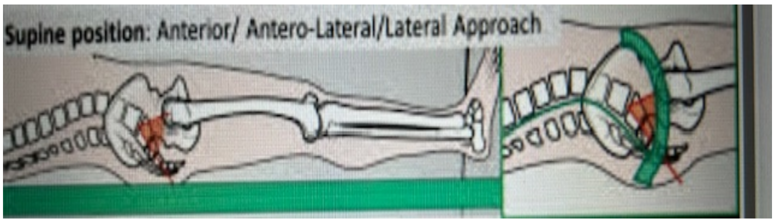


Figure 12: Table pushes against the PSIS in the supine position

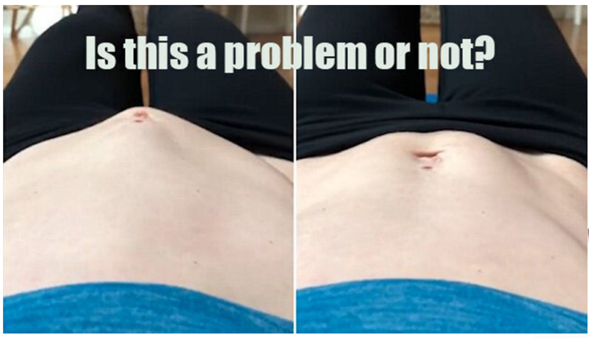


Figure 13: Abdominal 'tenting'

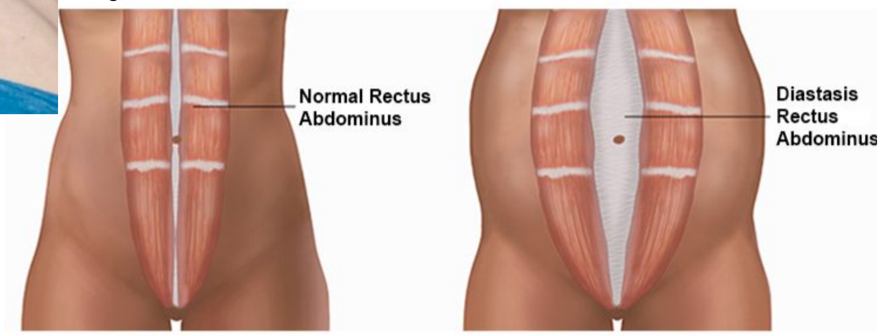


Figure 14: L) normal, R) diastasis rectus

These positions along with observation during ambulation will demonstrate the effect on pelvic and sacral function and will illuminate insight considering nutation and counter-nutation (Figure 15a,15b). (8)

Figure 15a: Sacral nutation and counter-nutation

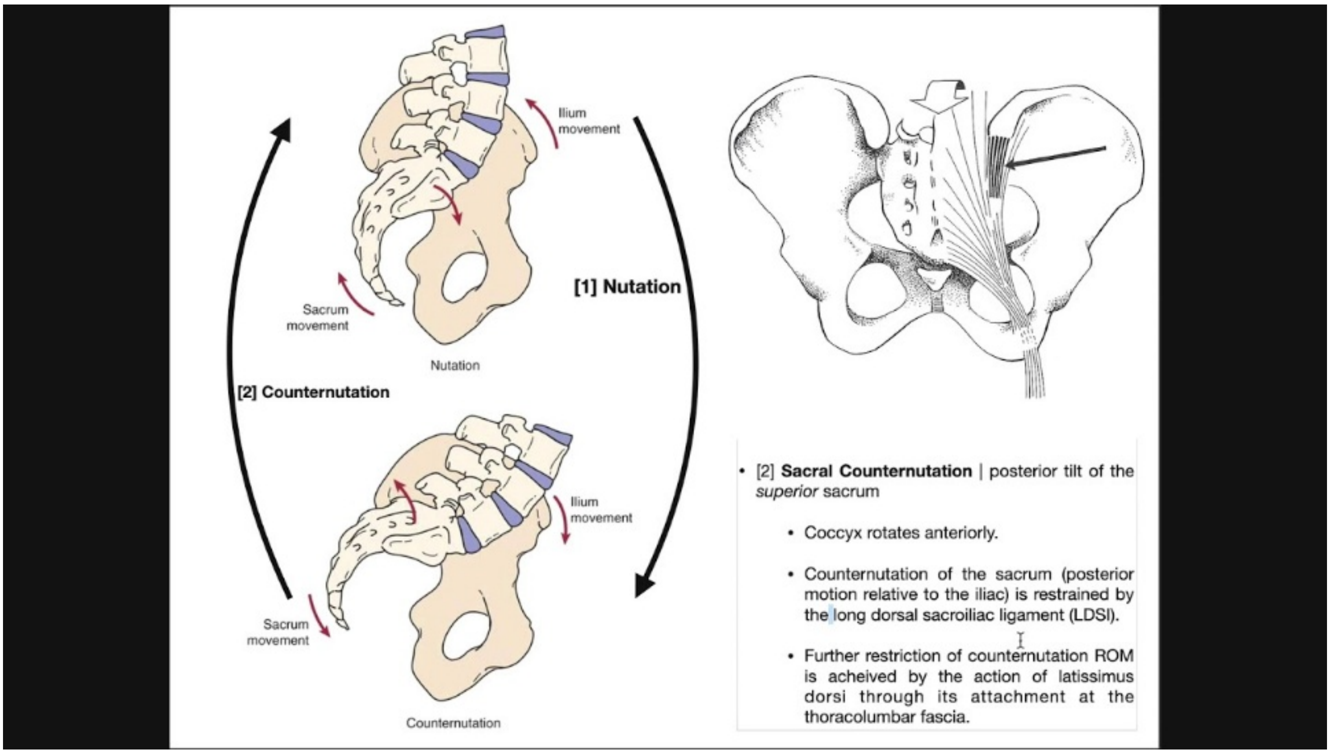
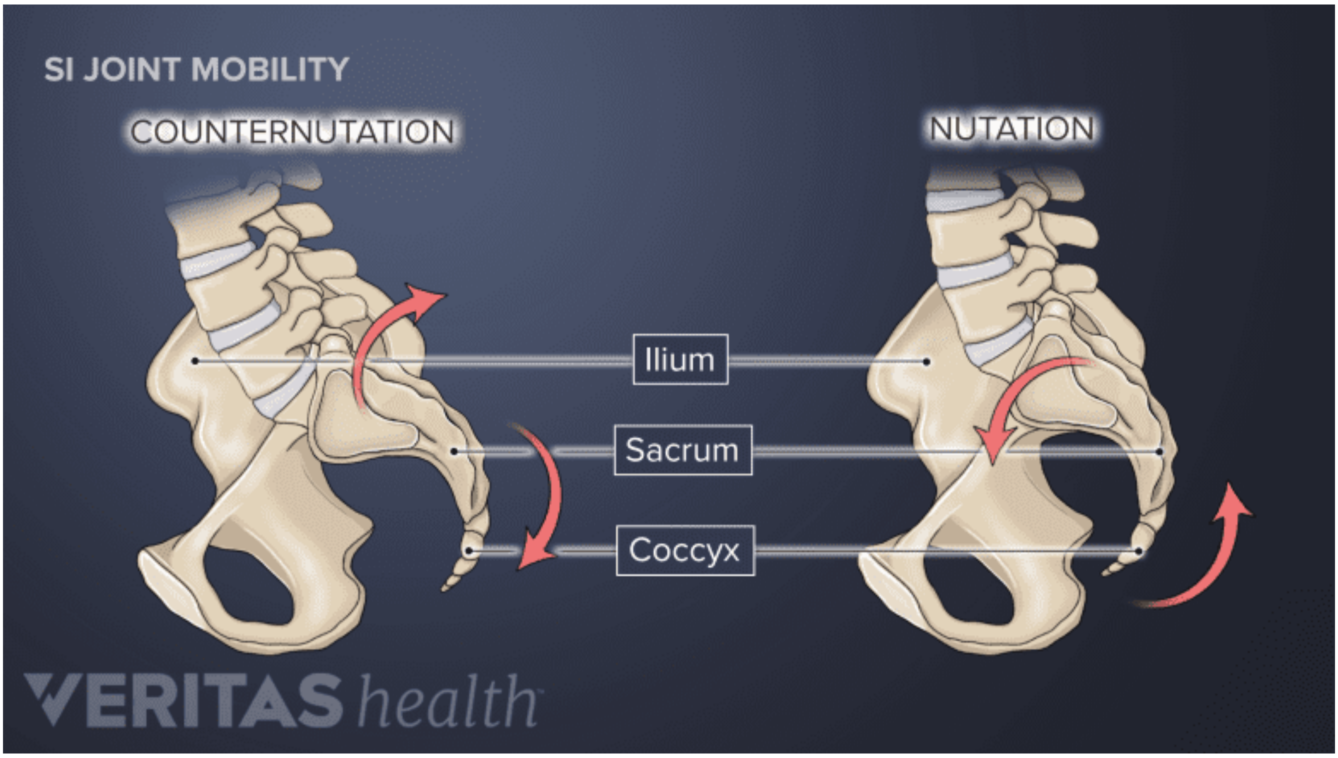


