Asia-Pacific Chiropractic Journal

Cervical segment disruption, displacement, and dysfunction with potential to activate somatosensory reflexes: Radiological indications of components of the Vertebral Subluxation Complex

Peter L Rome and John D Waterhouse

Narrative: We present a series of radiological findings related to disruption of cervical spinal segments.

These somatic anatomical sites of earlier physical disturbances are considered to have the potential to activate or re-activate noxious sensory insult and initiate somatosensory reflexes. These components comprise central elements of a vertebral subluxation complex (VSC).

The findings suggest that pathoanatomical segmental juxtaposition (displacement) and pathophysiological vertebral function (dysfunction) may activate noxious input to involve somatosensory, somato-autonomic, somato-somatic, somatovisceral and somatovascular reflexes.

Indexing terms: Chiropractic; Vertebral Subluxation Complex; Subluxation; Cervical; Radiography.

Introduction

'The central neural pathways that convey somatosensory and visceral information to the hypothalamus and limbic system are organised in a parallel fashion. Both somatosensory and visceral stimuli reach the hypothalamus through monosynaptic and polysynaptic pathways that share the same origins and terminations (for example, lateral hypothalamus and amygdala). For example, nociceptive information can reach the hypothalamus directly through the spinal cord and indirectly through the parabrachial nuclei, and visceral information can reach the hypothalamus directly through the nucleus of the solitary tract (NTS) and indirectly through the parabrachial nuclei or ventrolateral medulla'. (Burnstein, 1996)

'... the authors present a finely detailed exposition of matters which inform competent clinical assessment of the cervical spine which must be considered with any diagnosis of vertebral subluxation complex ...'

Radiological findings indicative of degrees of altered segmental physiology with the potential to activate noxious somatosensory and somato reflexes. (Schmörl & Junghanns, p217-219; Maixner, 1989) These findings are considered neural components of the vertebral subluxation complex (VSC). They may be correlated with clinical signs and symptoms. Apart from the physical disruptions of the VSC, the

neurological, muscular, and visceral components are recognised as distinct elements comprising the complex. (Sato et al, 1997; Sanvictores & Tadi, 2022)

It is recognised that many elements comprise the several forms of the chiropractic vertebral subluxation, this somatosensory model is but one. (Leach, 1994; Kent, 1996; Kent 2019) Maigne stated that there are '*certain minor mechanical derangements that can be present in the different elements of the intervertebral joint.*' (pp. 27, 52)

The VSC may be defined as '*an articular dysfunction, typically but not limited to the spine and pelvic joints, it is characterised by anatomical and neurophysiological signs and symptoms*'.

As noted by Li '*Subluxation should be defined in two ways: as a purely roentgenological diagnosis and as a combination of roentgenological signs with clinical signs*'. (Li et al, 1998)

The three main factors of a VSC are all pathophysiological. They are:

- Altered segmental function, particularly altered posterior motor units, with or without displacement and the neurosensory feedback effects as a result of the biomechanical alterations.
- Physiological changes brought about by noxious neural reflexes, trauma, strain, or inactivity, psychological stress, viscerosomatic reflexes, and chemical irritation may be considered contributors at various times. Jackson (p157)
- Sensory changes which Bruehl & Chung (2004) note may be found anywhere along the distribution of cervical nerve roots as well as altered upper extremity reflexes.

Physical mechanical injuries would be the most common contributors of the findings presented here. Jackson found that 90% of patients with symptoms referable to the cervical spine, had a history of neck trauma. Velmahos et al noted that even '*Low-energy trauma can produce significant injuries*'. We note also that at times, more minor structural or functional changes may be overshadowed by more serious radiological findings such that fractures then become the key focus at the expense of seemingly minor findings. (Jackson, p. 77; Velmahos et al, 2001)

History

Chiropractic involvement with radiology dates back over 120 years. Roentgen's discovery of cathode ray properties in 1895 was the same year that DD Palmer initiated chiropractic. The chiropractic profession has employed radiographic imaging since BJ Palmer introduced one of the first x-ray units. It was installed at the *Palmer College in Davenport*, Iowa in 1910. (Senzon, 2019; (Arnone et al, 2023)

Various chiropractic textbooks on radiology would indicate the significance of the various roles that imaging has within the profession. Radiology and radiography have also been a part of undergraduate chiropractic courses. The additional information gained from CTs and the MRI techniques have also been an asset when required. Chiropractic radiology specialists in the US undergo a 3-year postgraduate residency with 400 having become certified diplomates to date. (Bell et al, 2021).

Chiropractic textbooks and published papers on radiology are given in Table 1.

A search of the Index to Chiropractic Literature under the All Fields category reveals 261 items under [radiology] and 1610 under the search term [imaging]. (April 29, 2023) The Chiropractic literature carries several further papers on chiropractic radiology, and inter-professional collaborative and cooperation has led to joint research projects and development of this aspect of the profession. (Young, Howe, 1999; Hildebrandt, 2010; Sherman College, 2015; Young, 2019; (Painter & Thomas, 2023)

Table 1: Selection of published Chiropractic radiology textbooks and papers

Author	Year	Format	Topic
Arnone et al	2023	Journal paper	Practice survey
Bauer	1974 (Circa)	Lecture	Radiography, exposure Minimisation
Hildebandt	1985	Textbook	Techniques, interpretation
Howe JW	1984-2006	Numerous papers	Recognition (See Young K)
Keating	1995 (circa)	Paper	History chiropractic x-ray.
Marchiori	2013	eText	Radiology
Remier	1938	Textbook	Spinography
Rich	1964	Journal paper	Cineroentgenography
Rich	1965	Textbook	Radiography
Rich	1965	Atlas	Radiology Reference
Rich	1966	Journal paper	Cineroentgenography
Rosa et al	2015	Textbook chapter	MRI
Rowe L	1992	Thesis	Practice relevance
Sherman, Bauer	1982	Textbook	Radiography
Souza	2018	Textbook	Diagnosis & management
Thompson	1923	Textbook	Spinography
Wilson	1999	Textbook	Radiography
Winterstein	1970	Lecture notes	Radiography
Yochum & Rowe	1996	Textbooks 2 vols	Skeletal radiology

Digital imaging was developed in 1987. This resulted in a reduction in radiation exposure of 66%, followed by other technological advances especially MRI imaging and functional imaging which have also been incorporated into undergraduate training and clinical practices. In more recent years, functional Magnetic Resonance Imaging (fMRI) and upright and open MRI (uo-MRI) are available. This has contributed remarkably to the study of altered spinal articular mechanics (Rowe, 2006; Gatterman (d), pp. 77-83; Demetrious, 2007 x2)

Studies in the diagnostic standard of chiropractic radiology have been conducted with the finding that the level of chiropractic training in radiology is appreciable. (Frymoyer et al, 1985; Taylor et al, 1995; Assendelft et al, 1997; Marchiori et al, 1998; Harrison et al, 1998; de Zoete et al, 2002; de Zoete et al, 2015; Doktor et al, 2019)

Under a manual therapy model of care, osseous displacement up to the point of fracture or dislocations also would seem to require restoration. These more subtle findings may well produce symptoms which therefore have an inherent neurological sensory factor or radicular irritation both with CNS registration, even if they are of an 'insufficient displacement' (Kattan et al p. 91) to be appreciated or measurable on film.

It can be noted that an imaging finding does not have to be necessarily recent and can usually be clinically identified by examination and correlated with signs and symptoms. They can also be asymptomatic and long-standing, but more recently activated. These situations often occur when a patient does not recall a recent injury and may have forgotten earlier incidents, even as far back as early childhood.

Review

This presentation represents the importance of the contribution placed on these less prominent and functional radiological findings with the difference and significance behind their interpretation and relevance to manual interventions. (Oakley et al (a), 2021)

Conventional Chiropractic radiology primarily considers the presence of pathology, anomalies, and fractures, as well as red and orange flags of precautionary awareness. In addition, they may also indicate some of the relevant factors in symmetry and functional analysis in radiographic imaging and its appropriateness for manipulative care. This would include analysis of segmental and regional spinal function and pathomechanical transpositions. Biomechanical and abstruse evidence of anatomical changes are of great importance to chiropractors and others in manual therapy in order to determine optimal management, duration or care, selection of manipulative technique, and site(s) for focusing attention or other management. (Oakley et al, 2021)

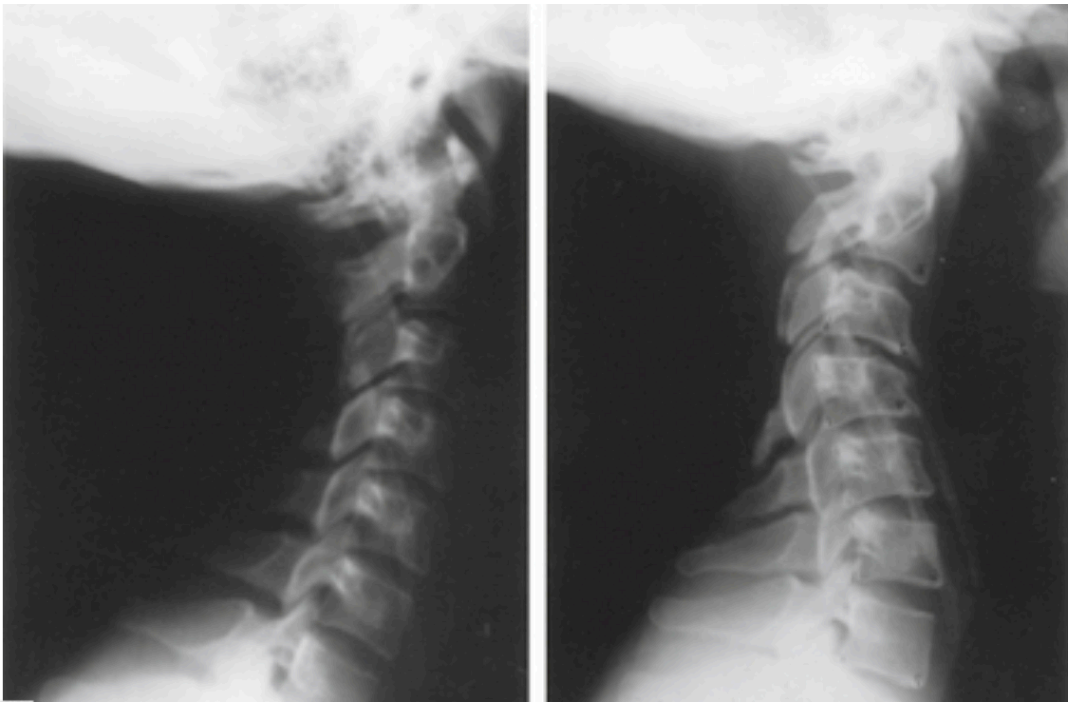


Fig 1. Two examples of cervical spines which would function differently to a normal gentle C-curve, and which respond differently to the same stressors and activate different sensory cascade. (See also Appendix 5)

The fundamental question is to determine the rationale for a radiological examination in the first place. It may be assumed that there are usually clinical symptoms or signs present to justify the procedure and it is these that motivate a patient to seek care.

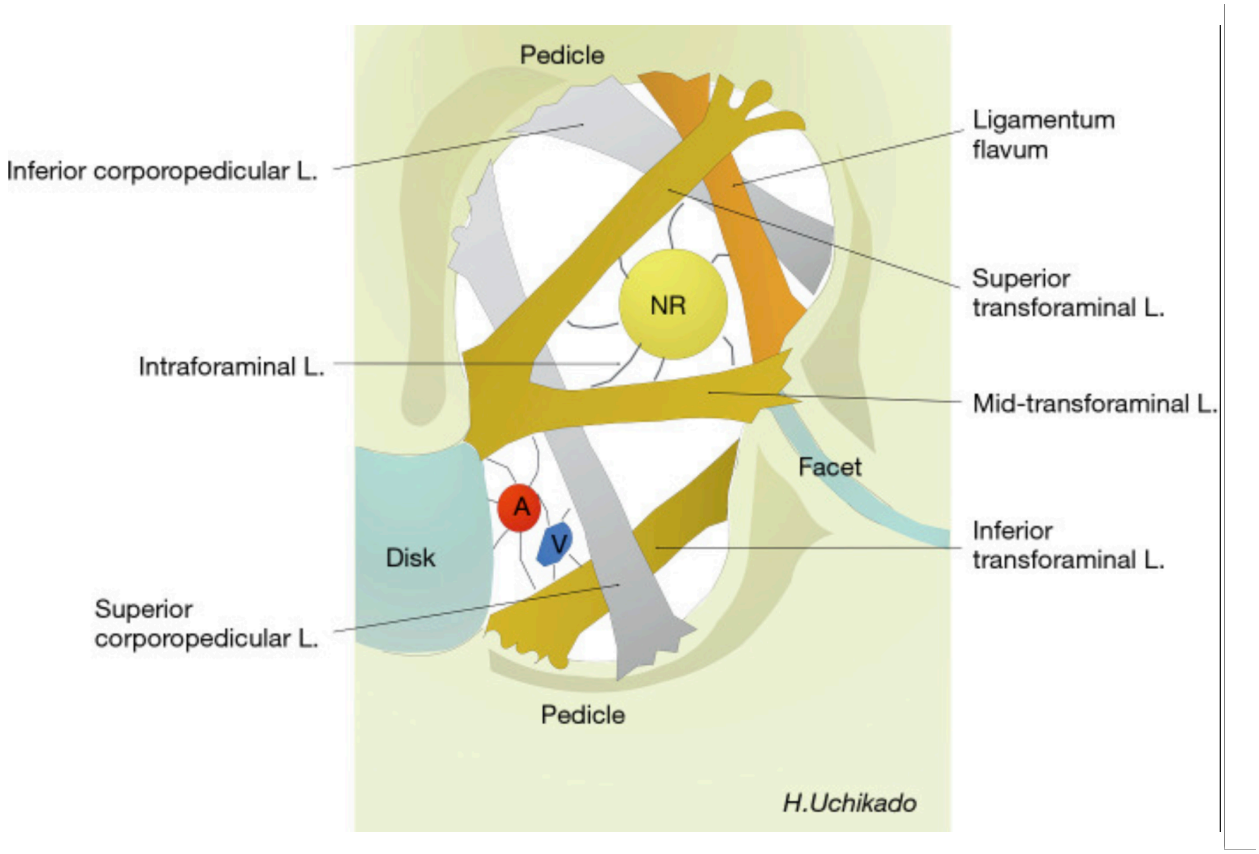
Based on Palmer's maxim that, '*Abnormal structure cannot do otherwise than produce abnormal functions*' supplemented by Stoddards's, '*structure governs function*', the concept of disrupted vertebral segments exhibiting patho-anatomy (structure), then pathomechanics (dysfunction), pathophysiology, and subsequent evidence would appear justified. (Palmer, 1910; (Stoddard, 1983)