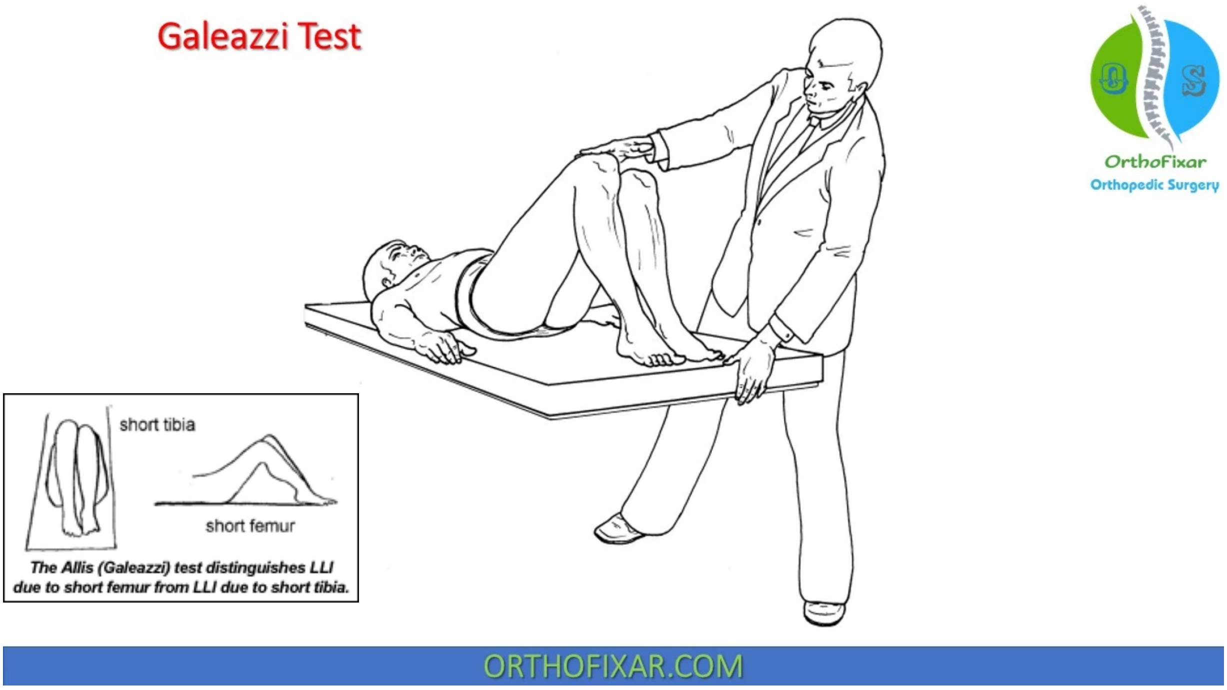
Figure 15b: Sacral nutation and counter-nutation



Memory tip: '**N**utation ~ **N**odding'

To be clear, there are times when there will actually be an osseous aetiology causing leg length disparities. These can be assessed initially without X-ray utilising the Allis (Galeazzi) test. (Figure 16) (9)

Figure 16: Allis (Galeazzi) test



It can be challenging to discern if the leg length disparity is due to postural distortion or an actual longer femur bone or tibia/fibula. There, the x-ray measurement is important.

Discussing people with actual osseous changes in leg length, there have been published studies of approximate prevalences for the general population reported. People with ≥0.5 cm was very common, about 90%. (J Pediatric Ortho), those with a deficiency of ≥ 1 cm are about 15%, (10) deficiency of ≥ 1.5 cm was 6% (AMBOSS Pub.), and finally deficiencies ≥ 2 cm was only 0.1% or 1 per 1000. (11) Understanding this we should check for osseous complications but comprehend that they are rare, in fully grown adults.

However, due to bone growth phenomenon and the asymmetric bone maturation in children and adolescents one must be skeptical of the studies published concerning paediatrics. It has been established that girls display growth spurts peaking earlier than boys, at around 12 - 14 years of age (12) and skeletal maturity is reached around 14 - 16. While boys typically hit peak growth at 14 - 18 years and maturity in many cases until 21 years of age. What has been found is that clinically significant structural differences (≥2 cm) occur in ~ 7 % of healthy children by one study. (13)

However, we do realise that commonly it is reported many children have slightly different foot lengths when purchasing footwear. Usually, the difference could be less than half a shoe size. Although this doesn't result in needing two distinct size shoes (PEDOTHODIS ASSOC. Canada). We should understand that this topic of bone maturation and leg length discrepancy probably goes under-reported in non-pathological cases but would be quite significant in structural musculoskeletal cases. This calls for greater scrutiny, since the commonly cited threshold of ≈ 3–5 mm for leg length deficiencies, often detectable with instrumented gait or force-plate analysis, does cause subtle changes in pelvic rotation and step length symmetry. (14)

As well as bone leg length, we need to understand that another factor in the overall vertical measurement from the foot to the pelvis and, hence, the entire posture, is foot arch height. We should be examining the feet without shoes and socks as we again must be sure as to the nature of the problem causing the leg length discrepancies. A flat foot or an over developed foot arch will change the overall apparent leg length measurement (Figure 17). (15)

Figure 17: The effect of foot-arch height

Ankle issues will also change the foot to lower leg /pelvic orientation (Figures 18 & 19) Both supination and pronation might cause a long leg.

Figure 18: The effect of pronation & supination

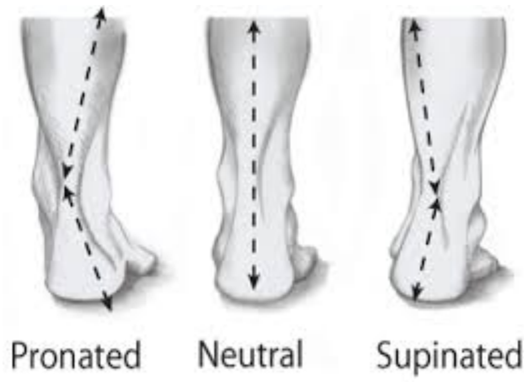
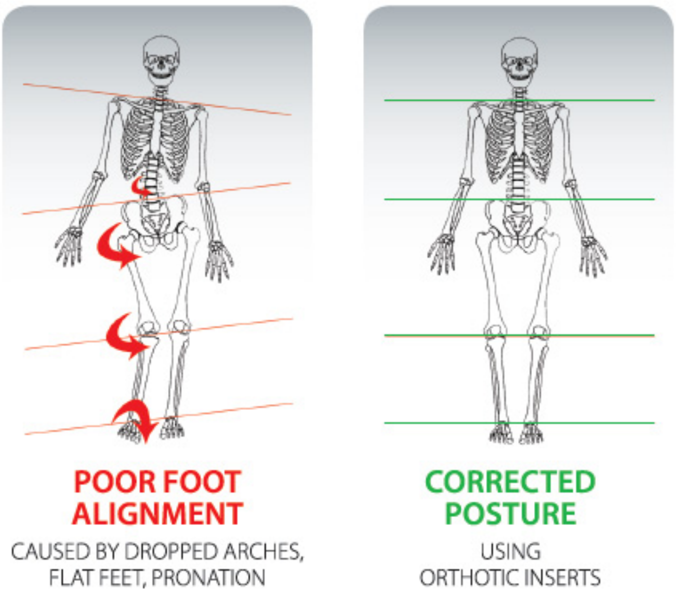


Figure 19: The effect of foot misalignment on posture



When examining the patient supine, one might apply the Allis (Galeazzi) Test to observe osseous discrepancies. If there is no leg length disparity supine while there was in the prone position, we assume there to be a SOT Category 1 or 3 condition. If one finds the leg length disparity only in the supine position, then a Cat 2 should be suspected. (16) The entire SOT process is much more entailed and here we offer only suggestions for action.

Returning to the examination of the patient in the prone position, let us again revisit the changes seen in the Derifield Leg Check. There is a myriad of reasons why head positions might affect the apparent leg length. One is purely a fascial mechanical phenomenon, another is spinal fixation compensation, yet another is neuro-reflexive. We will in this paper attempt to investigate all of the possible connections as best as possible. This, it is hoped, will lead the practitioner to a logical route to the aetiology of the patient's condition.

Considering the fascial effect, we must also understand that there are fascial sheaths connecting every part of the body. These fascial connections can be affected by, or cause torsion onto, all areas of the body. This fascial connection can change the myofascial tension from the tongue / head area all the way to the lower leg and heel area, as observed by this highly detailed human dissection illustrating one continual fascial tissue. (17) (Figures 20a, 20b) Hence this presents another connection between turning the head and the leg length changes. As the head rotates to one side, the fascial tension draws the long sheet of fascia into tension on the contralateral side along the entire fascial sheath to the end of that sheath on the foot/ heel. Another human dissection illustrates that the plantar fascia is intimately connected through the fascia all the way up to the frontalis and eyebrows. (Figure 20) '*From the foot, we can follow the myofascial interconnection through longitudinally, all the way to the skull. It begins with the left plantar fascia through to the Achilles tendon, up the calf to the hamstring attachment (which is in continuity with the sacrotuberous ligament). The fascia continues through the deep layer of the thoracolumbar fascia, to the erector spinae, and ending with the frontalis at the eyebrows*'. (18)

Figure 20a: The fascial plane from tongue to toes

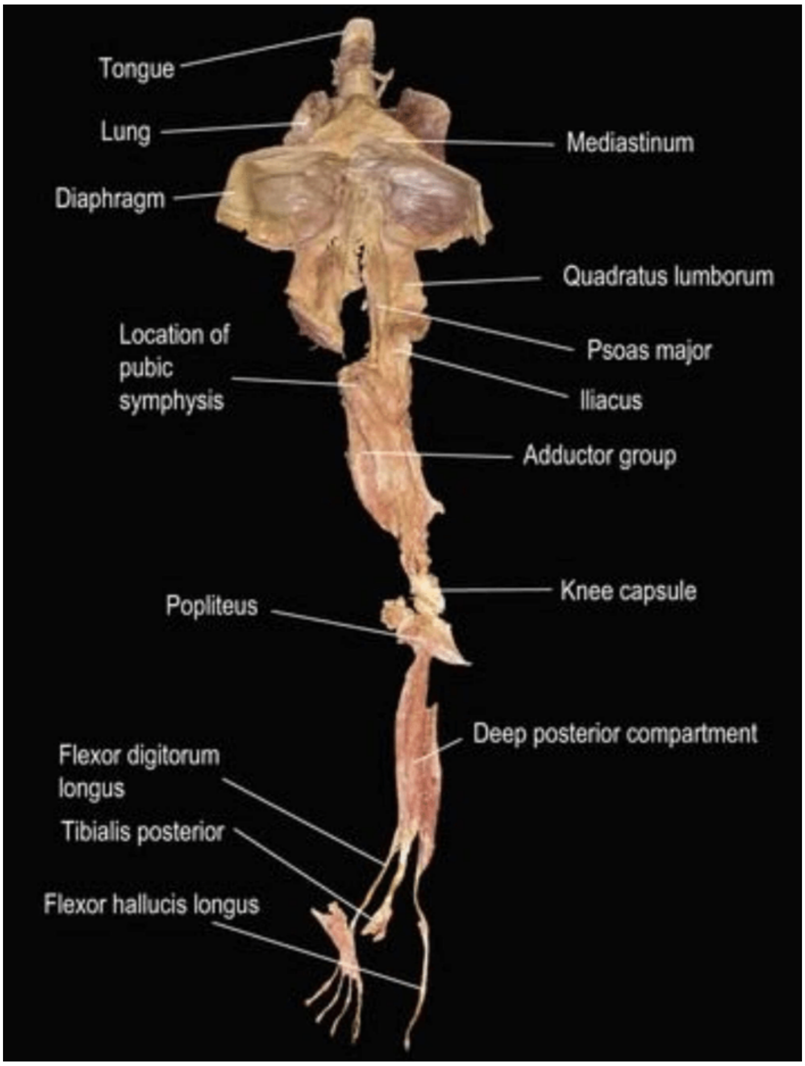
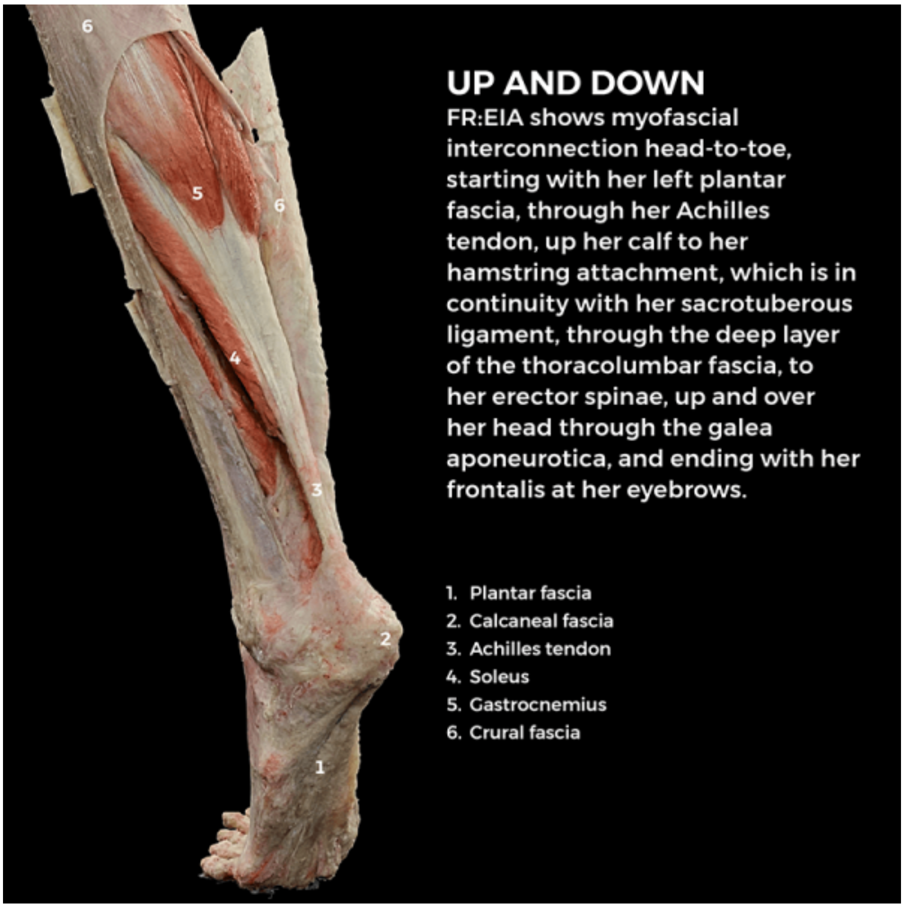


Figure 20b: Fascial connectivity about the leg, ankle, & foot



The body fascia is interconnected and creates a continuous sheet that creates torsion at one end when distortion is introduced to the complete opposite end. (Figure 21)

One can observe that changing the fascial tension by turning the head may very well cause a chain reaction of tension all the way to the foot. (19)

Figure 21: Pliable fascial envelope

Another anatomical connection is a structural one, particularly, the spinal movements. In particular we observe the Lovett brother relationships: an observation made since the early 20th century within the osteopathic and Chiropractic professions. It had been observed that posture and movement require a functional relationship between all parts of the axial skeleton as well as the appendicular skeleton. Furthermore, it had been observed and postulated that the lumbar and cervical vertebrae along with the pelvis and shoulder girdle all maintain a proprioceptive reflex mechanism for upright balance as well as mobility.

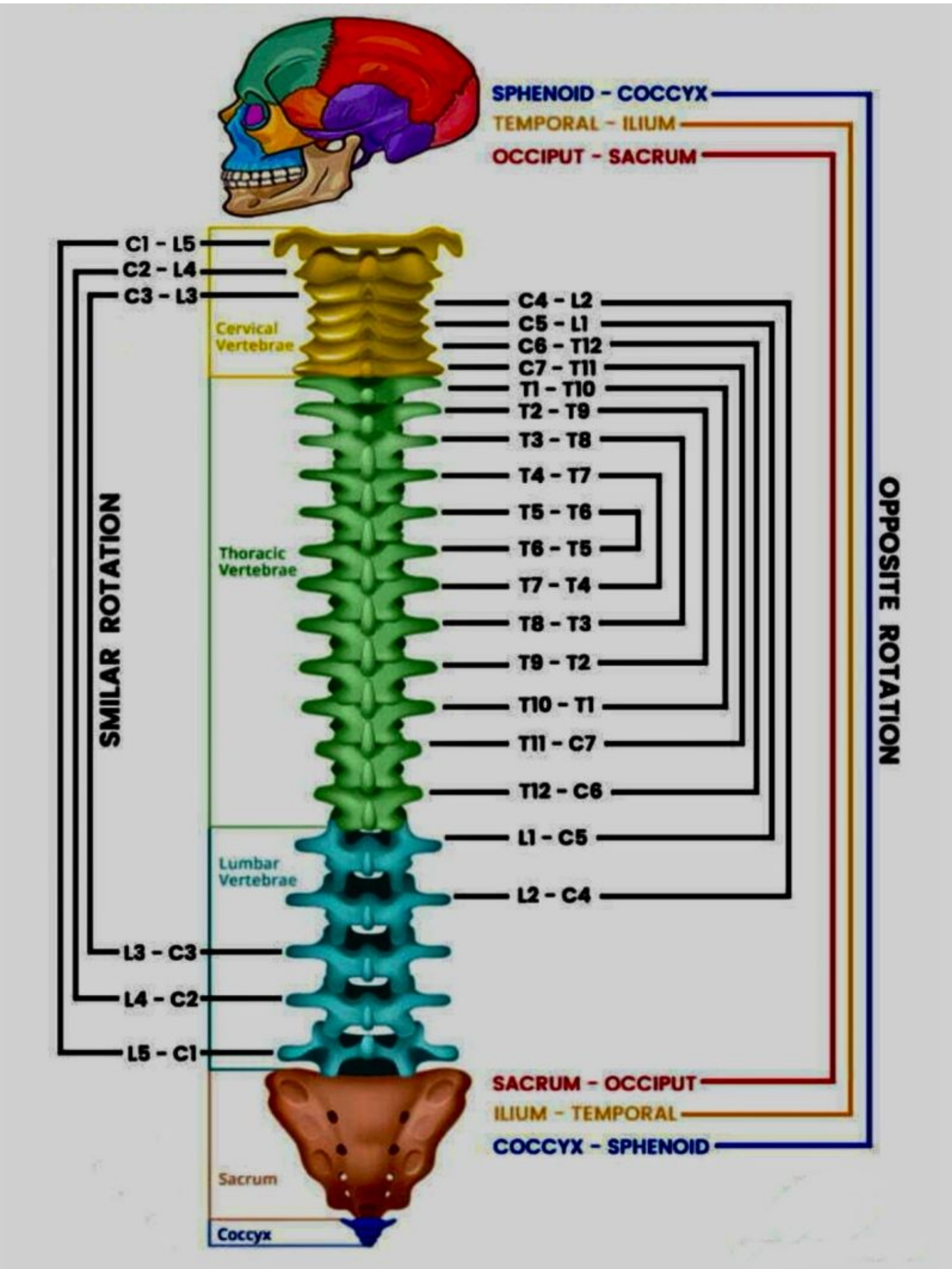
This work of Robert W Lovett's (Figure 22) bears his name has been discussed and studied by many including Walther who noted that '*The spine appears to function with a specific harmonious movement as an individual walks, runs, and otherwise performs daily activities. The vertebra working in conjunction with each other, such as the 1st lumbar and 5th cervical, are known as Lovett Brothers*'. Dr Blum, of SOT-USA reports on information concerning the basics of Sacro Occipital Technique (SOT) implies '*DeJarnette, a Chiropractor and osteopath, found a similar relationship between the sacrum and occiput, as well as between the cervical and lumbar vertebrae. He described that a relationship exists between the atlas and the 5th lumbar vertebra, axis and the 4th lumbar vertebra and so forth, following that pattern all the way to the mid thoracic region*'. DeJarnette called this relationship 'R + C' (resistance and contraction) factors and found that each vertebra within a pair affected one another. (20)