In past decades, a degree of scepticism existed over consistent evidence that the traditional allopathic definition of a subluxation was more involved. That early definition alluded to only the anatomical position of a vertebra. It did not consider the disturbed function factor, nor the potential of neural-based irritations or symptoms associated with noxious sensory insult and the autonomic nervous system reflexes. (Rome & Waterhouse Part 4, 2021)

Neck pain would be the most common neurological sensory symptom associated with mechanical disturbance of the cervical spine. (Harrison et al, 2004; Grob et al, 2007; Jouibari et al, 2019) Jackson and others also noted that mechanical disturbances may influence the cervical sympathetics by both irritation and reflex stimulation in such conditions as blurred vision, pupillary dilation, headaches, and auditory disturbances. (pp. 72, 73) Cervicogenic headaches are now a recognised condition of spinal (particularly the cervical spine), origin. (Haldeman & Dagenais, 2001; Al Khalili et al, 2023; Ormos et al, 2009)

In another aspect, Schmörl & Junghanns (pp. 207-10), discussed the model of nerve root pressure which focused on osseous occlusion of the intervertebral foramen (IVF). This model has recently been brought into focus by the study by Uchikado et al (2020) who discussed the intricate intrusive network of intraforaminal ligaments in the lumbar spine. (Figure 2) We would suggest that somewhat similar structures exist in the cervical spine IVFs, with the potential to irritate or compromise the nerve roots there once disrupted. We would suggest further that these may be one of the principal contributors to vertebrogenic headaches.

Fig 2: After Uchikado et al, 2020; Section of a typical lumbar IVF showing the intricate intrusive network of intraforaminal ligaments



The chiropractic subluxation is more of a complex which includes the factors of articular dysfunction, facet displacement, soft tissue structures, neural and vascular effects, and sensory afference and neural efference. Jackson (p, 44) states '*Because of their close proximity to the anterior and posterior walls of the intervertebral foramina, the cervical nerve roots are extremely vulnerable to compression or to irritation from any mechanical derangement or inflammatory condition in or about the foramina*'. She noted further that seemingly insignificant derangements of the cervical spine may activate neurological symptoms including sensory and motor deficits. (p. 74)

There is also a need for clarity of terminology with terms such as displaced, displacement, and dislocation seemingly used interchangeably at times.

Cervical spine

A global cervical spine in a neutral lateral view should be one of a 'normal' lordotic curve, the discs 2-3 times thicker anteriorly than posteriorly (Jackson, pp. 30, 32) and with the head vertically above the body in line with the centre of gravity. (Gatterman (b), p101; Jackson, p13) After all, it is the orthostatic cervical posture that is assumed by most patients during their waking hours. The neutral lateral view is at least as important as other functional views (Davis series). (Jackson 1966, pp. 177-95; (Dolan, 1977)

Radiological assessment of the posture of the erect cervical spine is readily appreciated from lateral sagittal views. Hadley (a), (p. 135) nominates erect weight bearing studies an '*advantage*' This view conveys much information in relation to vertebral and head position and function, and particularly when they are accompanied by a functional series and A-P views at least. These can highlight postural and segmental dysfunction and departure from a lordotic normal. As a structural disturbance, noted postural change would also function differently to the '*normal*' and altered sensory input to physiological normal. (Farid et al, 2018; Andrew et al, 2018; Peng et al, 2021)

In her 1966 textbook, Jackson stated that '*... marked derangements in the cervical spine may cause minimal symptoms whereas apparently insignificant derangements may cause severe nerve root irritation or compression*'. (Jackson p. 74) She also found that 25% of neck injuries involved osseous structures and 75% involved soft tissue. (p. 77) With 34 articulations in the cervical spine, optimal function becomes even more relevant.

In a symptomatic clinical presentation of identified vertebrogenic conditions, detailed spinal examinations would assess the mechanical integrity and anatomical status of the segments in order to determine any correlation with the presenting symptoms and clinical signs. In particular, the discal joints and zygapophyseal facet function. Depending on the severity of an identified etiological factor, a biomechanical disruption must alter normal function depending on the resting state and condition of the facets or disc involved, thereby activating noxious sensory input and somatoautonomic reflexes. (Sato et al, 1997)

Postural, deviations of the normal cervical spine lordosis or C-curve, may be asymptomatic. However, once segmental or regional disturbance occurs, it may be sufficient to activate a range of symptoms. Cervicogenic headaches and brachial neuritis can be two of the more common clinical presentations associated with the noxious sensory disturbance of segmental biomechanics. Townsend and Rowe (1952) found cervical muscle spasm resulting in a kyphotic cervical spine in cases of upper respiratory tract infections in children. (Harrison et al, 1998; Oakley et al 2021)

While imaging provides an analytical focus for both active and inactive vulnerable findings of disruption which may have contributed to symptomatic conditions, they provide a rationale for the radiological examination to be conducted. Kipalani and Mitra (2008) state in relation to cervical joint dysfunction that cervical facet pain is a common condition and has a 25%-66% prevalence in chronic pain.

The examination would involve spinal palpation of segments and local musculature in order to identify vertebral mobility (motion palpation), alignment, distortions, anomalies, muscle tone, regional range of motion, degree of nociceptive sensitivity, distribution of paresthesias as well as aggravating and relieving motions. Depending on outcomes, a physical and neurological examination may then follow. These procedures may identify segmental disturbance, even at times before symptoms develop or recur, and addressed on a prophylactic basis. They may subsequently be corroborated radiologically, particularly with functional plain films or fMRI. (De

Boer et al, 1985; Jull et al, 1988; Hubka & Phelan, 1994; Humphreys et al, 2004; Gatterman (a), 2005)

There are a number of clinical observations which can be inferred when considering functional factors. Jackson states that '*limitation of motion of the cervical spine from muscle spasm or fixation … will alter the point of greatest stress and strain depending on the degree and level of motion and the area of fixation*'. (Jackson, p. 35) and further, '*… marked derangements in the cervical spine may cause minimal symptoms whereas apparently insignificant derangements may cause severe nerve root irritation or compression*'. (Jackson, p. 74)

It is noted that the range of rotation varies at each segmental level and would be the focus of examination and analysis. Modifying adjustments (release with impulse) or manipulation/ mobilisation to normalise the function and positioning with consideration of the patient's age, physical status, and appropriateness for care. In the case of displacement, it would stand to reason to conduct the mobilising procedure with emphasis on a corrective direction. To do otherwise may exacerbate the symptoms or reduce the chances of an optimal outcome.

As summarised by Zhao et al in 2013, lateral rotation varies at each segmental level. This suggests that fixations at a particular level may influence a smooth flowing cervical motion of the vertebra in relation to adjacent and nearby segments. It also suggests that relatively little rotation and little impulse is required to release a fixation at these levels.

Table 2: Unilateral mean maximum axial rotation at each level of the axial cervical spine, after Zhao et al, 2013.

2.4° ±1.8°at Occ–C1
38.5° ±4.7° at C1–C2
3.1° ±1.1° at C2–C3
4.0° ±1.6° at C3–C4
5.3° ±1.5° at C4–C5
4.6° ±1.8°at C5–C6
2.3° ±1.3° at C6–C7
1.6° ±0.9° at C7–T1

Subluxation: Displacement and segmental dysfunction

There is potential for a pathoanatomical/pathophysiological vertebral disturbance that adversely effects the physiological range of motion of the segmental structure which may be termed vertebral dysfunction.

Dysfunction is but one of the elements comprising the VSC. Others include displacement fixation, hypermobility, hypomobility and aberrant motion. These may involve facet inflammatory response, altered proprioception and nociception. Each these may activate the autonomic nervous system (ANS) reflexes. (Sato, 1987; Schmidt, 2015; Harrison et al, 1998)

Functional fixations are sometimes designated as blockages. A fixation may occur in the neutral position or anywhere within the facet's normal range of motion. (Rome & Waterhouse, 2021) These are all considered under the classification of vertebral dysfunction as components of a VSC. Schafer (2013) stated that, in summary, the major characteristics of articular (total) fixations are that they:

1. are felt during motion palpation as being completely immobile in all directions and are asymptomatic;
2. are painful when challenged by the palpator; and
3. progress to true ankylosis. Thus, they are irreversible in the terminal stage.

A vertebral fixation may be described as one form of mechanical dysfunction in which the vertebra becomes static (or partially static - aberrant) in a position achieved during its normal physiological range of motion. (After Maile and Slongo, 2007)

In clarification, it is much more a blockage that a locking. A locked facet joint being more of a dislocation, where one facet jumps over and locks its adjacent articular pillar. (Picirilli et al, 2016)

While each of the radiological findings presented are not in themselves necessarily generating symptoms, it is the analytical assessment in diagnosing and correlating their clinical relevance with presented signs and symptoms which would logically invite correction or amelioration. However, for a displacement to persist there would have to be a state of functional fixation or motion blockage. Displacement may be regarded as a micro-displacement of up to 2 to 3 mm. It is acknowledged here that displacement without fixation is not possible otherwise it would continue as a motion segment. (Owens & Leach, 1990)

Cramer at al (2006) state:

1. '*if a subluxation (a malposition less than that produced by a dislocation) exists, a fixation must also exist*', and
2. 'a *fixation can exist even when the articular surfaces are in an ideal relationship during the static resting posture. Thus, a fixation is a dynamic factor; a subluxation*.'

It is suggested that the presented findings identify disruption of the cervical vertebrae that have the potential to activate noxious nociceptive and mechanoreceptive - particularly proprioceptive, sensory input. (Smith et al, 2019; Carta et a, 2021) The disruption may take the form of a functional fixation or compensating fixation which are both forms of dysfunction. However, if a pronounced articular sprain is involved the segment(s) may be regarded as hypermobile or unstable. If hypermobile or unstable (Schmorl & Junghanns, pp. 213-29) then compensatory fixations at other levels may also occur in response. Fixations appear to be a protective response to some vertebral disturbances. Addressing this reduced segmental motion is achieved by the use of segmental adjustments to normalise the function. The integration of activated or irritated neural elements broadens the involvement and effects of innervation through somato-autonomic reflex pathways. As such and where appropriate, these complexes warrant manual or instrument-assisted correction with the aim of restoration or improvement of segmental motion and juxtaposition. (Ferrantelli et al, 2005)

In addressing the VSC, a common chiropractic approach would be the *spinal adjustment of which there is a variety. This model of resolving the condition is defined here as the developed and refined form of manual or instrument intervention directed to restore joint and neural physiology of an articular subluxation and ameliorate associated signs and symptoms*. It can be noted that adjustments are one part of chiropractic's model of care, albeit an important one.

It is suggested that it is therefore preferable to adopt the more inclusive understanding of the vertebral subluxation complex model (VSC) to incorporate physiological (pathophysiological as functional and neurological factors) in addition to the anatomical factors.

We note the difference between a chiropractic adjustment and the less specific forms of manipulation which identifies manipulation as a generic term. Clinical outcomes using the term manipulation may be significantly misleading and should not be classified as or compared in efficacy in outcome studies. In such studies, the technique used necessitates clear identification and not generalised under broad terms like manual therapy or manipulation.

Clarity is needed to identify a focus for a manipulative procedure rather than non-specific generalised mobilisation due to the specificity of neurological segmental innervation. To assume a generalisation of efficacy under a broader term of manipulation is not a scientific evaluation.

In addition, it is not appropriate for the models of manipulation to be assessed by critics who do not accept these principles, yet cast opinion on such a different aspect of healthcare in a different profession on a topic that they have not seriously been educated in or formally researched.

Noxious somatosensory input

One of the integrated components of the VSC

A subluxated vertebral segment may be regarded as a key medium for assessing, accessing, and positively influencing somatosensory reflex activation through manual intervention. On identifying a VSC-related clinical condition, its correction implies a physical solution for a neuro-mechanical lesion. (Gatterman (d), p. 145) The vertebral adjustment would also focus on associated pathophysiology of the neural aberration to neutralise noxious sensory input from the segmental dysfunction. (Nordoff ,p. 144) This phenomenon is also noted by Sato et al who stated '*In contrast to the impressive body of knowledge concerning the effects of visceral afferent activity on autonomic functions, there is, generally speaking, much less information available on the reflex regulation of visceral organs by somatic afferent activity from skin, the skeletal muscle and their tendons, and from joints and other deep tissues. The elucidation of the neural mechanisms of somatically induced autonomic reflex responses, usually called somato-autonomic reflexes, is, however, essential to developing a truly scientific understanding of the mechanisms underlying most forms of physical therapy, including spinal manipulation and traditional as well as modern forms of acupuncture and moxibustion*'. (Sato et al, 1997)

The activation of somato-autonomic reflexes has been noted in a number of other studies by Schmidt and Sato. (Sato & Schmidt, 1987; Uchida & Budgell, 2009; Schmidt, 2015)

Jackson (pp. 72, 73) also noted that mechanical disturbances may influence the cervical sympathetics by both irritation and reflex stimulation in such conditions as cervicogenic blurred vision, pupillary dilation, headaches, and auditory disturbances. Cailliet identified similar signs and symptoms in his chapter on '*Subluxation of the cervical spine including the "whiplash" syndrome*'. (pp. 60-85)

Chiropractic subluxation

The Vertebral Subluxation Complex (VSC)

To clarify terms used, it is necessary to differentiate the term segmental '*misalignment*' from subluxation. Under a medical definition the term usually applies to vertebral misalignment of more than 3mm. (Scher, 1979; Green et al, 1981; Curtin & McEwain, 2004) White et al (1975) state that to classify instability displacement should be greater than 3.5mm and a segmental kyphosis of 11°. However, we would maintain that consideration must be applied to

misalignments of less than 3mm, especially those on examination determined as being associated with clinical symptoms and signs attributed to noxious neural effects.