There are studies investigating whether the Lovett relationship is spinal or Spino muscular. Some results suggest that during locomotion, rather than acting to stabilise the head against the effects of inertia, the superficial muscles of the neck, as monitored in one study, was found to help to stabilise the pelvis against torques imposed by the extrinsic muscles of the legs at the hip joint. It was suggested that a division of labor may exist between deep cervical muscles, that presumably provide postural stabilisation of the head, versus superficial cervical muscles that provide core stabilisation against torques applied to the pelvic and pectoral girdles by the extrinsic appendicular muscles. (21)

The diagram (Figure 22) demonstrates how distal structures are bio-mechanically connected to do either a similar or opposite rotation. It's less about motion, but more about the fact that these structures are linked. The spinal segments(vertebrae) apparently rotate the same, and are coupled from the ends of the spine into the middle meaning: C1 couples with L5, C2 couples with L4, C3 couples with L3, C4 couples with L2 and so on until they meet in the middle of the thoracic spine when T5 and T6 couple. Personally, I found this coupling of T5 and T6 intriguing since the T6 region of the spinal canal is where we find the narrowest section of the spinal canal in the entire spine. (22) Logically, this area would be able to tolerate the least amount of counter-rotation.

The relationship between the skull and cranial bones at the top of the spine and the sacrum, coccyx and pelvis at the bottom of the spine are in antagonistic biomechanical relationship. In these relationships as seen in the diagram, the sphenoid (keystone to the cranial vault) and the coccyx are coupled, which may explain why sometimes people who have a fall on their coccyx end up with severe headaches and what makes a tethered coccyx such a bothersome condition. We also have the temporal bone that couples with the ilium and the occipital bone that couples with the sacrum. All these motions are very slight and when we start walking the relationships change again as we start rotating, which starts another cascade of coupled cranium-pelvis motion and opposite movements of the rib cage (a hugely important structure).

Figure 22: Lovett brother relationships



There is also the system of neurological reflexes that we know to maintain the posture and facilitate motion. Some reflexes are primitive and may or may not still be affecting the neurological function of a grown child or adult. Considering the neurology of posture there are a few reflexes that might cause changes in pelvic position / leg length measurement through the change in head position or eye position.

These primitive reflexes, it is believed, are overridden by cerebral higher centres, but never really disappear. They can be observed again during stroke, or cerebral injury such as TBI or severe brain stem concussion. For example, we have seen extensor finger patterns after a severe brain injury (known as decerebrate posturing or fencing response). These are involuntary motor response caused by trauma to the brainstem, which leads to uncoordinated muscle activation and the unsuppressed activity of primitive reflexes. (23, 24, 25) This we have seen in more than a few football concussion cases. (Figure 24, 25)

Smooth-pursuit eye movement or the presence of nystagmus has an effect on overall posture while standing one leg affects balance. In particular, in the smooth pursuit eye movement with one leg standing, there were higher requirements for balance when the eyes and head move in the opposite direction and less difficult balance when the eyes follow the head in gaze. Therefore, this movement can be recommended to people who need to enhance their balance ability. (26) (Figure 23) It also demonstrates the effect visual activity has on bodily posture.

Figure 23: Pursuit ans nystagmus assessment

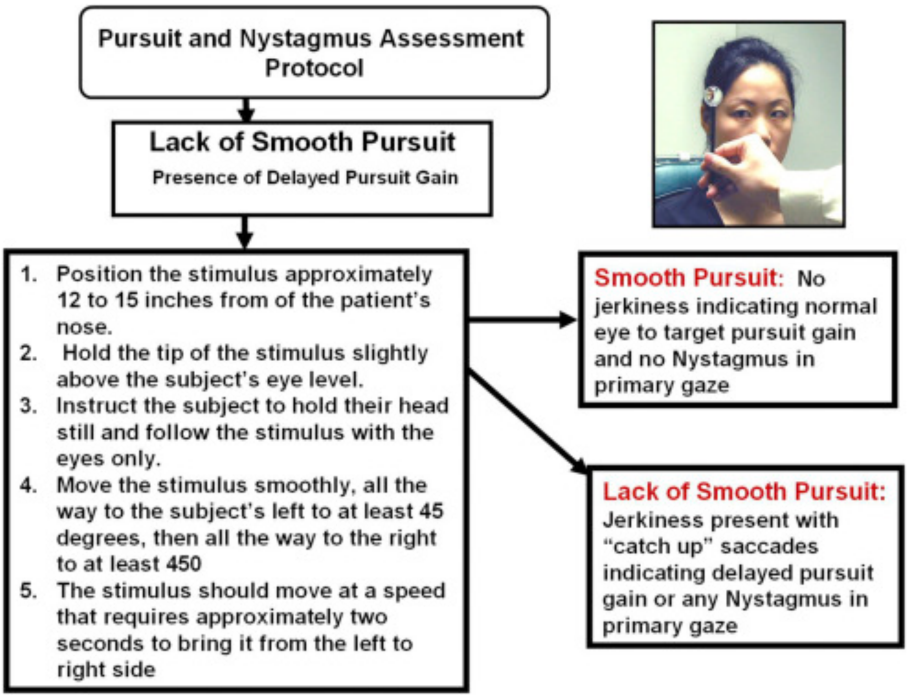


Figure 24: Unsuppressed activity of primitive reflexes

Figure 25: Football concussion

The Oculocephalic Reflex (Doll's Eyes), checks brainstem function by moving eyes opposite of head turns. The related Cervico-Ocular Reflex (COR) stabilises gaze with neck movements, while in compensation when a person moves their body(trunk), but not their head, the COR generates eye movements that are equal and opposite to the body's rotation, establishing an intimate connection between overall posture and stabilising the visual image on the retina. (27)

We have observed that the patient's eye position will play a role in which muscles in the limbs, upper and lower, will be facilitated or de-facilitated in preparation for movement. As the eyes move so the head does follow, look before you leap so to speak. So, at any time a portion of our muscles are contracted, a portion is ready to contract, and a portion are resting. This allows for quick reaction. The agonist (Prime Mover) is the main muscle that contracts from eye position. The antagonist is the opposing muscle that relaxes to allow movement but provides control and stability. The Synergists are helper muscles that assist the prime mover or stabilise joints. (28)

Eye movement and neck muscle activation are intimately linked through the vestibulo-ocular reflex (VOR) and proprioception, coordinating to stabilise gaze and orient vision, with neck muscles sending signals about head position that help the brain interpret eye movement and control posture, a connection crucial for smooth vision but often disrupted in conditions like whiplash. (29) While cervical conditions and visual links seem obvious, eye tracking reveals strong links to low back pain (LBP). (30) It has been reported that poor eye movement control (like slow pursuits, bad saccades) can be triggered by back muscle tension as the body compensates for visual instability, a core issue in chronic LBP.

When you move your eyes, neck muscles subtly adjust, and conversely, neck muscle vibrations can trick your brain into perceiving eye movement, showing how neck proprioception (body sense) and vision work together to define where you're looking. (31) Gaze Control is when the brain processes signals from both your eyes and neck muscles to maintain a stable visual field, allowing you to scan your environment without getting dizzy or losing focus. Fluctuations in this modulation of the EMG activity by eye position can be observed. When the head is free to move, the muscles show phasic discharges having similar preferential orientations. For a given muscle, this orientation covers a quite large angle: many muscles contribute to a given movement. The timing of the discharge of the different muscles as a function of the direction of the head movement was examined. (32)

The cervico-ocular reflex (COR) stabilises the eye in response to trunk-to-head movements. The COR is elicited by proprioception of the facet joints of the cervical spine and deep muscles of the neck. There is continuity between the deep neck muscles and the deep low back muscles. This continuity is primarily established through the deep intrinsic muscle groups of the spine and the enveloping fascial networks that run the entire length of the vertebral column, from the skull to the sacrum. (33) The strength of the COR can be modified as a result of altered visual input. (34, 35)

This interaction between eye movement and neck muscle activity is likely to influence the control of neck movement which in turn affects pelvic balance. (36) (Figure 26) During neck rotation SternoCliedo, Mandibular, and Multifidus fEMG was less when the eyes were maintained with a constant intra-orbit position that was opposite to the direction of rotation compared to trials in which the eyes were maintained in the same direction as the head movement. The inter-relationship between eye position and neck muscle activity may affect the control of neck posture and movement. Eye movements trigger specific neck muscle contractions, especially deep neck flexors and rotators, to stabilise your gaze, a system crucial for posture and balance. (37)