In essence, the current understanding of an efficacy-base regarding a VSC tends to explain the cause as the persistent effect of such deviations from the ideal or 'normal'. In relation to intra-articular separation, Whang, Patel and Vaccaro (2011) suggest that a subluxation/dislocation of the facet joints are indicated by articular apposition of less than 50% or diastasis greater than 2mm. The clinical issue is then raised regarding the presentation of symptoms associated with a displacement of less than 3mm or the diastasis of 2mm.

The medical literature would suggest that a subluxation (plain displacement) should be more than 3mm of displacement to be clinically noted, an opinion that appears at variance with the literature. Further, we would argue that the degree of even minimal displacement is relevant when that deviation is related to clinical signs and or symptoms. Sher opines that 'A displacement of more than 3 mm on flexion-extension spine radiographs is considered abnormal and indicates instability'. (Sher, 1979)

Displacement appears as the term of preference used for minor translation. This does not clarify as to when a displacement becomes a subluxation, or when a subluxation is regarded as a Grade1 spondylolisthesis, nor does it imply the more common signs and symptoms. Again, we would argue that any displacement or dysfunction remains relevant and deserving of clinical examination and possible intervention. Regardless, medically the sensory impact of structural, neural, and functional changes are rarely noted. Curtin and McElwain (2005) state that '*In adults, this type of anterolisthesis can be normal if <3 mm, but is a rare finding*'.

A *Radiopaedia* MRI review by Ren portrays a range of changes in the cervical spine from which it may be interpreted that the different levels may well function differently from each other.

Fig 3: Structural and functional analysis of a cervical spine (Lateral view)

The authors' findings and observations of signs of potential dysfunctional and previous disturbance on this sagittal cervical CT are noted. *Please see Radiopaedia website for sagittal bone window to scan through on CT*.

Notes in relation to Figure 3:

Male aged 60-70 +/-

Spinous fracture at C7

Slightly kyphotic upper cervical spine C0-C6

Hypolordosis between

C2/3 facet not parallel.

C4/5 facet approximation

C5/6 Scalloped facets and increased interarticular space.

C6/7 C7 superior facet indented by the C6 inferior articular pillar

Wedging of the T4/T5 disc

Flexion of T1 segment

T1/T2disc degeneration

Calcific spurs at anterior C4, C5, and T3/4 posterior at C6

Small end plate indentations posteriorly in T3, T4 and T5

Disc spacing

A further milder pre-fracture neck injury (MVA acceleration/deceleration) approximately 20 years prior suggested by osteophytic formation C5-T1./

Patient possibly led a reasonably active life – not heavy manual labour, possibly a casual involvement in sport -perhaps tennis. (Based on Ren J, 2005: https://radiopaedia.org/cases/displaced-c7-spinous-process-clay-shoveler-fracture)

The dysfunction element

Manual medicine is based on neurophysiological and biomechanical relationships. Impaired sensorimotor regulation leads to segmental and somatic dysfunctions. At the spinal level, somatosensory and vegetative dysfunctions arise through the segmental allocation. (Schnell et al, 2022)

A subluxation without displacement may or may not be symptomatic due to the loss of motion and altered sensory feedback, depending on which type of sensory receptors are triggered. This may be regarded as a non-displaced fixation type of VSC. This may have been contributed to by poor posture, past trauma, or an adaptive change over a long period of time, with a subsequent dampening effect of the mechanoreceptors and nociception to a point below patient awareness – asymptomatic.

Depending on the type and severity of segmental disturbance, certain structures such as ligaments may be physically damaged, some to the extent that they heal and the scar tissue formation eventually becomes calcified. (Hadley (a), pp. 233-8) Others may not be displaced, but may become symptomatic due to localised pathomechanical dysfunction and sensory feedback. It is the sensory activated effects that are discussed here. Such findings would include:

- Joint hypomobility – fixation, blockage (Hadley (a) p130,139) (Rome & Waterhouse Pt 1, 2021)
  - Joint hypermobility – instability (Gatterman (a), p 169,70,172-9)
  - Aberrant joint motion (Gatterman (a), various)

- Palpation for deviations, muscle tonicity (Read, 2011) (McDowall et al, 2017)
- Splinting or hypertonicity of the postural muscles. (Gatterman (a), p154)
- Spasm of the intrinsic spinal muscles segmentally. (Gatterman (a), various)
- Soft tissue adaptation in ligaments. (Gatterman (a), various) (Jackson, 120-5; Dai, 2004)

- Functional compensatory response in segments other than the level of primary dysfunction. (Nordoff, p. 139; Baziuk, 21017)
  - Subjective tenderness or pain over involved articulations on pressure.

In spinal examination Lewit noted findings under such terms as asymmetry, anomaly of function, malalignment, irregularity of alignment, asymmetrical rotation, functional anomaly, disturbed function, and, loss of mobility. These may also be similar changes which take place in a sprained or strained ankle with loss of function, displacement, soft tissue involvement and noxious neural sensory activation, particularly nociceptive input. One difference however, is the vertebral proximity and potential interaction with the prolific spinal neural elements. (Lewit, 1999, pp. 34-6; Henderson, 2012; Schmörl & Junghanns, p. 203)

Long standing radiological findings discussed here whether of traumatic, anomalous or non-traumatic origin may be vulnerable to physical and sensory activation or reactivation, and once disturbed, may become symptomatic. With considerations of neural involvement, the restoration of normal physical and physiological function as well as associated displacement - if present – to as normal as possible, would be the objective of intervention. This would invite a biomechanical correctional focus of manual adjustments. (Nordoff, p. 139)

Central to the VSC model and its clinical findings are its potential effects on tissue and functional physiology within and around the segmental structure and especially involving the apophyseal joints. Maigne discusses many of these in his chapter on '*Minor mechanical disturbances of the intervertebral joint*' or '*Minor intervertebral derangements*'. (Maigne, pp. 27-51, 192-209, 390)

Pathophysiological changes may be reflected in the following:-

- Articular physiology – functional ROM
- Articular cartilage tissue
- Neural physiology
  - Noxious somatosensory input from all structures including nociception, proprioceptive, other mechanoreceptors (Smith et al, 2019)
  - Radicular irritation
  - Afferent reflexes, sensory input, also viscerosomatic
  - Efferent autonomic reflexes – somatic, vascular and visceral
- Inflammatory response - calor, rubor, tumor, dolor, and loss of function (laesa)
- Lymphatic changes within the IVF
- Connective tissues; ligaments, tendons, muscular
- Vascular changes both within the IVF and vascular reflexes

Medical subluxation

The traditional medical definition of a subluxation considers just the mechanical displacement of a bone. Realistically, this could only happen in a dry skeleton. Displacement is only one of the factors to be considered in a complex articular subluxation, especially a vertebral one.

The medical definition of a subluxation is defined by Dorland's as '*An incomplete or partial dislocation*'. (Agnew, 1965)

Dailey et al (2009) stated that medically, the '*lack of standard definitions when differentiating facet subluxations from dislocations may explain our relatively modest interobserver reliability*'. This ambiguity is clarified for chiropractic in a definition by the World Health Organisation (WHO, 2005) which states a subluxation is

> A lesion or dysfunction in a joint or motion segment in which alignment, movement integrity and/or physiological function are altered, although contact between joint surfaces remains intact. It is essentially a functional entity, which influences biomechanical and neural integrity.

Further, in differentiating the vertebral subluxation of spinal joints from other articulations, it defines a VSC as

> Subluxation complex (vertebral) A theoretical model and description of the motion segment dysfunction, which incorporates the interaction of pathological changes in nerve, muscle, ligamentous, vascular, and connective tissue. (WHO, 2005)

On the other hand, Hadley (a) stated that

> Any mal-alignment in this curve (the cervical lordosis) or irregularity in the spacing of the sections indicates a disturbance in the structure or the articulations of these cervical units. (p. 430)

He addressed associated neural involvement under Cervical foramen encroachment. (Hadley, 1976, pp. 431-8) Schmörl and Junghanns noted a wide range of non-musculoskeletal signs, symptoms and dysfunction associated with structural and physiological changes to the cervical spine. (Giles, pp. 36-9; Schmörl & Junghanns, pp. 216-29)

A further consideration in radiological interpretations has been noted by Cailliet (p. 75) who stated that '*Definite signs and symptoms may exist in the presence of "negative" x-rays*'. Jackson opined that '*clinical findings must also be correlated with the radiographs*'. (p. 163) The authors note that a report of a 'negative' x-ray does not necessarily equate with 'negative' symptoms.

A study on this aspect by Oakley et al concluded that '*Medical radiologists in this study made generalized, non-specific comments regarding cervical lordosis, if mentioned at all. This suggests that they may not perceive the importance of cervical spine alignment as being involved in a patient's complaint even when evidence suggests that cervical spine sagittal alignment is implicated in neck and headache symptomatology, physiological function, neurophysiological outcomes, and degenerative changes. This situation may fuel existing barriers between differing healthcare professionals as to how much emphasis should be placed on spinal alignment in the aetiology of a patient's cranio-cervical complaints*.' We hesitate to comment on the unfortunate ramifications for patients on such observations. (Oakley et al, 2021)

Aetiologies

There are numerous potential contributory factors leading to a VSC. Some may be instantaneous such as car accidents, whiplash, or falls, while others may be of slow onset such as postural strains or stress resulting in muscular hypertonicity which may be reflected in vertebral hypomobility.

Forces of physical trauma, whether major or minor, would constitute the cause of many perhaps most cervical spine injuries presenting for chiropractic care. It has been stated that 75% of these are of the soft tissues. (Jackson p77) It is foreseeable that the affected mobility of a cervical segment and noxious sensory activation from disrupted articulations involved, as well as soft tissues, could establish elements of the VSC. Disturbance of old injuries, degenerative discs or facets which change segmental motion could also generate noxious sensory input.

These disrupted vertebrae may exhibit excessive segmental or joint motion (hypermobility, instability) or restricted facet or segmental motion (hypomobility or functionally fixated) leading to further irritation and noxious sensory input from nociceptors, proprioceptors, and other mechanoreceptors. Cramer et al (2006) found that their studies '*... provided strong evidence that decreased vertebral motion (vertebral fixation) produced degenerative changes in the Z joint that were greater for longer periods of fixation*'.

While motor vehicle accidents are a particularly common cause, trampolines can be another (Jackson, p. 91; Demetrious (a), 2007) as well as some vigorous sporting injuries. Some prolonged postures or innocuous activities such as turning over in bed, or under a general anaesthetic (Jackson, pp. 91, 95) may trigger VSCs at times, although susceptibility to these types of incidents would usually be the re-activation of dormant prior injuries.

Clinical considerations

Considering of the presented aspects of radiological findings may allow correlation with a patient's stated symptoms and clinical signs. It is acknowledged that opinion on these aspects may be subject to personal interpretation. They are however put forward here in order to explore and discuss their merits or otherwise, and potentially extract additional clinical information from a radiological examination (See Appendix 1. A radiological structural interpretation of signs of cervical spine dysfunction with potential for sensory and autonomic reflex implications.)

Radiology also acknowledges the possibility of red and orange flags which include fractures, underlying pathology including cancer, osteopenia, osteoporosis, arterial plaques and '*incidentalomas*' (Chojniak, 2015). General considerations of a functional and structural interpretation include

- Age at onset of suspected aetiology
- Age at onset of symptoms
- Aggravating factors -*v*- Relieving factors
- Comparison to 'normal'
- Congenital anomalies (Jackson, p. 70)
- Degree of force - mild, moderate, severe
- Degree of strain - soft tissue damage
- Direction of force(s) impacting (Schmörl & Junghanns, p. 20; Kattan, p. 23)
- Duration since incident
- Expected signs and symptoms -v- Reported signs and symptoms
- Identify aetiology confirmatory or contrary
- Occupation, hobbies, sport
- Head position at time of injury (Kattan, p. 23)
- Pre-existing conditions
- Type of force(s)
- Adjunctive therapy or exercise

While whiplash-type injuries (*Whiplash Associated Disorders* - WADs) are a topic in themselves they are only alluded to here in recognition of their significance and frequency as causes of cervical disorders. (Cailliet, 1964; Foreman & Croft, 2002, p. 186; Nordhoff, 2005; Centeno et al, 2007)

Imaging

Imaging facilitates the identification of specific levels that may have the potential to activate noxious sensory input, one of the primary effects of a VSC. There are two basic techniques in plain film radiography which enhance a biomechanical functional and structural analysis of the spine. Orthostatic regional weight bearing and functional views tend to provide information from both segmental and regional pathomechanics and/or dysfunction. (McGregor et al, 1995; Dvorak et al, 1988; Frobin et al, 2002; Davidorf et al, 1993)

At times, full-spine analysis is also indicated. (Thompson, 2001; Coleman et al., 2011)

Radiological findings for consideration under a structural and functional interpretation would include:

- Alignment of spinous processes, vertebral bodies, spinolaminar line.,
- Assessment for suitability of care, also for red and orange flags or referral
- Assessment for technique selection and duration of care
- Assessment for management
- Assessment for prognosis (Miles et al, 1988)
- Evidence of previous injury and degree of it, perhaps whiplash (WAD)
- Facet degeneration or sclerosis

Functional compensatory response in segments other than the level of primary dysfunction:

- Intervertebral disc condition; degeneration, height, wedging, vacuum phenomenon.
- Isolate primary segment(s) of involvement:
- Joint aberrant motion (fMRI, cineroroentgenography)
- Joint hypermobility, instability
- Joint hypomobility, functional fixation (Hadley(a), pp. 130, 139; Rome & Waterhouse, Part 1, 2021)

Lines of mensuration (See Appendix 2)

Objective and subjective tenderness or pain

Posture and postural deviations from 'normal'.

Stress points (Jackson, p35-39)

Symmetry of motion (Hadley(a), p. 124; Bryner 1986; Robinson et al, 1987)

Symmetry of osseous features (See also main chart – Appendix 1)

Hadley(a) notes the advantage of erect lateral cervical spine plain film (pp. 121-4) and instances the added information to be extracted from functional views (pp. 121, 125-6). Such views may reveal functional fixations but may also accentuate instability or hypermobility of segments. (Hadley(a) pp. 130,139)

The significance of erect or weight-bearing films to a chiropractor is that aspects of interpretation are enhanced or symptoms exacerbated by the effects of postural stressors on the spine. It may be noted that this technique does not necessarily compromise the ability for detection of pathological findings compared to recumbent techniques. Erect posture films

contribute significantly to cervical spine assessment and type of intervention. (Dolan, 1977; Epstein et al, 1977, pp. 262, 277; Lowe et al, 1976)

Functional clinical considerations may involve spinal compensation on a gross as well as a segmental level on how the spine or segments respond to localised pathomechanical conditions. Such findings would include adapting to a congenital anomaly, a functional fixation, and articular instability. They may be identified as secondary or tertiary subluxations. (Baziuk, 2017)

An accurate image of relatively minor biomechanical disturbances including 1-2mm vertebral displacements with associated altered articular function may be noted radiologically, particularly if they correlate with spinal examinations and patient symptoms and signs. This then assists with management and prognosis. In addition, it may indicate which incident in the patient's history, chronicity and perhaps legal issues surrounding certain instances such as the direction, and severity of impacting forces.

Radiological considerations

One of the underlying neural elements in a segmental spinal disturbance is the activation of somatosensory reflexes generated by physical or functional disturbances. As suggested by the radiological findings presented here, a noxious or irritant effect upon sensory receptors can be generated implicating the autonomic nervous system. (Sato et al., 1997)

These findings mostly due to spinal mechanical dysfunction and limited segmental translation must result in a somatosensory effect with potential flow-on to a somato-autonomic reflex. This is not necessarily the evidence of pathostructural radiological findings as such, but signs that there has been disturbance be it recent, old, or exacerbated. This stimulation may be acute or chronic depending on severity of the initiating factor, particularly if nociceptive in nature. Once disrupted, healing, compensation, and adaptation can evolve and may indicate site(s) associated with signs and symptoms. (Honda, 1985; Cervero & Tattersall, 1987; Katter et al, 1996; Palecek et al, 2003; Wang et al, 2022)

Biomechanical disturbance resulting in dysfunction with or without displacement, can lead to noxious sensory activation and identified as radiological findings may be classified as a part of a vertebral subluxation complex (VSC). Divergence from a segment's normal anatomic relationship or physiological function would be key contributors to the VSC.

The appended synopsis highlights radiological findings that have the potential to activate noxious somatosensory input and ANS reflexes, both being components of a vertebral subluxation complex. They represent radiological signs and considerations of probable physical disturbance and dysfunction, and therefore when activated or reactivated, have the potential to generate a noxious sensory barrage, galvanising autonomic reflexes as per Sato et al's (1997) extensively referenced *Somatosensory input on autonomic function*. These have been noted as '*stimulation of the posterior cervical sympathetics of the sensory elements …*'. (Cailliet, p. 69)

It is noted here that there are various degrees of segmental disturbance up to (and beyond) the point of a fracture. It is these early disturbances that deserve functional and positional consideration, particularly when deemed responsible for cervicogenic symptoms and signs.

The essence of the findings presented is that they either indicate or suggest that the spine or a segment may function differently to its previous normal, or has the potential to do so. If activated, these may not become clinically relevant to the patient until symptomatically activated. In recognising this potential, it may identify a role for preventive care including certain exercise programmes.

While there may be some degree of improvement in a scoliosis with manipulative care, the primary goal is to minimise adverse symptoms by restoring as much physiological segmental motion as possible. This may then require supportive care and management of symptoms.

The activation of a noxious sensory barrage from mechanoreceptors physiologically implicates the autonomic nervous system. Apart from nociception that may be activated, associated pain or ache essentially indicates that other sensory receptors have been activated. (Sato et al, 1997, pp. 4, 7, 8) One of these indicative signs in disturbance involves head repositioning and hand co-ordination. (Smith et al, 2019; Owens et al, 2006)

To the extent that these radiological findings exist, suggests that some form of disturbance has occurred and have been or are generating noxious input to the autonomic nervous system. At least a part of the confirmation in an ætiological role may be the diminution of associated symptoms once the biomechanical findings are modulated. (Heikkilä & Aström, 1996; Rogers, 1997; Haavik-Taylor & Murphy, 2007; Palmgren et al, 2009; Reid et al, 2014; Lee et al, 2015; Peng et al, 2021; Mohamed et al, 2022; Cid et al, 2022;English et al, 2022)

Discussion

The clinical findings associated with noxious sensory input may often be correlated with radiological evidence. This includes those that have been essentially dormant for a considerable time.

A broader analysis of these findings is attached as Appendix 3. This is an example of a much deeper assessment and clinical correlation of a hypolordotic cervical; spine. It is suggested as an evolving proposal of corroborating the clinical and radiological findings.

It is the subsequent aggravation or activation of these inert healed lesions that ensuing symptoms motivate a patient to seek relief. Both Hadley and Jackson acknowledge the superimposition of trauma upon an undisturbed and stable older injury. (Hadley(a), p. 130; Jackson, p. 70; Nordoff, p. 139) Although being present as congenital, anomalies would be examples of a dormant lesion with the potential to be reactivated. Over time, the spine may well have adapted and compensated to this stress before being disturbed. (Jackson, p. 70)

Other lesions would be well-established and tend to have a recurring tendency after periods of quiescence. Due to degrees of weakness and instability, some of these cases may require ongoing maintenance or supportive care on a similar basis as preventative dentistry.

A cervical rib would be a typical example of an anomaly having existed all a patient's life then abruptly becoming symptomatic, and diagnosed as an incidental finding. It may occur unilaterally or bilaterally and may be associated with a thoracic outlet syndrome for instance. It is suggested there that it is the physical disturbance of the atypical associated pseudo-articulations which produce the nociceptive symptoms. One would expect the disturbed pseudo-articulation to not only function differently prior to the disruption, but also to bombard noxious sensory impulses into the ascending pathways to the thalamus, cerebellum, and the parietal lobe of the cerebral cortex via the dorsal horn, anterior spinothalamic tract and the medial lemniscus. (de Farias et al, 2020)

Schnell et al state clearly that '*Segmental nociafferences*', e.g. from vertebral joints, skin, musculature or even internal organs, are primarily processed in the spinothalamic projection neuron, consequently, incoming nociafferents at the spinothalamic projection neuron can also modulate sympathetic activity. The autonomic nervous system plays a role in the segmental motor (reflex) response. The autonomic nervous system also plays a role in mediating visceral nociafferents as well as in segmental motor (reflex) response. (Schnell et al, 2022)

To be clinically significant and symptomatic, this input would need to be chronic or acute. Minor sensory activations would probably dissipate as a temporary irritation.

The more readily identifiable mechanoreceptor symptoms which when aggravated by somatosensory disturbances, present various types and degrees of pain. (Dydyk & Conermann, 2023) Physiologically, these bring into play the range of somato-autonomic reflexes including;

somatosympathetic, somatoparasympathetic, somatovascular and somatovisceral reflexes. (Bolser et al, 1991; Fine, 2011; Macefield et al, 2012; Daligadu et al, 2013; Inami et al, 2017; Kawai et al, 2017; Brown et al, 2018; Udit et al, 2022; Watanabe et al, 2023)

It is noted that even subclinical neck pain can have wider effects on the body (Maixner, p. 189; Haavik & Murphy, 2011; Daligadu et al, 2013; Karellas et al, 2019)

Somatosensory receptors include sensations of pain, proprioception (kinesthesia), touch, pressure. and vibration. The sensory feedback that may become noxious with intense hyper-activation through a subluxation, includes proprioceptors and other mechanoreceptors as well as the nociceptive free nerve endings. The sensory activation may be of a chronic, low-grade nature or acute, sharp pain, intermittent or constant. (Zegarra-Parodi, 2004; Doherty, 2020; Bartee et al, 2022)

- Baroreceptors – arterial blood pressure changes
- Free nerve endings III* - sharp pain or cool/cold
- Free nerve endings IV* – Dull or aching pain or touch or warmth.
- Golgi tendon organs - muscle tension, joint torque
- Kraus end bulbs (specialised regions) - cold
- Meissner corpuscles* - touch, motion
- Merkel complex - fine touch
- Muscle spindles* (anulospiral and flower spray endings – muscle length and velocity
- Pacinian corpuscles* – joint movement, vibration
- Proprioceptors* – register positional changes, gross and localised
- Ruffini corpuscles* - joint angle, skin stretch

*Primary receptors thought to be associated with subluxation

Apart from the more severe injuries. whiplash injuries have been shown to effect segmental motion as found by Kristjansson et al in 2003 when they stated '*Significantly more women in the whiplash-associated disorders group (35.3%) had abnormal increased segmental motions compared to the insidious onset neck pain group (8.6%) when both the rotational and the translational parameters were analysed*.'

In 1978, Penning noted the flexion/extension range of sagittal cervical range of motion. (Table 3). Again, this data is integral under a model of care where even subtle deviations from the normal function and become associated with certain autonomic symptoms. (McGregor et al, 1995)

Moriya et al, 1989, found that averaged axial cervical rotation from C0 to C7 totalled 105°, and 70% of the motion occurred between C0 and C2. The average rotation of segments below C2 ranged from 4° to 8°.

Table 3: Flexion/extension of individual cervical segments, full range (after Penning 1978)

Segment	Average	Range
CO/C1	30°	25°-45°
C1/C2	30°	25°-45°
C2/C3	12°	5°-16°
C3/C4	18°	13°-26°
C4/C5	20°	15°-29°
C5/C6	20°	16°-29°
C6/C7	15°	6°-25°

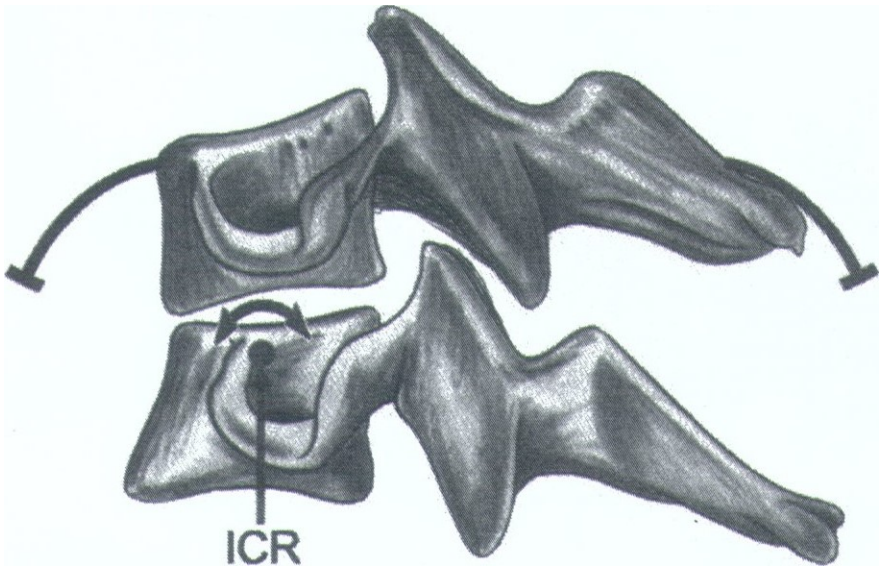


Fig 4: C4 segmental flexion upon C5, left lateral view

After Schwartz et al. J Athl Train. 2005;40(3):155–161.
These vertebrae (nominated here as C4/C5) represent either a sprain and/or a subluxation as identified by the separation of the facet surfaces plus the separation of spinous processes. The wedging of the intervertebral disc would also be noted in this situation, but is within normal limits for plain segmental flexion unless subject to nuclear disc damage. In normal segmental flexion the facet surfaces remain parallel and closer with a glide or imbrication taking place without separation.

Conclusion

There appears to be an assumption that chiropractors employ radiological imaging using the same criteria as conventional medicine. That is only a part of the chiropractic interpretation, it also comprises assessing many of the more abstruse if less severe findings in evaluating a patient's films for cause, history, prognosis, and management. Such findings related to the cervical spine have been presented here.

The importance of cervical spine and optimal cervical function is a goal of manipulative care. Functional subluxations of cervical vertebrae are noted etiological factors in a range of cervicogenic conditions as recorded in the literature. Apart from segmental disturbance, cervical spine sagittal postural alignment is also implicated in neck and headache symptomatology, physiological function, neurophysiological outcomes, and degenerative changes. This situation may fuel existing barriers between differing healthcare professionals as to how much emphasis should be placed on spinal function and alignment in the aetiology of a patient's cranio-cervical complaints, as distinct from pathological findings alone. (Schnell, 2022)

The plethora of studies relating to postural and segmental disturbances would signify an association between spinal integrity and vertebrogenic symptoms. Physical/mechanical disorders would seem to require a physico-mechanical solution unless severe enough to warrant surgery or only be eligible for symptom management. One would opine that pharmaceuticals may help some symptoms but will not restore the physical disturbances.

We suggest that the acknowledged activating factor attributed to initiating cervicogenic headaches, elements of the VSC including the biomechanical disruption of dysfunction with or without displacement, and which are found to respond positively to vertebral adjustments, may also explain other activating somatic factors of other somatoautonomic and somato-visceral, somatovascular and somatosomatic signs including symptoms in other regions of the body. (Sato et al, 1997; Wagner, 2022)

In support of the observation and subluxation concepts presented here, the physician Wagner noted that manipulative alleviation of the aetiological element of cervical segmental dysfunction provided an explanation for the cause of cervicotrigeminal, cervicocephalic and cervocobrachial syndromes, He noted further that following diagnostic testing and the exclusion or contradictive factors, this model of care offered an expanded perspective beyond the conventional model of care. (Wagner, 2022)

We conclude that these findings suggest a disruption of spinal biomechanics as segmental dysfunction with or without displacement, and that they have the capacity to activate somatosensory input to the autonomic nervous system. They may also be recognised as clinical signs with or without symptoms, with some being recognised upon spinal examination prior to a radiological study.