The data shows that compensatory eye, head, and body movements stabilise gaze during straight walking. While orienting mechanisms direct the eyes, head, and body. (38) Slow eye movements increase sway, possibly by an efference stimulation, which explains why spontaneous nystagmus causes postural imbalance. (39) Upper vs. lower cervical spine might result in tonic neck reflex-induced alterations in the activity of the lumbar paraspinal musculature and effect Pelvic orientation. (40, 41)

The Primitive Tonic Reflexes appear in infancy and are integrated into normal movement patterns as the infant develops during the first 6 - 12 months of life. These reflexes are thought to help the infant learn to organise motor behaviour. Integration refers to the inhibition by higher centres of neurological control which modify the reflex in such a way that the pattern of response is no longer stereotypical. The reflex does not disappear; it may reactivate under stress or during activities requiring great strength. If these so-called primitive reflexes are persistently displayed beyond the expected or typical developmental period, their presence has been considered an indication that underlying developmental or neurological issues may exist. When these reflexes do not integrate, they may interfere with a child's development of more advanced motor skills. (42)

Looking at more of these primitive reflexes and their role in the development of posture, feeding, and mobility we need to understand them as they are the undercurrent over which our developed brain functions. Many of these reflexes do in fact reappear in times of upper neuron impairment as stroke, and even as noted in times of severe stress. For example, the Tonic Reflexes present during infancy. The Asymmetrical Tonic Neck Reflex (ATNR) begins at about 0 - 2 months and is thought to be integrated by 4 - 6 months. The stimulus is rotation of the head. The response to the head rotation is the arm and leg on the ‘jaw’ side extends. Arm and leg on the ‘skull’ side flex. The Importance for Baby is to assist with early eye-hand regard, provides vestibular stimulation, changes the distribution of muscle tone. This facilitates the body positioning for feeding. Many times, in later life when due to injury certain muscles are de-facilitated, or not working in their neurologically functional muscle group, we find that recruitment begins to take place and older neurological connections are invoked. (43)

Discussing the Tectospinal Tract (Major Pathway), its origin is located in the Superior colliculus (SC) (deep layers). These fibres decussate (cross midline) in the dorsal tegmental decussation. Then descend in the brainstem and cervical spinal cord terminating in the Upper cervical spinal cord (mostly C1–C4). This tract coordinates reflexive head and neck movements with eye movements and influences the motor neurons and interneurons controlling suboccipital muscles, (e.g., rectus capitis posterior major/minor, obliquus capitis muscles). This is the primary tract connecting SC output to upper-cervical musculature.

The Medial Longitudinal Fasciculus (MLF) whose role is gaze posture integration. It links eye movement control centres with cervical spinal motor circuits. It connects SC to oculomotor nuclei, vestibular nuclei, and cervical spinal interneurons. While the MLF does not originate in the SC, the SC projects to the gaze centres (e.g., paramedian pontine reticular formation, vertical gaze centres) that feed into the MLF. This allows eye movements to automatically modulate upper-cervical muscle tone which pairs with pelvic movement. (44)

The Tectoreticulospinal Pathways where we find the SC sends projections to the pontine and medullary reticular formation. From there, Reticulospinal Tracts descend bilaterally to cervical spinal segments influencing postural muscles of the neck including suboccipital muscles. This provides sustained tone adjustments linked to visual orientation and attention. These tracts are major contributors to bodily postural adjustments following eye movement commands. (45)

Continuing with the Tectovestibular Pathways (Indirect), SC also influences vestibular nuclei, which project via the Medial Vestibulospinal Tract (MVST) and strongly targets upper cervical motor neurons (C1–C4). This controls head stabilisation, righting reflexes, and eye–head coordination. This pathway helps the neck adjust when visual motion signals from the low back require head stabilisation. (46)

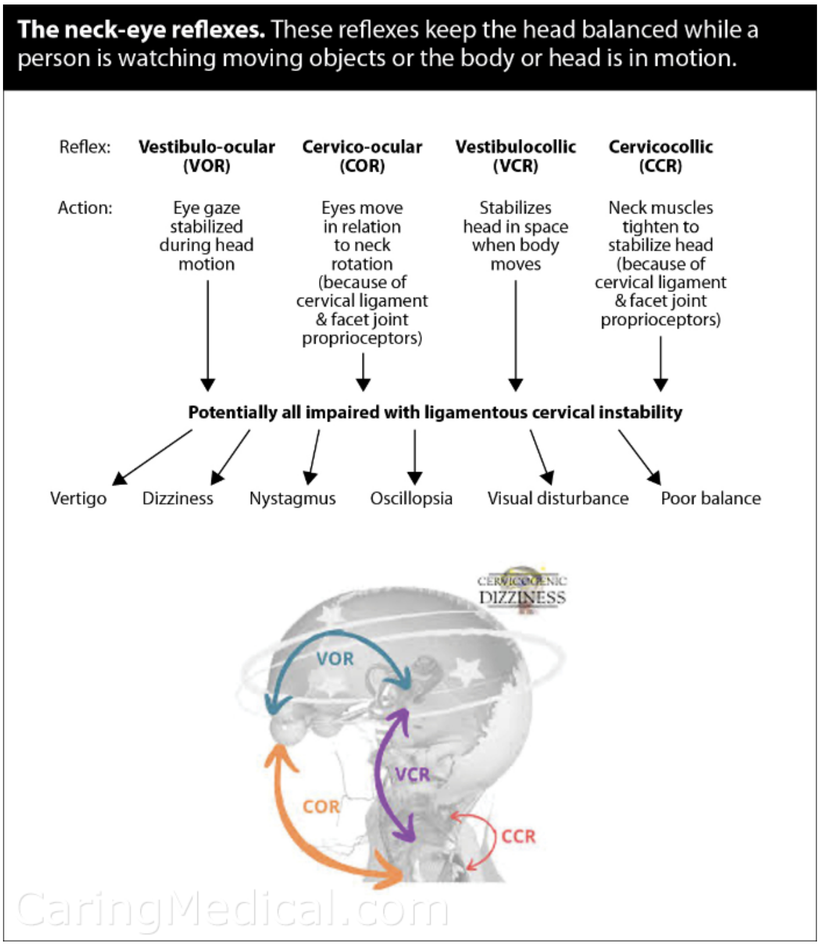
The Tectovestibular Pathways (Indirect). SC also influences vestibular nuclei, which project via the Medial Vestibulospinal Tract (MVST) Strongly targets upper cervical motor neurons (C1–C4). This controls head stabilisation, righting reflexes, and eye–head coordination. This pathway helps the neck adjust when visual motion signals from the low back require head stabilisation. (47)

The reticulospinal tract is crucial for maintaining upright posture by subconsciously controlling extensor muscles against gravity, providing baseline muscle tone, and making rapid adjustments for balance. Integrating sensory input from the vestibular system, which will be affected by head position, cerebellum, and proprioceptors in the cervical facets and cervical musculature, are utilised to stabilise the body during movement and prevent falls.

The medial and lateral pathways control flexors and extensors, forming the stability needed for skilled voluntary actions. Its function is vital for everyday balance and recovery from neurological injury maintaining balance during shifts in body position or external disturbances. The tract makes anticipatory adjustments, preparing muscles for upcoming movements to prevent imbalance before they happen (e.g., when you decide to reach for something, or eyes glance in incoming object).

The Medial Reticulospinal Tract originates in the pons and medulla, travels down the front (anterior) of the spinal cord. It generally stimulates extensor muscles (like those in the back) and inhibits flexors, crucial for axial posture. The Lateral Reticulospinal Tract originates from different brainstem nuclei, travels down the anterolateral cord. It tends to facilitate limb flexors and inhibit extensors that are important for limb coordination during movement. (48)

Figure 26: Neck-eye reflexes



> We have observed that due to the complex neural wiring between the eyes, the superior colliculus in the midbrain and the suboccipital muscles, eye movements constantly impact the tone of the upper cervical musculature which we have seen impact the low back and pelvic positions.

This has been called the gaze–posture coupling system, where eye movements and head/neck movements are coordinated throughout the body. The gaze-posture coupling system describes the continuous, coordinated interplay between where you look (gaze) and your body's orientation (posture) to maintain balance, gather visual information, and guide actions, showing how head/eye movements stabilise vision via the Vestibulo-Ocular Reflex (VOR) while the entire body sways and adjusts. (49)

Less obvious reflexes are the sucking and rooting reflexes. They begin to develop in utero as the sucking reflex for example begins at around 32 weeks of gestation and involves babies or automatic need to suck when something as the finger or thumb is in its mouth. The rooting reflex which involves turning the head and opening the mouth when the side of the mouth is touched is triggered by the sucking reflex. We observed in these reflexes sucking and rooting reflex in utero that the stimulation to the mouth area of the foetus causes the lower end of the foetus to align itself with the head area aligning the foetus for better rooting and sucking. While the sucking and rooting reflexes themselves are facial-oral responses, their abnormal presence in older children and adults, as previously mentioned, can be part of a larger pattern of retained primitive reflexes. The persistence or re-emergence of multiple primitive reflexes is associated with broader issues, including poor muscle tone, coordination problems, and atypical posture and gait, as mature postural reflexes may not have fully developed or integrated to take over normal motor control functions.