Last word

> *'Somatosensory and visceral sensory neurons provide afferent input throughout the body, allowing the sensory arm of the PNS to detect both noxious and immune stimuli and to integrate these signals to drive the autonomic reflexes that coordinate inflammatory responses.'* (Udit, 2022)

John D Waterhouse
DC (ret), FACC
Melbourne

Peter L Rome
DC (ret), FICCS, FACC
Melbourne
cadaps@bigpond.net.au

Cite: Rome PL. Waterhouse JD. Cervical segment disruption, displacement, and dysfunction with potential to activate somatosensory reflexes: Radiological indications of components of the Vertebral Subluxation Complex. Asia-Pacific Chiropr J. 2023;4.2. apcj.net/papers-issue-4-3/#RWCervicalSubluxation.

See also

Rome PL. Waterhouse JD. The Vertebral Subluxation premise: Part 1: The medical literature regarding nomenclature. Asia-Pacific Chiropr J. 2023;4.1. URL apcj.net/papers-issue-4-1/#RWVSCPremisePart1.

Rome PL. Waterhouse JD. The Vertebral Subluxation premise: Principle 1 continued, The medical literature regarding nomenclature and onset. Asia-Pacific Chiropr J. 2023;4.2. URL apcj.net/papers-issue-4-2/#RWVSCPrinciple1b

Rome PL. Waterhouse JD. The Vertebral Subluxation premise: Principle 2, the somatic vertebrogenic element. Asia-Pacific Chiropr J. 2023;4.2. URL apcj.net/papers-issue-4-2/#RWVSCPrinciple2

Rome PL. Waterhouse JD. The Vertebral Subluxation premise: Principle 3, altered physiological functions. Asia-Pacific Chiropr J. 2023;4.2. URL apcj.net/papers-issue-4-2/#RWVSCPrinciple3

Rome PL. Waterhouse JD. The Vertebral Subluxation premise: Principle 4, Segmental and neural disturbance is associated with clinical signs and symptoms, and a range of conditions. Asia-Pacific Chiropr J. 2023;4.2. URL apcj.net/papers-issue-4-2/#RWVSCPrinciple4

Rome PL. Waterhouse JD. The Vertebral Subluxation premise: Principle 5, the intent is to correct dysfunction and restore normal function. Asia-Pacific Chiropr J. 2023;4.2. URL apcj.net/papers-issue-4-2/#RWVSCPrinciple5

References

Agnew LRC, et al, Eds. Dorland's Illustrated Medical Dictionary. Philadelphia: WN Saunders Co; 1965:1457.

Al Khalili Y, Ly N, Murphy PB. Cervicogenic Headache. 2022 Oct 3. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 29939639.

Ames CP, Blondel B, Scheer JK, et al. Cervical radiographical alignment: comprehensive assessment techniques and potential importance in cervical myelopathy. Spine (Phila Pa 1976). 2013 Oct 15;38(22 Suppl 1):S149-60. doi: 10.1097/BRS.0b013e3182a7f449.

Andrew D, Yielder P, Haavik H, Murphy B. The effects of subclinical neck pain on sensorimotor integration following a complex motor pursuit task. Exp Brain Res. 2018 Jan;236(1):1-11. doi: 10.1007/s00221-017-5103-4. Epub 2017 Oct 12. PMID: 29026942.

Antos JC, Keating Jr JC, Robinson GK. Interrater reliability of fluoroscopic detection of fixation in the mid-cervical spine. Chiropr Tech. 1990;2(2):53-55.

Aoyama R, Shiraishi T, Kato M, et al. Characteristic findings on imaging of cervical spondylolisthesis: Analysis of computed tomography and X-ray photography in 101 spondylolisthesis patients. Spine Surg Relat Res. 2018 Jan 27;2(1):30-36. doi: 10.22603/ssrr.2017-0017. PMID: 31440643; PMCID: PMC6698550.

Apfelbeck L. An integrative treatment approach of a patient with cervical radiculitis: A case report. J Chiropr Med. 2005 Spring;4(2):97-102. doi: 10.1016/S0899-3467(07)60119-0. PMID: 19674652; PMCID: PMC2647039.

Arnone PA, Kraus SJ, Farmen D, Lightstone DF, Jaeger J, Theodossis C. Examining clinical opinion and experience regarding utilization of plain radiography of the spine: evidence from surveying the chiropractic profession. J Clin Med. 2023 Mar 10;12(6):2169. doi: 10.3390/jcm12062169. PMID: 36983168; PMCID: PMC10054546.

Assendelft WJ, Bouter LM, Knipschild PG, Wilmink JT. Reliability of lumbar radiograph reading by chiropractors. Spine. 1997;22(11):1235-41

Bartee L, Shriner W, Creech C. Somatosensory receptors. From: Principles of biology. Libre Texts. University of California Davis. Citing: Anon, 2022. Somatosensory Receptors. Available at: https://bio.libretexts.org/@go/page/44194 [Accessed April 25, 2023].

Bauer F. Exposure calculations. The Siemens Point System: Adapted for chiropractic spinography. Undated lecture notes. Circa 1974.

Baziuk V. What are secondary and tertiary subluxations? https://www.drverabaziuk.com/what-are-secondary-and-tertiary-subluxations/ Sept 5, 2017.

Bell DC, Slalski M, et al. Radiology training for chiropractic radiologists in the United States of America. https://radiopaedia.org/articles/radiology-training-for-chiropractic-radiologists-in-the-united-states-of-america. (Extracted Jan 9, 2021.

Bell DJ. Olisthesis. The reading room. https://radiopaedia.org/articles/olisthesis. 2018.

Bennett SF, Hayde TM. Cervical spondylolisthesis: a case report. J Chiropr. 1991;28(2):69-71.

Biedermann H. Radiology in manual therapy in children. In: Manual therapy in children. Edinburgh. Churchill Livingstone. 2004;213-272.

Bolser DC, Hobbs SF, Chandler MJ, et al. Convergence of phrenic and cardiopulmonary spinal afferent information on cervical and thoracic spinothalamic tract neurons in the monkey: implications for referred pain from the diaphragm and heart. J Neurophysiol. 1991 May;65(5):1042-54. doi: 10.1152/jn.1991.65.5.1042. PMID: 1869904.

Bourdeinyi A, Plotkina O. Diagnostics of musculoskeletal pain in various locations of the body, and approaches to its effective treatment. Clinical Investigations. 2020;10(4): https://www.openaccessjournals.com/articles/diagnostics-of-musculoskeletal-pain-in-various-locations-of-the-body-and-approaches-to-its-effective-treatment-13868.html

Braakman M, Braakman R. Hyperflexion sprain of the cervial spine: Follow-up of 45 cases. Acta Orthop Scand 1987;58:388-393.

Bruehl S, Chung OY. Interactions between the cardiovascular and pain regulatory systems: an updated review of mechanisms and possible alterations in chronic pain. Neurosci Biobehav Rev. 2004 Jul;28(4):395-414. doi: 10.1016/j.neubiorev.2004.06.004. PMID: 15341037.

Brown R, Burton AR, Macefield VG. Autonomic dysreflexia: Somatosympathetic and viscerosympathetic vasoconstrictor responses to innocuous and noxious sensory stimulation below lesion in human spinal cord injury. Auton Neurosci. 2018 Jan;209:71-78. doi: 10.1016/j.autneu.2017.07.003. Epub 2017 Jul 13. PMID: 28728939.

Bryner P. Essay: symmetry a premise of chiropractic diagnosis and therapy. J Aust Chiropr Assoc. 1986;10(4):172-6)

Burstein R. Somatosensory and visceral input to the hypothalamus and limbic system. Prog Brain Res. 1996;107:257-67. doi: 10.1016/s0079-6123(08)61869-5. PMID: 8782524.

Cailliet R. Subluxations of the cervical spine including the 'whiplash' syndrome. In:Neck and arm pain. Philadelphia: FA Davis Co. 1964;60-85

Carta G, Gambarotta G, Fornasari B.E, et al. The neurodynamic treatment induces biological changes in sensory and motor neurons in vitro. Sci Rep. 2021;11, 13277. https://doi.org/10.1038/s41598-021-92682-2

Centeno CJ, Elkins W, Freeman M, et al. Total cervical translation as a function of impact vector as measured by flexion-extension radiography. Pain Phys. 2007;10(5):667-71.

Cervero F, Tattersall JE. Somatic and visceral inputs to the thoracic spinal cord of the cat: marginal zone (lamina I) of the dorsal horn. J Physiol. 1987 Jul;388:383-95. doi: 10.1113/jphysiol.1987.sp016620. Erratum in: J Physiol (Lond) 1987 Dec;393:777. PMID: 3450285; PMCID: PMC1192554.

Chojniak R. Incidentalomas: managing risks. Radiol Bras. 2015 Jul-Aug;48(4):IX-X. doi: 10.1590/0100-3984.2015.48.4e3. PMID: 26379332; PMCID: PMC4567356.

Chu EC. Reducing cervical retrolisthesis with long-term monthly chiropractic maintenance care: A case report. J Med Cases. 2022 Jul;13(7):359-364. doi: 10.14740/jmc3960. Epub 2022 Jul 20. PMID: 35949943; PMCID: PMC9332823.

Cid MM, Calixtre LB, da Silva Grüninger BL, et al. Reliability of the joint position sense error test for women with neck pain and asymptomatic men and women. J Manipulative Physiol Ther. 2022 Sep 30:S0161-4754(22)00119-1. doi: 10.1016/j.jmpt.2022.08.007. Epub ahead of print. PMID: 36192261.

Coleman RR, Lopes MA, Suttles RA. Computer modelling of selected projectional factors of the 84-in focal film distance anteroposterior full spine radiograph compared with 40-in focal film distance sectional views. J Chiropr Med. 2011 Mar;10(1):18-24. doi: 10.1016/j.jcm.2010.05.003. Epub 2011 Jan 21.

Cramer G, Budgell B, Henderson C, Khalsa P, Pickar J. Basic science research related to chiropractic spinal adjusting: the state of the art and recommendations revisited. J Manipulative Physiol Ther. 2006 Nov-Dec;29(9):726-61. doi: 10.1016/j.jmpt.2006.09.003. PMID: 17142166.

Curtin P, McElwain J. Assessment of the "nearly normal" cervical spine radiograph: C2-C3 pseudosubluxation in an adult with whiplash injury. Emerg Med J. 2005 Dec;22(12):907-8. doi: 10.1136/emj.2004.020115. PMID: 16299212; PMCID: PMC1726654.

Dai LY. Significance of prevertebral soft tissue measurement in cervical spine injuries. Eur J Radiol. 2004 Jul;51(1):73-6. doi: 10.1016/S0720-048X(03)00142-6.

Dailey AT, Shaffewy CI, Rampersaud R, et al. Utility of helical computed tomography in differentiating unilateral and bilateral facet dislocation. J Spinal Cord Med. 2009;32(1):43-48.

Daligadu J, Haavik H, Yielder PC, Baarbe J, Murphy B. Alterations in cortical and cerebellar motor processing in subclinical neck pain patients following spinal manipulation. J Manipulative Physiol Ther. 2013;36(8):527-537.

Davidorf J, Hoyt D, Rosen P. Distal cervical spine evaluation using swimmer's flexion-extension radiographs. J Emerg Med 1993;11:55-59.

Davies NJ. Chiropractic paediatrics: A clinical handbook. Edinburgh: Churchill Livingstone.2000.

Davis AG. Injuries of the cervical spine. JAMA 1945;Jan 20:127:149-156, April 7:936

Deboer KF, Harmon R Jr, Tuttle CD, Wallace H. Reliability study of detection of somatic dysfunctions in the cervical spine. J Manipulative Physiol Ther. 1985 Mar;8(1):9-16. PMID: 3989400.

de Farias LPG, Menezes DC, Faé IS, et al. Anatomical variations and congenital anomalies of the ribs revisited by multidetector computed tomography. Radiol Bras. 2020 Nov-Dec;53(6):413-418. doi: 10.1590/0100-3984.2019.0131.

de Zoete A, Ostelo R, Knol DL, et al. Diagnostic accuracy of lumbosacral spine magnetic resonance image reading by chiropractors, chiropractic radiologists and medical radiologists. Spine. 2015;40(11):E653-60.

de Zoete A. Assendelft WJ, Algra PR, et al. Reliability and validity of lumbosacral spine radiograph reading by chiropractors, chiropractic radiologists, and medical radiologists. Spine. 2002;27(17):1926-1933.

Demetrious J. Clinical pearl. Upright dynamic MRI (case report). eJ Acad Chiropr Orthop. 2007;4(4):2-7. (Abstract only)

Demetrious J.(a) Post-traumatic upper cervical subluxation visualized by MRI: a case report. Chiropr Osteop. 2007 Dec 19;15:20. doi: 10.1186/1746-1340-15-20. PMID: 18093309; PMCID: PMC2253541.

Doktor K, Vilholm ML. Hardardóttir A, Christensen HW, Lauritsen JL. European guidelines on quality criteria for diagnostic radiographic images of the lumbar spine – an intra- and interobserver reproducibility study. J Chiropr Man Ther. 2019;27:20. doi: 10.1186/s12998-019-0241-3. eCollection 2019.PMID: 31069046

Dolan KD. Cervical spine injuries below the axis. Radiol Clin North Am. 1977 Aug;15(2):247-59. PMID: 887738.

Dougherty P. Neuroscience online. Somatosensory pathways. University of Texas Health. 2020. McGovern Medical School. https://nba.uth.tmc.edu/neuroscience/m/s2/chapter04.html

Dvorak J, Froehlich D, Penning L, Baumgartner H, Panjabi MM. Functional radiographic diagnosis of the cervical spine: flexion/extension. Spine (Phila Pa 1976). 1988 Jul;13(7):748-55. doi: 10.1097/00007632-198807000-00007. PMID: 3194782.

Dydyk AM, Conermann T. Chronic Pain. [Updated 2022 Nov 7]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK553030/

El-Feky M. Flexion teardrop fracture. https://radiopaedia.org/articles/flexion-teardrop-fracture-1. 25 Jan, 2023. (Accessed May 6, 2023.

English DJ, Zacharias A, Green RA, Weerakkody N. Reliability of cervicocephalic proprioception assessment: a systematic review. J Manipulative Physiol Ther. 2022 Oct 19:S0161-4754(22)00118-X. doi: 10.1016/j.jmpt.2022.08.005.

Epstein BS, Epstein JA, Jones MD. Degenerative spondylolisthesis with an intact neural arch. Radiolog Clinics of North Am 1977;15(2):275-87.

Eriksen K. Upper cervical subluxation complex. Philadelphia: Lippincott Williams & Wilkins.2004.

Ernst A, Niedeggen A. Reconstitution of lost cervical spine function: management strategies. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2005;4:Doc20. Epub 2005 Sep 28. PMID: 22073068; PMCID: PMC3201010.

Farid B, Yielder P, Holmes M, Haavik H, Murphy BA. Association of subclinical neck pain with altered multisensory integration at baseline and 4-week follow-up relative to asymptomatic controls. J Manipulative Physiol Ther. 2018 Feb;41(2):81-91. doi: 10.1016/j.jmpt.2017.09.003. PMID: 29482829.

Fedorchuk C, Lightstone G, Reduction in cervical anterolisthesis & pain in a 52-year-old female using Chiropractic BioPhysics® Technique: A case study and selective review of literature [case report]. Ann Vert Sublux Res. 2016;Summer;3:118-125

Ferrantelli JR, Harrison DE, Harrison DD, Stewart D. Conservative treatment of a patient with previously unresponsive whiplash-associated disorders using clinical biomechanics of posture rehabilitation methods. J Manipulative Physiol Ther. 2005 Mar-Apr;28(3):e1-8. doi: 10.1016/j.jmpt.2005.02.006. Erratum in: J Manipulative Physiol Ther. 2005 Jul-Aug;28(6):460. PMID: 15855899.

Fielding JW, Hawkins RJ. Atlanto-axial rotatory fixation. (Fixed rotatory subluxation of the atlanto-axial joint). J Bone Joint Surg Am. 1977 Jan;59(1):37-44. PMID: 833172.

Fine PG. Long-term consequences of chronic pain: mounting evidence for pain as a neurological disease and parallels with other chronic disease states. Pain Medicine, 2011;12(7):996-1004

Foreman SM, Croft AC. Whiplash injuries. The cervical acceleration/deceleration syndrome. 3rd edn. Philadelphia: Lippincott Williams & Wilkins:2002

Frobin W, Leivseth G, Biggemann M, Brinckmann P. Sagittal plane segmental motion of the cervical spine. A new precision measurement protocol and normal motion data of healthy adults. Clin Biomech (Bristol, Avon). 2002 Jan;17(1):21-31. doi: 10.1016/s0268-0033(01)00105-x. PMID: 11779643.

Frymoyer, J.W., R.B. Phillips, A.H. Newberg, et al. 1986. A comparative analysis of the interpretations of lumbar spinal radiographs by chiropractors and medical doctors. Spine 1985;11:1020-1023.

Gatterman MI. (a). Foundations of chiropractic subluxation. 2nd edn. St Louis: Elsevier Mosby;2005

Gatterman MI (b). Chiropractic management of spine related disorders. Baltimore: Williams & Wilkins:1990.

Gatterman MI. (c) Chiropractic management of neck pain of mechanical origin. In: In: Giles LGF, Singer KP. Clinical anatomy and management of cervical spine pain. Edinburgh: Butterworth Heinemenn; 2006:143-144.

Gatterman MI.(d) Whiplash: A patient-centred approach to management. St Louis: Elsevier;2012.

Gay RE. The curve of the cervical spine: variations and significance. J Manipulative Physiol Ther 1993;16(9):591-594.

Gelley G. The effects of spinal manipulation on performance on neck pain patients during Fitts task, NIH, US National Library of Medicine. Clinical Trials.gov. 2020. https://clinicaltrials.gov/ct2/show/NCT04347551

Giles LFG, Singer KP. Eds. Clinical anatomy and management of cervical spine pain. Vol 3. Edinburgh: Butterworth Heinemann: 2005;127.

Giles LGF, Baker PG. Clinical anatomy and management of cervical spine pain. Vol 3. Edinburgh: Butterworth Heinemann: 2005:10.

Goel A, Sharma R, Skandhan A, et al. Olisthesis. Reference article, Radiopaedia.org (Accessed on 16 Apr 2023) https://doi.org/10.53347/rID-37071

Goldthwait JE, Brown LT, Swaim LT, Kuhns JG. Essentials of body mechanics in health and disease. Philadelphia: JB Lippincott Co. 1952;51-53.

Green JD, Harle TS, Harris JH Jr. Anterior subluxation of the cervical spine: hyperflexion sprain. AJNR Am J Neuroradiol. 1981 May-Jun;2(3):243-50.

Grgić V. Cervikogena disfagija: teskoće s gutanjem uzrokovane funkcijskim i organskim poremećajima vratne kraljeznice [Cervicogenic dysphagia: swallowing difficulties caused by functional and organic disorders of the cervical spine]. Lijec Vjesn. 2013 Mar-Apr;135(3-4):92-9. Croatian. PMID: 23671976.

Grin A, Krylov V, Lvov I, et al. External multicenter study of reliability and reproducibility for lower cervical spine injuries classification systems-Part 2: An analysis of the subaxial cervical spine injury classification and cervical spine injury severity score scale. Global Spine J. 2019;11(1): DOI: 10.1177/2192568219896546

Grob D, Frauenfelder H, Mannion AF. The association between cervical spine curvature and neck pain. Eur Spine J. 2007 May;16(5):669-78. doi: 10.1007/s00586-006-0254-1. Epub 2006 Nov 18. PMID: 17115202; PMCID: PMC2213543.

Haavik H, Murphy B. Subclinical neck pain and the effects of cervical manipulation on elbow joint position sense. J Manipulative Physiol Ther. 2011 Feb;34(2):88-97. doi: 10.1016/j.jmpt.2010.12.009. PMID: 21334540.

Haavik-Taylor H, Murphy B. Cervical spine manipulation alters sensorimotor integration: a somatosensory evoked potential study. Clin Neurophysiol. 2007 Feb;118(2):391-402. doi: 10.1016/j.clinph.2006.09.014. Epub 2006 Nov 29. PMID: 17137836.

Hadley LA. Anatomico-roentgenographic studies of the spine. 3rd printing. Springfield, Charles C Thomas.1976.

Hadley LA. Apophyseal subluxation. Disturbances in and about the intervertebral foramen causes back pain. J Bone Joint. 1936:18(2)428-433.

Hadley LA. Intervertebral joint subluxation, bony impingement and foramen encroachment with nerve root changes. Am J Roentgenol Radium Ther. 1951 Mar;65(3):377-402. PMID: 14819421.

Hadley LA. Subluxation of the apophyseal articulations. with bony impingement as a cause of back pain. Phys Ther. 1935;15(4)141-143.

Haldeman S, Dagenais S. Cervicogenic headaches: a critical review. Spine J. 2001 Jan-Feb;1(1):31-46. doi: 10.1016/s1529-9430(01)00024-9. PMID: 14588366.

Haldeman S.(a) Principles and practice of chiropractic. Norwalk; Appleton & Lange. 1992:395-397.

Harris JH Jr, Carson GC, Wagner LK. Radiologic diagnosis of traumatic occipitovertebral dissociation: 1. Normal occipitovertebral relationships on lateral radiographs of supine subjects. AJR Am J Roentgenol. 1994 Apr;162(4):881-6. doi: 10.2214/ajr.162.4.8141012. PMID: 8141012.

Harrison DD, Harrison DE, Janik TJ, et al. Modelling of the sagittal cervical spine as a method to discriminate hypolordosis: results of elliptical and circular modelling in 72 asymptomatic subjects, 52 acute neck pain subjects, and 70 chronic neck pain subjects. Spine (Phila Pa 1976). 2004 Nov 15;29(22):2485-92. doi: 10.1097/01.brs.0000144449.90741.7c. PMID: 15543059.

Harrison DD, Janik TJ, Troyanovich SJ, Harrison DE, Colloca CJ. Evaluation of the assumptions used to derive an ideal normal cervical spine model. J Manipulative Physiol Ther. 1997 May;20(4):246-56. PMID: 9168409.

Harrison DD, (a) Janik TJ, Troyanovich SJ, Holland B. Comparisons of lordotic cervical spine curvatures to a theoretical ideal model of the static sagittal cervical spine. Spine (Phila Pa 1976). 1996 Mar 15;21(6):667-75. doi: 10.1097/00007632-199603150-00002. PMID: 8882687.

Harrison DD, (b) Troyanovich SJ, Harrison DE, Janik TJ, Murphy DJ. A normal sagittal spinal configuration: a desirable clinical outcome. J Manipulative Physiol Ther. 1996 Jul-Aug;19(6):398-405. PMID: 8864971.

Harrison DE, Harrison DD, Betz JJ, Janik TJ, Holland B, Colloca CJ, Haas JW. Increasing the cervical lordosis with chiropractic biophysics seated combined extension-compression and transverse load cervical traction with cervical manipulation: nonrandomized clinical control trial. J Manipulative Physiol Ther. 2003 Mar-Apr;26(3):139-51. doi: 10.1016/S0161-4754(02)54106-3. Erratum in: J Manipulative Physiol Ther. 2005 Mar-Apr;28(3):214. PMID: 12704306.

Harrison DE, Harrison DD, Troyanovich SJ. Reliability of spinal displacement analysis of plain x-rays: a review of commonly accepted facts and fallacies with implications for chiropractic education and technique. J Manipulative Physiol Ther. 1998;21(4):252-66.

Heikkilä H, Aström PG. Cervicocephalic kinesthetic sensibility in patients with whiplash injury. Scand J Rehabil Med. 1996; 28(3):133-8. PMID: 8885035.

Henderson CNR. The basis for spinal manipulation: Chiropractic perspective of indications and theory. J Electromyogr Kinesiol. 2012;22(5):632-42. http://dx.doi.org/10.1016/j.jelekin.2012.03.008.

Hildberand RW. Chiropractic spinography: a manual of technology and interpretation. 2nd edn, Baltimore. Williams and Wilkins. 1985.

Hildebrandt P. What is chiropractic radiology. Radiology Today. 2010;11(8): https://www.radiologytoday.net/archive/rt0810p20.shtml#

Honda CN. Visceral and somatic afferent convergence onto neurons near the central canal in the sacral spinal cord of the cat. J Neurophysiol. 1985 Apr;53(4):1059-78. doi: 10.1152/jn.1985.53.4.1059. PMID: 3998792.

Hohl M. Soft-tissue injuries of the neck in automobile accidents. Factors influencing prognosis. J bone Joint Surg – A 1974;56(8):160383-1691.

Humphreys BK, Delahaye M, Peterson CK. An investigation into the validity of cervical spine motion palpation using subjects with congenital block vertebrae as a 'gold standard'. BMC Musculoskelet Disord. 2004 Jun 15;5:19.

Hubka MJ, Phelan SP. Interexaminer reliability of palpation for cervical spine tenderness. J Manipulative Physiol Ther. 1994 Nov-Dec;17(9):591-5. PMID: 7884328.'

Inami A, Ogura T, Watanuki S, et al. Glucose metabolic changes in the brain and muscles of patients with nonspecific neck pain treated by spinal manipulation therapy: A [18F]FDG PET study. Evid Based Complement Alternat Med. 2017;2017:4345703. doi: 10.1155/2017/4345703. Epub 2017 Jan 12.

Jackson R. The cervical syndrome. 3rd edn. Springfield: Charles C Thomas. 1966.

Jacobson G & Adler DC. An evaluation of lateral atlanto-axial displacement in injuries of the cervical spine. Radiology, 1953;61(3):355-362)

Jiang SD, Jiang LS, Dai LY. Degenerative cervical spondylolisthesis: a systematic review. Int Orthop. 2011 Jun;35(6):869-75. doi: 10.1007/s00264-010-1203-5. Epub 2011 Jan 25. PMID: 21264670; PMCID: PMC3103955.

Jonsson K, Niklasson J, Josefsson PO. Avulsion of the cervical spinal ring apophyses: acute and chronic appearance. Skeletal Radiol. 1991;20(3):207-10. doi: 10.1007/BF00241672. PMID: 2057796.

Jouibari MF, Le Huec JC, Ranjbar Hameghavandi MH, et al. Comparison of cervical sagittal parameters among patients with neck pain and healthy controls: a comparative cross-sectional study. Eur Spine J. 2019 Oct;28(10):2319-2324. doi: 10.1007/s00586-019-06117-8. Epub 2019 Aug 23. Erratum in: Eur Spine J. 2020 Jan;29(1):198. PMID: 31444609.

Jull G, Bogduk N, Marsland A. The accuracy of manual diagnosis for cervical zygapophysial joint pain syndromes. Med J Aust. 1988 Mar 7;148(5):233-6. doi: 10.5694/j.1326-5377.1988.tb99431.x. PMID: 3343953.

Jutkowitz J. A normal sagittal spinal configuration: a desirable clinical outcome. J Manipulative Physiol Ther. 1997 May;20(4):288-93. PMID: 9168416.

Kamel M, Moustafa IM, Kim M, Oakley PA, Harrison DE. Alterations in cervical nerve root function during different sitting positions in adults with and without forward head posture: A cross-sectional study. J Clin Med. 2023 Feb 23;12(5):1780. doi: 10.3390/jcm12051780.