After a concussion or TBI, the brain's higher functions can be temporarily overwhelmed, causing primitive reflexes, like the rooting reflex (head turning to stimuli) or the fencing response (Asymmetrical Tonic Neck Reflex - ATNR), to re-emerge, disrupting normal posture, balance, and coordination. These reflexes are usually integrated early in life, but brain injury can reactivate them, leading to fogginess, dizziness, and abnormal motor and gait patterns that affect sensorimotor control and posture, indicating neurological disruption. (50)

The upright posture reflex, also known as the righting reflex, has the main function to maintain an upright posture and balance in response to gravity and movement. It is an involuntary automatic process that uses sensory information from the eyes, the ears and muscles to trigger subconscious muscular response ensuring the body remains aligned and upright when disturbed. The Righting reflex develops after birth and becomes a fundamental part for postural control in life. It is essential for balance and coordination. The key components are, the Labyrinthine Righting Reflex, we have discussed, which uses inner ear input and output from the head; the Optical Righting Reflex, which uses vision to orient the head and then the entire body; and the Body/Neck Righting Reflexes that are body-driven reflexes that follow the head's orientation. (51)

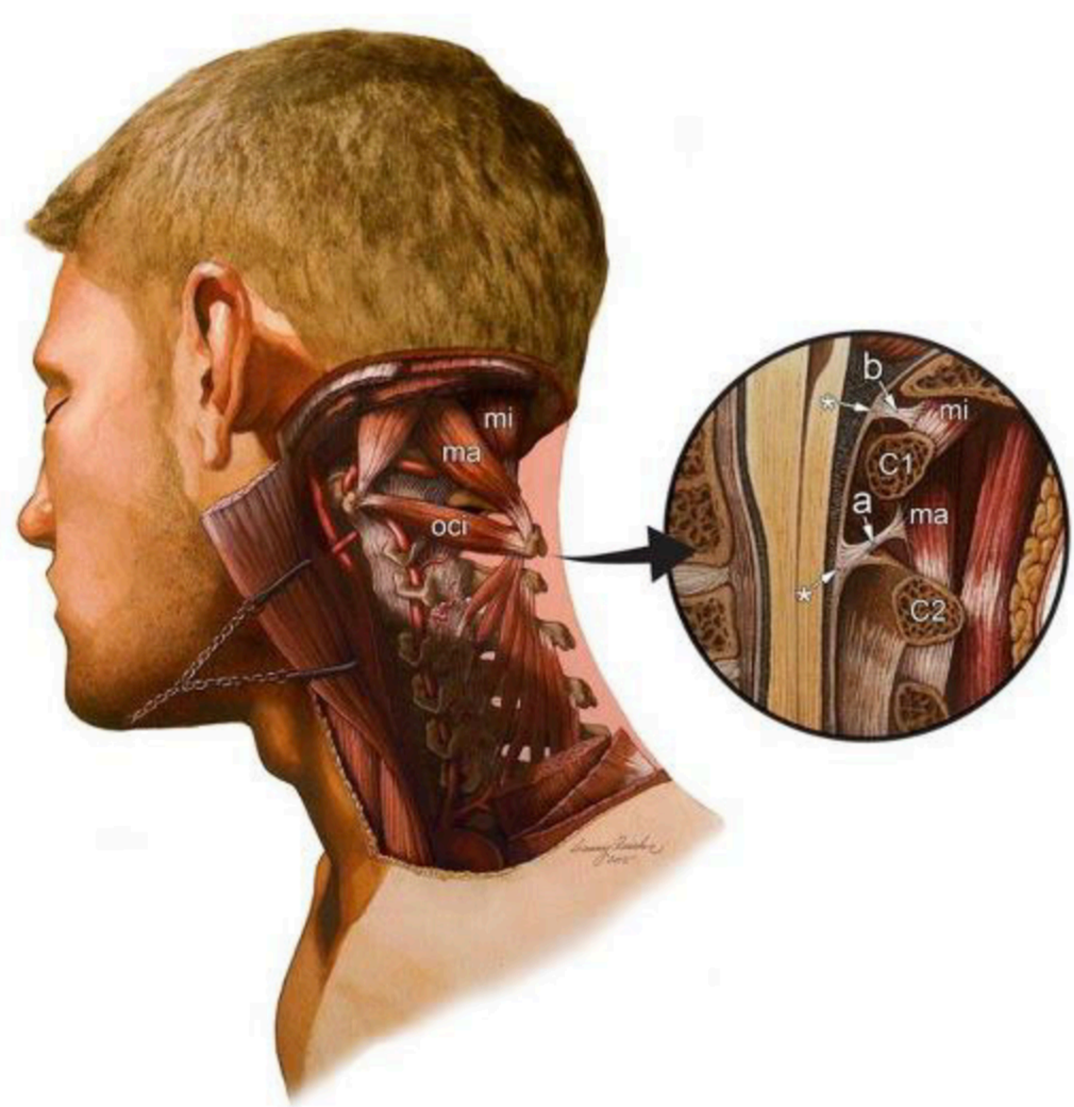
The head righting reflex activates the postural rather than primitive class of reflexes. Once developed this reflex is designed to be active in functioning throughout our lives. It supports stamina, visual processing, and efficient recovery from head neck and back injuries. It is an automatic system that keeps your head upright and level with the horizon, using input from your inner ear (vestibular) and eyes (ocular) to adjust head and neck muscles, forming the foundation for balance, posture, and coordinated movement, helping one to sit up, roll over, and maintain visual focus despite body shifts. (52)

It functions through a set of reactions for keeping the head and, therefore, eyes perpendicular to the ground. It causes muscle adjustment to maintain the body moving to accomplish this as the head moves in the opposite direction of the body's tilt. As an example, in the general the individual's head and shoulders moves to the left the pelvis should automatically go slightly to the rights to maintain midline position. If the individual tilts forward at the head and shoulders, then the pelvis should move back.

This reflex helps develop proper balance coordination visual perception. In individuals with autism, the head writing reflexes are often underdeveloped. The reflex can be reinstated and increased with neck injuries such as whiplash. (53)

We can observe how poor posture is often seen as a reciprocal relationship between head and pelvic position and can evolve forward head position. Anterior pelvic tilt will cause exaggerated low back curve anterior pelvic tilt and create a cervical spine in extension. The 'Head-pelvic reflexes' can refer as well to how the head and pelvis movements are coordinated, such as the pelvo-ocular reflex uses head position to orient the pelvis. It can also describe how the asymmetrical tonic neck reflex (ATNR) can influence pelvic symmetry during movement, as discussed in research from National Institutes of Health, or the integrated development of postural reflexes which allows for the separation of shoulder and pelvic movement.

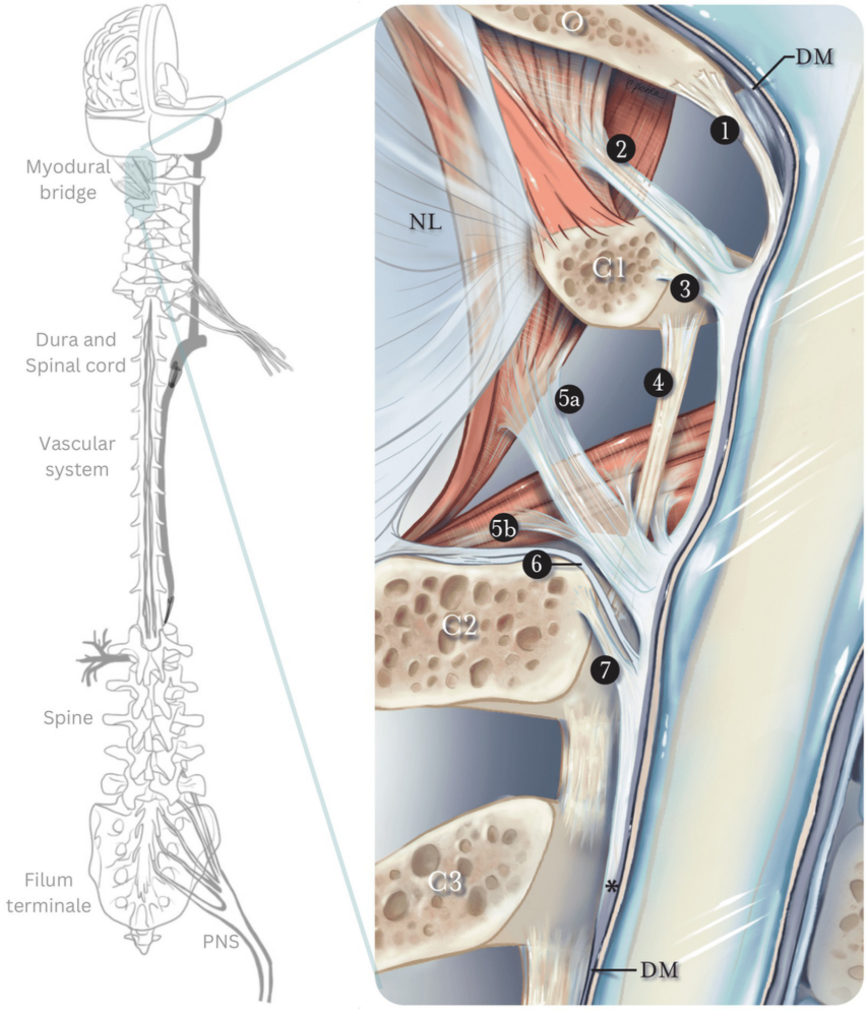
Figure 27: Showing upper cervical structures