Kaneoka K, Ono K, Inami S, Ochiai N, Hayashi K. The human cervical spine motion during rear-impact collisions: A proposed cervical facet injury mechanism during whiplash trauma. J Whiplash Related Disorders 2002;1(1):85-97.

Karellas AM, Yielder P, Burkitt JJ, McCracken HS, Murphy BA. The influence of subclinical neck pain on neurophysiological and behavioural measures of multisensory integration. Brain Sci. 2019 Dec 9;9(12):362. doi: 10.3390/brainsci9120362.

Kattan KR (ed). "Trauma" and "No-Trauma" of the cervical spine. Springfield, Ill: Charles C Thomas Publisher. 1975.

Katter JT, Dado RJ, Kostarczyk E, Giesler GJ Jr. Spinothalamic and spinohypothalamic tract neurons in the sacral spinal cord of rats. II. Responses to cutaneous and visceral stimuli. J Neurophysiol. 1996 Jun;75(6):2606-28. doi: 10.1152/jn.1996.75.6.2606. PMID: 8793766.

Kawai K, Kawai AT, Wollan P, Yawn BP. Adverse impacts of chronic pain on health-related quality of life, work productivity, depression and anxiety in a community-based study. Fam Pract. 2017 Nov 16;34(6):656-661. doi: 10.1093/fampra/cmx034. PMID:

Keating JC. History notes re: X-ray, spinography, roentgenology, radiology, etc. Circa 1995:1-15. https://chiro.org/Plus/History/Persons/X-Ray-history/X-ray_history.pdf

Keats TE, Anderson MW. Atlas of normal roentgen variants that may simulate disease. 7th. edn. St Louis: Mosby Inc;2001. (stair step p 224,225)

Keats TE, Johnstone WH. Notching of the lamina of C7: a proposed mechanism. Skel Rad. 1982l7L273-4.

Kent C. Anterior cervical subluxation with instability: a radiological case report. ICA Rev. 1992;48(5):44-47:

Kent C. Models of vertebral subluxation: A review. J Vertebral Su=bluxation Research. 1996;1(1):1-7.

Kent C. Proposed neurological processes associated with models of vertebral subluxation: dysafferentation, dyskinesia, dysautonomia, neuroplasticity, and ephaptic transmission. Arch Neurol Neurosci. 2019;3(1):ANN.MS.ID.000555.

Kim HS, Wu PH, Jang IT. Narrative review of pathophysiology and endoscopic management of basivertebral and sinuvertebral neuropathy for chronic back pain. J Korean Neurosurg Soc. 2022 Nov 28. doi: 10.3340/jkns.2022.0140. Dept Neurosurgery Nanoori Gangnam Hospital, Seoul. June 13, 2022. https://www.jkns.or.kr/journal/view.php?doi=10.3340/jkns.2022.0140

Kirpalani D, Mitra R. Cervical facet joint dysfunction: a review. Arch Phys Med Rehabil. 2008 Apr;89(4):770-4. doi: 10.1016/j.apmr.2007.11.028. PMID: 18374011.EG46

Knott PT, Mardjetko SM, Techy F. The use of the T1 sagittal angle in predicting overall sagittal balance of the spine. Spine J. 2010 Nov;10(11):994-8. doi: 10.1016/j.spinee.2010.08.031. PMID: 20970739.

Koslosky E, Gendelberg D. Classification in Brief: The Meyerding Classification System of Spondylolisthesis. Clin Orthop Relat Res. 2020 May;478(5):1125-1130.

Kristjansson E, Leivseth G, Brinckmann P, Frobin W. Increased sagittal plane segmental motion in the lower cervical spine in women with chronic whiplash-associated disorders, grades I-II: a case-control study using a new measurement protocol. Spine (Phila Pa 1976). 2003 Oct 1;28(19):2215-21.

Kristjansson E, Treleaven J. Sensorimotor function and dizziness in neck pain: implications for assessment and management. J Orthop Sports Phys Ther. 2009 May;39(5):364-77. doi: 10.2519/jospt.2009.2834. PMID: 19411769.

Lauridsen H. Conservative management of cervical hypermobile/instability. Eur J Chiro. 2003;47(3):79-89.

Leach RA. The chiropractic theories: Principles and clinical applications. 3rd edn. Baltimore: Williams & Wilkins.1994.

Lee C, Woodring JH, Rogers LF, Kim KS. The radiographic distinction of degenerative slippage (spondylolisthesis and retrolisthesis) from traumatic slippage of the cervical spine. Skeletal Radiol. 1986;15(6):439-43. doi: 10.1007/BF00355101. PMID: 3764470.

Lee HS, Chung HK, Park SW. Correlation between trunk posture and neck reposition sense among subjects with forward head neck postures. Biomed Res Int. 2015;2015:689610. doi: 10.1155/2015/689610. Epub 2015 Oct 25.

Lee SH, Son ES, Seo EM, Suk KS, Kim KT. Factors determining cervical spine sagittal balance in asymptomatic adults: correlation with spinopelvic balance and thoracic inlet alignment. Spine J. 2015 Apr 1;15(4):705-12. doi: 10.1016/j.spinee.2013.06.059.

Lewit K. Manipulative therapy in rehabilitation of the locomotor system. 3rd edn. Oxford. Butterworth Heinemann;1999;34-36.

Li YK, Zhang YK, Zhong SZ. Diagnostic value on signs of subluxation of cervical vertebrae with radiological examination. J Manipulative Physiol Ther. 1998;21(9):617-20

Liebenson C. Active muscular relaxation techniques. Part I. Basic principles and methods. J Manipulative Physiol Ther. 1989 Dec;12(6):446-54. PMID: 2697735.

Lin RM, Tsai KH, Chu LP, Chang PQ. Characteristics of sagittal vertebral alignment in flexion determined by dynamic radiographs of the cervical spine. Spine (Phila Pa 1976). 2001;26(3):256-61.

Ling FP, Chevillotte T, Leglise A, et al. Which parameters are relevant in sagittal balance analysis of the cervical spine? A literature review. Eur Spine J. 2018 Feb;27(Suppl 1):8-15. doi: 10.1007/s00586-018-5462-y.

Lippa L, Lippa L, Cacciola F. Loss of cervical lordosis: What is the prognosis? J Craniovertebr Junction Spine. 2017 Jan-Mar;8(1):9-14. doi: 10.4103/0974-8237.199877.

Lipson SJ, Fox Da, Sosman JL. Symptomatic intravertebral disc herniation (Schmorl's node) in the cervical spine. Ann Rheum Dis. 1985;44:857-0.

Liu J, Ebraheim NA, Haman SP, Shafiq Q, et al. Effect of the increase in the height of lumbar disc space on facet joint articulation area in sagittal plane. Spine (Phila Pa 1976). 2006 Apr 1;31(7):E198-202. doi: 10.1097/01.brs.0000206387.67098.a0. PMID: 16582840.

Lowe RW, Hayes D, Kaye J, Bagg RJ, Luekens CA. Standing roentgograms in spondylolisthesis. Clin Orthop Rel Research 1976;117:80-84.

Macefield VG, Burton AR, Brown R. Somatosympathetic Vasoconstrictor Reflexes in Human Spinal Cord Injury: Responses to Innocuous and Noxious Sensory Stimulation below Lesion. Front Physiol. 2012 Jun 25;3:215. doi: 10.3389/fphys.2012.00215. PMID: 22737131; PMCID: PMC3382416.

Mahmoud NF, Hassan KA, Abdelmajeed SF, Moustafa IM, Silva AG. The relationship between forward head posture and neck pain: A systematic review and meta-analysis. Curr Rev Musculoskelet Med. 2019 Dec;12(4):562-577. doi: 10.1007/s12178-019-09594-y. PMID: 31773477; PMCID: PMC6942109.

Maigne R. Orthopaedic medicine. A new approach to vertebral manipulation. Springfield: Charles C Thomas Publisher. 1972.

Maile S, Slongo T. Atlantoaxial rotatory subluxation: realignment and discharge within 48 h. Eur J Emerg Med. 2007;14(3):167-9

Maixner W. Autonomic and somatosensory interactions: physiological and pathophysiological implications. Proc Finn Dent Soc. 1989;85(4-5):395-407. PMID: 2699765.

Mann NS, Brewer H, Sheth B. Upper esophageal dysphagia due to marked cervical lordosis. J Clin Gastroenterol. 1984 Feb;6(1):57-60. PMID: 6699394.

Marchiori DM, Hawk C, Howe J. Chiropractic radiologists: A survey of demographics, abilities, educational attitudes, and practice trends. J Manipulative Physiol Ther. 1998;21(6):392-398.

Marchiori DM. eClinical imaging with skeletal, chest, and abdomen pattern differentials. 3rd edn. London: Elsevier 2013

McAviney J, Schulz D, Bock R, Harrison DE, Holland B. Determining the relationship between cervical lordosis and neck complaints. J Manipulative Physiol Ther. 2005 Mar-Apr;28(3):187-93. doi: 10.1016/j.jmpt.2005.02.015. PMID: 15855907.

McDowall D, Emmanuel E, Grace S, Chaseling M. Tone as a health concept: An analysis. Complement Ther Clin Pract. 2017 Nov;29:27-34. doi: 10.1016/j.ctcp.2017.08.001. Epub 2017 Aug 12. PMID: 29122266.

McGregor M, Mior S, Shannon H, et al. The clinical usefulness of flexion-extension radiographs in the cervical spine. Top Clin Chiropr. 1995;2(4):18-28.

Meschan I. Synopsis of roentgen signs. Philadelphia: WB Saunders Co. 1963:220.

Miles KA, Maimaris C, Finlay D, Barnes MR. The incidence and prognostic significance of radiological abnormalities in soft tissue injuries to the cervical spine. Skeletal Radiol. 1988;17(7):493-6. doi: 10.1007/BF00364043.

Mohamed AA, Jan YK, Raoof NA, et al. Effect of biofeedback corrective exercise on reaction time and central somatosensory conduction time in patients with forward head posture and radiculopathy: A randomized controlled study. J Chiropr Med. 2022 Mar;21(1):39-50. doi: 10.1016/j.jcm.2022.01.001.

Morgan L. A normal sagittal spinal configuration: a desirable clinical outcome. J Manipulative Physiol Ther. 1997 Feb;20(2):130-1; author reply 131-3. PMID: 9046462.

Moriya H, Mimura M, Watanabe T, et al. Three-dimensional motion analysis of the cervical spine with special reference to the axial rotation. Spine. 1989;14(11):1135-39.

Mostafaee N, HasanNia F, Negahban H, Pirayeh N. Evaluating differences between participants with various forward head posture with and without postural neck pain using craniovertebral angle and forward shoulder angle. J Manipulative Physiol Ther. 2022 Mar-Apr;45(3):179-187. doi: 10.1016/j.jmpt.2022.06.007. Epub 2022 Jul 25. PMID: 35902274.

McWilliam R, Murphy A, Bell D, et al. Thoracic spine (AP view). Reference article, Radiopaedia.org (Accessed on 10 May 2023) https://doi.org/10.53347/rID-49207

Myrtveit SM, Skogen JC, Wenzel HG, Mykletun A. Somatic symptoms beyond those generally associated with a whiplash injury are increased in self-reported chronic whiplash. A population-based cross-sectional study: the Hordaland Health Study (HUSK). BMC Psychiatry. 2012 Aug 31;12:129. doi: 10.1186/1471-244X-12-129. PMID: 22935146; PMCID: PMC3476995.

Navone SE, Marfia G, Giannoni A, Beretta M, Guarnaccia L, Gualtierotti R, Nicoli D, Rampini P, Campanella R. Inflammatory mediators and signalling pathways controlling intervertebral disc degeneration. Histol Histopathol. 2017 Jun;32(6):523-542. doi: 10.14670/HH-11-846. Epub 2016 Nov 16. PMID: 27848245.

Nordhoff LS. Motor vehicle collision injuries. Biomechanics, diagnosis, and management. 2nd edn. Sudbury, Mass: Jones & Bartlett Publishers:2005 p 144.

Norton TC, Oakley PA, Harrison DE. Improving the cervical lordosis relieves neck pain and chronic headaches in a pediatric: a Chiropractic Biophysics® (CBP®) case report with a 17-month follow-up. J Phys Ther Sci. 2022 Jan;34(1):71-75. doi: 10.1589/jpts.34.71. Epub 2022 Jan 12. PMID: 35035083; PMCID: PMC8752283.

Núñez-Pereira S, Hitzl W, Bullmann V, Meier O, Koller H. Sagittal balance of the cervical spine: an analysis of occipitocervical and spinopelvic interdependence, with C-7 slope as a marker of cervical and spinopelvic alignment. J Neurosurg Spine. 2015 Jul;23(1):16-23. doi: 10.3171/2014.11.SPINE14368. Epub 2015 Apr 24.

Nyberg RE, Russell Smith A. The science of spinal motion palpation: a review and update with implications for assessment and intervention. J Man Manip Ther. 2013 Aug;21(3):160-7. doi: 10.1179/2042618613Y.0000000029.

Oakley P (a), Sanchez L, Harrison D. Medical radiologists may not consider the cervical lordosis in radiology reports: A comparison of subjective qualitative assessment versus objective quantitative mensuration in 100 consecutive patients at one medical imaging centre. J Contemp Chiropr. 2021;4(1):17-25. (Retrieved from https://journal.parker.edu/index.php/jcc/article/view/148)

Oakley PA, Kallan SZ, Harrison DE. Structural rehabilitation of the cervical lordosis and forward head posture: a selective review of Chiropractic BioPhysics® case reports. J Phys Ther Sci. 2022 Nov;34(11):759-771. doi: 10.1589/jpts.34.759. Epub 2022 Nov 1. PMID: 36337218; PMCID: PMC9622351.

Ormos G, Mehrishi JN, Bakács T. Reduction in high blood tumor necrosis factor-alpha levels after manipulative therapy in 2 cervicogenic headache patients. J Manipulative Physiol Ther. 2009 Sep;32(7):586-91. doi: 10.1016/j.jmpt.2009.08.006. Erratum in: J Manipulative Physiol Ther. 2009 Oct;32(8):701. PMID: 19748410.