Collaborative Illustration by Frank Scali and Danny Quirk

Another major factor in head-neck-body connection is the myodural bridge (54) (Figures 27 & 28) The myodural bridge links suboccipital muscle fascia and the dura. These myodural bridges provide passive and active anchoring of the spinal cord. They may also be involved in a dural tension monitoring system to prevent dural infoldings and maintain patency of the spinal cord. The Myodural bridge and its connections to the dura and spine are complex and may have complications within the calvarium. (Figure 28) 'The posterior atlanto-occipital membrane (PAOM) (1) extends from the occiput and coalesces with the dura mater at the cerebrospinal junction. The superior myodural bridge (2) merges with the superior vertebrodural ligament (3) of the atlas and fuses with the PAOM at the level of the atlanto-occipital interspace. The inferior myodural bridge comprised of the rectus capitis posterior major fascia (5a) and obliquus capitis inferior fascia (5b) courses between the atlanto-axial ligamentum flavum (4) as bundles of dense fibres. The inferior myodural bridge fuses with the PAOM. The nuchal bridge (6) merges with the inferior vertebrodural bridge (7) and attaches to the PAOM. The PAOM terminates at the level of C3 after this transition point (*). The dura mater (DM) continues as an independent structure after that. O, occiput; C1, atlas; C2, axis; C3, third cervical vertebra; NL, nuchal ligament; PAOM, posterior atlanto-occipital membrane'. (Adapted from Scali et al.) (Figure 28)

Figure 28: Showing dural bridges and connections. From Frontiers in Neurology

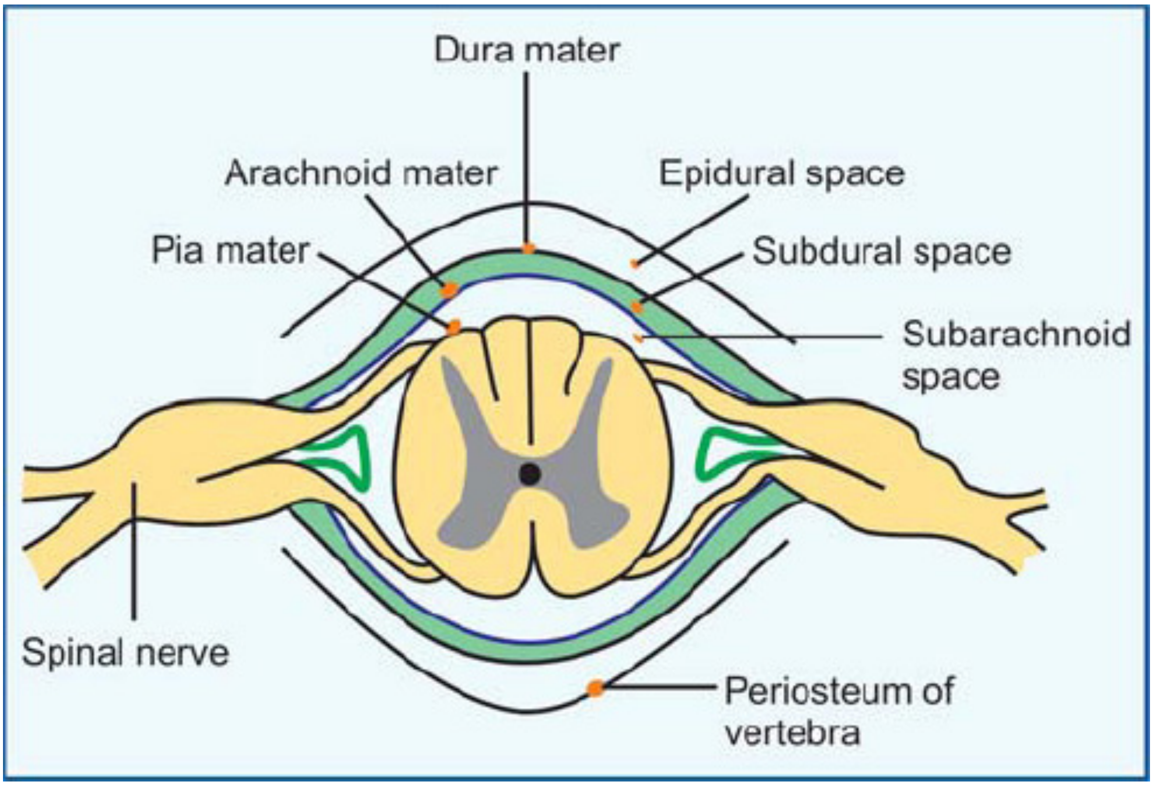


Modulation of dural tension may be initiated via a sensory reflex to muscular contractile tissues. Unanticipated movements such as hyperflexion extension injuries (whiplash) stimulate deep suboccipital muscles and transmit tensile forces through the bridge to the cervical dura. A complication of myodural torque appears to be due to its connection to the periosteum of the vertebral canal. The inter-canal periosteum connects to the outer layer of the dura mater, forming the dural sac, but in the spinal canal, the dura has only one (meningeal) layer because the vertebral periosteum acts as its outer layer, with a space (epidural) filled with fat and veins in between, while the dura itself fuses only to the bone at the skull base and coccyx. Meningeal torque, complicated by myodural bridge aberrations or tension on the dural sac (the membrane holding the spinal cord), can create a connection between neck movement (like turning the head) and lower back pain, often through the spinal cord's tethering system, where neck issues (muscle tension) pull on the dura, transmitting tension down the spine, potentially causing lumbopelvic positional shifts, non-specific low back pain and headaches, sometimes related to conditions like

CSF leaks or connective tissue issues, highlighting a shared central pathway for common spinal pain. (55)

Here, we observe the complication of myodural torque due to its connection to the periosteum of the vertebral canal. The inter-canal periosteum of each vertebra connects to the outer layer of the dura mater, forming the dural sac, so, in the spinal canal, the dura has only one (meningeal) layer because the vertebral periosteum acts as its outer layer, with a space (epidural) filled with fat and veins in between, while the dura itself fuses only to the bone at the skull base. (56) (Figure29)

Figure 29: Cross-section showing spaces and relationships



Conclusion

This paper has attempted to explain the importance of the proper procedures, the protocols, and the possible findings related to leg length checks. An explanation was presented as to how those findings can be physiologically justified. Factors such as fascia, muscle, spinal structure, dural torsion, osseous growth, and neurological reflexes were substantially discussed.

It is our sincere hope that upon reading this work practitioners will come away with a new respect for this tool, making leg length checks a pivotal procedure in their office protocols, and comprehend the benefit of the information gleaned from these tests.

Gilbert Weiner
DC, LST, FFCLB
Adjunct Research Faculty
Northeast College of Health Sciences
Private Practice, Bellingham , MA
drweiner@hotmail.com

Cite: Weiner G. The Leg Length Check and its importance to the complete practice of Chiropractic. Asia-Pac Chiropr J. 2026;6.4
www.apcj.net/papers-issue-6-4/#WeinerDerifield

Grok prompt

If you have Grok installed, then here is the prompt to review this paper and test your understanding with a 5 question quiz. Simply copy and paste this prompt into Grok:

> Review www.apcj.net/papers-issue-6-4/#WeinerDerifield and use scientific language to provide a two paragraph summary with 3 bullet points and make a quiz of 5 questions

References

1. Thompson Terminal Point Technique .313 Russell Slade Blvd. Coralville, IA 52241
2. Cooperstein. R . Validity of compressive leg checking in measuring artificial leg-length inequality PMID: 14673405 DOI: 10.1016/j.jmpt.2003.08.002
3. Casey A. Murphy, MD, Ariean Loo-Hernandez, DO.(2024) Cervical Whiplash. Pain / Neuromuscular Medicine Rehabilitation, November 10, 2011 Last updated: May 30, 2024
4. Morin, M., et al. (2016). "Cervical Spine Involvement in Mild Traumatic Brain Injury: A Review." J Sports Med (Hindawi Publ Corp) 2016: 1590161
5. AMA Guides Sixth 2025: Current medicine for permanent impairment ratings
6. Luers, P (2019). Spinal Alteration of Motion Segment Integrity Using the Sixth Edition. AMA Guides Digital, DOI: https://doi.org/10.1001/amaguidesnewsletters.2019.MayJun02. Volume/Issue: Volume 24: Issue 3,Page Range: 10–13
7. Ohm, J D.C. Alcantara, A. D.C.. The Webster Technique: Definition, Application and Implications. J. Pediatric, Maternal & Family Health - May 10, 2012.pg.49
8. Blum C, & Serola R. Sacroiliac joint myoligamentous interrelationships: Implications of sacral nutation dysfunction on whole body kinematics.
9. Scaglietti O. Riccardo Galeazzi, 1866-1952. Journal of Bone and Joint Surgery (British). 1953;35-B:679-680
10. Merchant, R.M.; Tolk, J.J.; Ayub, A.A.; Eastwood, D.M.; Hashemi-Nejad, A. The Importance of Monitoring and Factors That May Influence Leg Length Difference in Developmental Dysplasia of the Hip. Children 2022, 9, 1945. https://doi.org/10.3390/children9121945
11. Althobaiti MS, Aloraini LI, Alamri S, Binsaddik OK, Alobaysi YMY, Alabdulrahman FK, Al Shahrani OAS, Al-Awn RMM, Shafiy GA. Updates in the Management of Leg Length Discrepancy: A Systematic Review. Cureus. 2024 Jun 18;16(6):e62599. DOI 10.7759/cureus.62599. PMID: 39027766; PMCID: PMC11257626.

12. Calfee, R. P., et al. (2010). "Skeletal and chronological ages in American adolescents: current findings in skeletal maturation." J Child Orthop 4(5): 467-470

13. Drnach M, Kreger A, Corliss C, Kocher D. Limb length discrepancies among 8- to 12-year-old children who are developing typically. Pediatr Phys Ther. 2012 Winter;24(4):334-7. DOI 10.1097/PEP.0b013e3182691c48. PMID: 22965205.

14. Dobler, F., et al. (2025). "Gait asymmetries in children and adolescents with mild leg length discrepancy." Gait Posture

15. Jafarnezhadgero, A., et al. (2018). "The effects of low arched feet on lower limb joints moment asymmetry during gait in children: A cross sectional study." Foot (Edinb) 34: 63-68.

16. Rozeboom D, Blum CL. Sacral Block Technic: Balancing Sacrospinal Function: A Case Report. WFC's and FCER's International Conference on Chiropractic Research, Montreal, Canada – Apr 30 – May 2, 2009 (CM-14).

17. BODY WORLDS: Vital.This Project was financed [in part] by a grant from the federal Department of Treasury, under the administration of the Commonwealth of Pennsylvania, Department of Community & Economic Development.

18. Thomas W. Myers, Anatomy Trains: Myofascial Meridians for Manual Therapists and Movement Professionals.

19. Bordoni, Bruno & Myers, Thomas. (2020). A Review of the Theoretical Fascial Models: Biotensegrity, Fascintegrity, and Myofascial Chains. Cureus. 12. 10.7759/cureus.7092.

20. Blum CL. R + C Factors and Sacro Occipital Technique Orthopedic Blocking: a pilot study using pre and post VAS assessment. J Can Chiropr Assoc. 2015 Jun;59(2):134-42. PMID: 26136605; PMCID: PMC4486986.

21. Alicia M Boynton, David R Carrier, The Human Neck is Part of the Musculoskeletal Core: Cervical Muscles Help Stabilize the Pelvis During Running and Jumping, Integrative Organismal Biology, Volume 4, Issue 1, 2022, obac021, https://doi.org/10.1093/iob/obac021

22. Kang, M. S., et al. (2012). "A PET/CT-based Morphometric Study of Spinal Canal in Korean Young Adults: Anteroposterior Diameter from Cervical Vertebra to Sacrum." Korean J Spine 9(3): 165-169

23. Knight, J. and L. C. Decker (2025). Decerebrate and Decorticate Posturing. StatPearls. Treasure Island (FL).

24. Idro, R., et al. (2005). "Decorticate, decerebrate and opisthotonic posturing and seizures in Kenyan children with cerebral malaria." Malar J 4: 57.

25. Botvin JG, Keith RA, Johnston MV. Relationship between primitive reflexes in stroke patients and rehabilitation outcome. Stroke. 1978 May-Jun;9(3):256-8. doi: 10.1161/01.str.9.3.256. PMID: 644625.

26. Cui, Z., et al. (2022). "The Effects of Different Kinds of Smooth Pursuit Exercises on Center of Pressure and Muscle Activities during One Leg Standing." Healthcare (Basel)10(12)

27. Campbell, D., et al. (2023). "Cervico-Ocular and Vestibulo-Ocular Reflexes in Subclinical Neck Pain and Healthy Individuals: A Cross-Sectional Study." Brain Sci 13(11).

28. Safavynia, S. A., et al. (2011). "Muscle Synergies: Implications for Clinical Evaluation and Rehabilitation of Movement." Top Spinal Cord Inj Rehabil 17(1): 16-24.

29. Zamyslowska-Szmytke, E., et al. (2019). "Cervico-ocular reflex upregulation in dizzy patients with asymmetric neck pathology." Int J Occup Med Environ Health 32(5): 723-733S., et al. (2005). "Effect of gaze direction on neck muscle activity during cervical rotation." Exp Brain Res 167(3): 422-432.

30. Franklin, Z. C., et al. (2018). "Eye Gaze Markers Indicate Visual Attention to Threatening Images in Individuals with Chronic Back Pain." J Clin Med 8(1).

31. Bexander1, C. S. M. and P. W. Hodges (2023). "Neck muscle activation in response to eye movement depends on sitting posture and is modified in whiplash associated disorders: Cross-sectional study." Musculoskelet Sci Pract 67: 102837.

32. Roucoux, A., et al. (1989). "Neck muscle activity in eye--head coordinated movements." Prog Brain Res 80: 351-362; discussion 347-359

33. Cael, C. (2010). Functional anatomy: Musculoskeletal anatomy, kinesiology, and palpation for manual therapists. Philadelphia, PA: Wolters Kluwer Health/Lippincott, Williams & Wilkins. Jurryt de Vries, Britta K. Ischebeck, Lennard P. Voogt, Malou Janssen, Maarten A. Frens, Gert-Jan Kleinrensink, Jos N. van der Geest, Cervico-ocular Reflex Is Increased in People With Nonspecific Neck Pain, Physical Therapy, Volume 96, Issue 8, 1 August 2016, Pages 1190–1195, https://doi.org/10.2522/ptj.20150211

34. Montfoort, I., et al. (2008). "Adaptation of the cervico- and vestibulo-ocular reflex in whiplash injury patients." J Neurotrauma 25(6): 687-693.

35. Park, S. Y., et al. (2024). "Investigating Eye Movement and Postural Stability Relationships Using Mobile Eye-Tracking and Posturography: A Cross-Sectional Study." Bioengineering (Basel) 11(8).

36. Bexander, C. S., et al. (2005). "Effect of gaze direction on neck muscle activity during cervical rotation." Exp Brain Res 167(3): 422-432.

37. Imai, T., et al. (2001). "Interaction of the body, head, and eyes during walking and turning." Exp Brain Res 136(1): 1-18.

38. Glasauer S, Schneider E, Jahn K, Strupp M, Brandt T. How the eyes move the body. Neurology. 2005 Oct 25;65(8):1291-3. DOI 10.1212/01.wnl.0000175132.01370.fc. Epub 2005 Jul 28. PMID: 16051645.

39. Nansel, D. D., et al. (1993). "Effect of cervical spinal adjustments on lumbar paraspinal muscle tone: evidence for facilitation of intersegmental tonic neck reflexes." J Manipulative Physiol Ther 16(2): 91-95.

40. Blum CL. R + C Factors and Sacro Occipital Technique Orthopedic Blocking: a pilot study using pre and post VAS assessment. J Can Chiropr Assoc. 2015 Jun;59(2):134-42. PMID: 26136605; PMCID: PMC4486986.

41. Gieysztor, E. Z., et al. (2018). "Persistence of primitive reflexes and associated motor problems in healthy preschool children." Arch Med Sci 14(1): 167-173.

42. Hindle, K. B., et al. (2012). "Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function." J Hum Kinet 31: 105-113

43. Nansel, D. & Waldorf, T & Cooperstein, Robert. (1993). Effect of cervical spinal adjustments on lumbar paraspinal muscle tone: Evidence for facilitation of intersegmental tonic neck reflexes. Journal of manipulative and physiological therapeutics. 16. 91-5.

44. de Vries J, Ischebeck BK, Voogt LP, Janssen M, Frens MA, Kleinrensink GJ, van der Geest JN. Cervico-ocular Reflex Is Increased in People With Nonspecific Neck Pain. Phys Ther. 2016 Aug;96(8):1190-5. DOI 10.2522/ptj.20150211. Epub 2016 Feb 4. PMID: 26847014.

45. Morningstar, M. W., et al. (2005). "Reflex control of the spine and posture: a review of the literature from a chiropractic perspective." Chiropr Osteopat 13: 16

46. Morningstar, M. W., et al. (2005). "Reflex control of the spine and posture: a review of the literature from a chiropractic perspective." Chiropr Osteopat 13: 16

47. Maitland, s. Baker, S. Ipsilateral Motor Evoked Potentials as a Measure of the Reticulospinal Tract in Age-Related Strength Changes. Front. Aging Neurosci., 02 March 2021

48. Sec. Parkinson's Disease and Aging-related Movement Disorders.Volume 13 - 2021 | https://doi.org/10.3389/fnagi.2021.612352

49. Haworth, Joshua & Vallabhajosula, Srikant & Stergiou, Nicholas. (2014). Gaze and posture coordinate differently with the complexity of visual stimulus motion. Experimental brain research. 232. 10.1007/s00221-014-3962-5.

50. Yoo H, Mihaila DM. Rooting Reflex. [Updated 2023 Apr 24]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK557636/

51. Glen Gillen, (2016) Chapter 18 - Trunk Control: Supporting Functional Independence,Stroke Rehabilitation. 4e. Mosby, pps 360-93,nISBN 9780323172813, https://doi.org/10.1016/B978-0-323-17281-3.00018-6

52. Troiani, D., et al. (2005). "Head-body righting reflex from the supine position and preparatory eye movements." Acta Otolaryngol 125(5): 499-502.

53. Kumar, S., et al. (2004). "Cervical muscle response to whiplash-type right anterolateral impacts." Eur Spine J 13(5): 398-407

54. Enix, D. E., et al. (2014). "The cervical myodural bridge, a review of literature and clinical implications." J Can Chiropr Assoc 58(2): 184-92

55. Wiltse, L. L. (2000). "Anatomy of the extradural compartments of the lumbar spinal canal. Peridural membrane and circumneural sheath." Radiol Clin North Am 38(6): 1177-1206.

56. Clinical Anatomy for Students: Problem Solving Approach.R 10.5005/jp/books/10116_84.T Spinal Cord. https://doi.org/10.5005/jp/books/10116_84 Jaypee Brothers Medical Publishers (P) Ltd.8 2006/01/01E Kulkarni Neeta V