Owens E, Leach RA. Alterations in radiographic findings in the cervical spine after chiropractic adjustment. (Paper accepted for the 1990 Internatl Conf on Spinal Manipulation.

Owens EF Jr, Henderson CN, Gudavalli MR, Pickar JG. Head repositioning errors in normal student volunteers: a possible tool to assess the neck's neuromuscular system. Chiropr Osteopat. 2006 Mar 6;14:5. doi: 10.1186/1746-1340-14-5.

Painter FM, Thomas GP. Chiropractic radiology. Chiropractic Resources Organization. Radiology. https://chiro.org/radiology/. (Accessed April 18, 2023).

Palecek J, Paleckova V, Willis WD. Fos expression in spinothalamic and postsynaptic dorsal column neurons following noxious visceral and cutaneous stimuli. Pain. 2003 Jul;104(1-2):249-57. doi: 10.1016/s0304-3959(03)00013-7. PMID: 12855335.

Palmer DD. Chiro Adjustor. Portland Printing House, Portland. 1910:306.

Palmgren PJ, Lindeberg A, Nath S, Heikkilä H. Head repositioning accuracy and posturography related to cervical facet nerve blockade and spinal manipulative therapy in healthy volunteers: a time series study. J Manipulative Physiol Ther. 2009;32(3):193-202. doi: 10.1016/j.jmpt.2009.02.003. PMID: 19362229.

Pate D. C2-C3 subluxations: pseudo and true. Dynamic Chiropr. 1998. https://dynamicchiropractic.com/article/37448-c2-c3-subluxations-pseudo-and-true.

Pate D. Subluxation is a radiographic entity. Dynamic Chiropractic 1993;11(7). https://dynamicchiropractic.com/article/42189-subluxation-is-a-radiographic-entity.

Pedersen PL. A prospective pilot study of the shape of cervical hypolordosis. Europ J Chjiropr 1990;38:148-163

Peng B, Yang L, Li Y, Liu T, Liu Y. Cervical proprioception impairment in neck pain-pathophysiology, clinical evaluation, and management: A narrative review. Pain Ther. 2021 Jun;10(1):143-164. doi: 10.1007/s40122-020-00230-z. Epub 2021 Jan 12. PMID: 33464539; PMCID: PMC8119582.

Penning L. Functional pathologiy of the cervical spine: radiographic studies of function and dysfunction in congenital disorders, cervical spondylosis and injuries. Philadelphia: Williams & Wilkins;1968

Penning L. Normal kinematics of the cervical spine. In: Giles LFG, Singer KP. Eds. Clinical anatomy and management of cervical spine pain. Vol 3. Edinburgh: Butterworth Heinemann: 2005:53-70.

Penning L. Normal movements of the cervical spine. Am J Roentgenol. 1978 Feb;130(2):317-26. doi: 10.2214/ajr.130.2.317. PMID: 414586.

Physiopedia online. Cervical instability. https://www.physio-pedia.com/Cervical_Instability (Accessed may 1, 2023)

Piccirilli M, Liberati C, Santoro G, Santoro A. Cervical posttraumatic unilateral locked facets: clinical, radiologic, and surgical remarks on a series of 33 patients. Clin Spine Surg. 2016 Jul;29(6):261-5. doi: 10.1097/BSD.0b013e3182870c3f. PMID: 27137154. Cited by;https://radiopaedia.org/articles/locked-facet-joint?lang=gb

Protopsaltis TS, Scheer JK, Terran JS, et al. International Spine Study Group. How the neck affects the back: changes in regional cervical sagittal alignment correlate to HRQOL improvement in adult thoracolumbar deformity patients at 2-year follow-up. J Neurosurg Spine. 2015 Aug;23(2):153-8. doi: 10.3171/2014.11.SPINE1441. Epub 2015 May 15. PMID: 25978077.

Read K. Resolution of hypertonicity in a pediatric patient undergoing chiropractic care: A case report. J Clin Chiropr Pediatr. 2011;12(1):883-6.

Reid SA, Callister R, Katekar MG, Rivett DA. Effects of cervical spine manual therapy on range of motion, head repositioning, and balance in participants with cervicogenic dizziness: a randomized controlled trial. Arch Phys Med Rehabil. 2014 Sep;95(9):1603-12. doi: 10.1016/j.apmr.2014.04.009. Epub 2014 May 2. PMID: 24792139.

Remier PA. Modern x-ray practice and chiropractic spinography. 1st edn. Palmer College. 1938

Ren J. Displaced C7 spinous process (clay-shoveler) fracture. Radiopaedia.org https://radiopaedia.org/cases/displaced-c7-spinous-process-clay-shoveler-fracture . (Citing Curtin & McEwain 2005)

Rey-Eiriz G, Alburquerque-Sendin F, Barrera-Mellado I, et al. Validity of the posterior-anterior middle cervical spine gliding test for the examination of intervertebral joint hypomobility in mechanical neck pain. J Manipulative Physiol Ther. 2010;33(4):279-285.

Rich EA. Manual of radiography and diagnostic roentgenology. Indianapolis. RAE Publishing.1965.

Rich EA. Atlas of clinical radiology. Indianapolis. RAE Publishing. 1965.

Rich EA.(a) Atlas of clinical roentgenology. Indianapolis. RAE Publishing.1965.

Rich EA. Cineroentgenological observations of the human systems. Scientific Yearly Lincoln College of Chiropractic. 1966;1:1-9.

Rich EA. Observations noted in 11,000 feet of experimental cineroentgenography film. ACA J Chiropr. 1964;1(March):11-12.

Ritzmann D, Birthing interventions and the newborn cervical spine. In: Biedermann H. Radiology in manual therapy in children. In: Manual therapy in children. Edinburgh. Churchill Livingstone. 2004;75-84

Robinson RO, Herzog W, Nigg BM. Use of force platform variables to quantify the effects of chiropractic manipulation on gait symmetry. J Manipulative Physiol Ther. 1987 Aug;10(4):172-6. PMID: 2958572.

Rogers RG. The effects of spinal manipulation on cervical kinesthesia in patients with chronic neck pain: a pilot study. J Manipulative Physiol Ther. 1997 Feb;20(2):80-5.

Rome P. Waterhouse JD. Neurodynamics of vertebrogenic somatosensory activation and Autonomic Reflexes - a review: Part 2 Autonomic nervous system and somatic reflexes. Asia-Pacific Chiropr J. 2021;1.4. URL apcj.net/papersissue-2-4/ #RomeWaterhousePart2

Rome P. Waterhouse JD. Neurodynamics of vertebrogenic somatosensory activation and Autonomic Reflexes - a review: Part 4 Vertebrogenicity. Asia-Pacific Chiropr J. 2021;1.4. URL apcj.net/papers-issue-2-4/#RomeWaterhousePart4Vertebrogenicity

Rome P. Waterhouse JD. Neurodynamics of vertebrogenic somatosensory activation and Autonomic Reflexes - a review: Part 7 The Cervicogenic Factor. Asia-Pacific Chiropr J. 2021;1.4. URL apcj.net/papers-issue-2-4/ #RomeWaterhousePart7Cervicogenic

Rome P. Waterhouse JD. Neurodynamics of vertebrogenic somatosensory activation and Autonomic Reflexes - a review: Part 9 Cervicogenic headaches. Asia-Pacific Chiropr J. 2021;1.4. URL apcj.net/papers-issue-2-4/ #RomeWaterhouseCervicogenicHeadaches

Rome P. Waterhouse JD. Neurodynamics of vertebrogenic somatosensory activation and Autonomic Reflexes - a review: Part 8 The Cranial Nerves and the Cervical Spine. Asia-Pacific Chiropr J. 2021;1.4. URL apcj.net/papers-issue-2-4/ #RomeWaterhousePart8CranialNerves

Rome P. Waterhouse JD. The fixation element of the articular subluxation: More than a vertebral dysfunction. Part 1 of a series. Asia-Pacific Chiropr J. 2021;1.3. URL www.apcj.net/rome-and-waterhouse-fixation-element-of-subluxation//

Rosa S, Baird JW. The craniocervical junction: observations regarding the relationship between misalignment obstruction of cerebrospinal fluid flow, cerebellar tonsillar ectopia, and image-guided correction. In: Smith FW, Dworkin JS. The craniocervical syndrome and MRI. Basel. Karger.2015.48-66.

Rothschild BM, Ho J, Masharawi Y. Macroscopic anatomy of the vertebral endplate: quid significat? Anthropol Anz. 2014;71(3):191-217. doi: 10.1127/0003-5548/2014/0365. PMID: 25065116.

Rowe L, Steiman I. Anterolisthesis in the cervical spine – spondylosis. J Manipulative Physiol Ther. 1987;10(1):11-20.

Rowe LJ Diagnostic imaging of mechanical and degenerative syndromes of the cervical spine. In: Giles LGF, Singer KP. Clinical anatomy and management of cervical spine pain. Edinburgh: Butterworth Heinemenn; 2006:89-111.

Rowe LJ. Skeletal radiology and its applications to the practice of chiropractic. Thesis. Master of Applied Science. Royal Melbourne Institute of Technology University. 1992.

Ruch WJ. Atlas of common subluxations of the human spine and pelvis. Boca Raton:CRC Press;1997.

Sacher R. Birth trauma and its implications for neuromotor development. In: Biedermann H. Radiology in manual therapy in children. In: Manual therapy in children. Edinburgh. Churchill Livingstone. 2004;85-98

Sanvictores T, Tadi P. Neuroanatomy, autonomic nervous system visceral afferent fibers and pain. 2022 Oct 3. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 32809678.

Sato A, Sato Y, Schmidt RF. The impact of somatosensory input on autonomic functions. In: Blaustein MP, Grunicke H, Pette D, Schultz G, Schweiger M. (eds). Rev Physiol Biochem Pharmacol. Berlin: Springer;1997;130:1-2

Sato A, Schmidt RF. The modulation of visceral functions by somatic afferent activity. Jpn J Physiol. 1987;37(1):1-17. doi: 10.2170/jjphysiol.37.1. PMID: 3302431.

Sato K, Chitose SI, Sato K, Sato F, Ono T, Umeno H. Dysphagia precipitated by cervical lordosis in the aged. Ear Nose Throat J. 2022 Mar;101(3):194-198. doi: 10.1177/0145561320946644. Epub 2020 Aug 25. PMID: 32841071.

Schafer RC. Motion palpation and chiropractic technique.2013. (Citing Gillet HJ and Faye LF. https://chiro.org/ACAPress/Motion_Palpation.html (Accessed May 3, 2023)

Scheer JK, Tang JA, Smith JS, et al. Cervical spine alignment, sagittal deformity, and clinical implications: a review. J Neurosurg Spine. 2013 Aug;19(2):141-59. doi: 10.3171/2013.4.SPINE12838. Epub 2013 Jun 14. PMID: 23768023.

Schenk, R., Coons, L., Bennett, S., Huijbregts, P. (2006). Cervicogenic dizziness: a case report illustrating orthopaedic manual and vestibular physical therapy co-management. J Manual Manip Ther. 2006;14(3):56 – 68

Scher AT. Anterior cervical subluxation: an unstable position. AJR. 1979;133:275-280.

Schleicher P, Pingel A, Kandziora F. Safe management of acute cervical spine injuries. EFORT Open Reviews. 2018;3(5):347-357. 10.1302/2058-5241.3.170076

Schmidt RF. The impact of somatosensory input on autonomic function. Autonomic neuroscience basic and clinical 2015;192,30-

Schmörl G, Junghanns H. The Human spine in health and disease. New York. Grune & Stratton. 1971.

Schnell H, Wagner FM, Locher H. Die segmentale und somatische Dysfunktion : Wie funktioniert Manuelle Medizin? [Segmental and somatic dysfunction: How does manual medicine work?]. Orthopade. 2022 Apr;51(4):253-262. German. doi: 10.1007/s00132-022-04230-z. Epub 2022 Mar 8. PMID: 35258631; PMCID: PMC8967751.

Swartz EE, Floyd RT, Cendoma M. Cervical spine functional anatomy and the biomechanics of injury due to compressive loading. J Athl Train. 2005 Jul-Sep;40(3):155-61. PMID: 16284634; PMCID: PMC1250253.

Senzon SA. The Chiropractic Vertebral Subluxation Part 3: Complexity and Identity From 1908 to 1915. J Chiropr Humanit. 2019 Apr 6;25:36-51. doi: 10.1016/j.echu.2018.10.003. PMID: 31019419; PMCID: PMC6472124.

Sher AT. Anterior cervical subluxation: an unstable position. AJR. 1979;133:275-280

Sherman College of Chiropractic. A brief history of x-ray technology in chiropractic science. 2015. https://www.sherman.edu/brief-history-x-ray-technology-chiropractic-science/. (Accessed Jan 4 2021.

Sherman R, Bauer F. (Eds.) X-ray X-pertise - from A to X. Australian Edition. 153 pages. Pub; Parker Chiropractic Research Foundation, Fort Worth, Texas. 1982.

Short K. C-spine imaging in ED, https://aci.health.nsw.gov.au/__data/assets/pdf_file/0005/273902/eci-cspine-imaging-in-ed-k-short.pdf. (Accessed May 5, 2023)

Smith DL, Haug MJ, Walsh MS. The effect of posture on neck proprioception and head/neck stabilization in asymptomatic participants. J Can Chiropr Assoc. 2019 Aug;63(2):100-110. PMID: 31564748; PMCID: PMC6743652.

Souza TA. Differential Diagnosis and Management for the Chiropractor. 5th edn. Sudbury US. Jones and Bartlett Publishers. 2018.

Stoddard A. Osteopathic practice. Second edition. Hutchinson, London. 1983 pp 4.

Swartz EE, Floyd RT, Cendoma M. Cervical spine functional anatomy and the biomechanics of injury due to compressive loading. J Athl Train. 2005 Jul-Sep;40(3):155-61. PMID: 16284634; PMCID: PMC1250253.

Takeshima T, Omokawa S, Takaoka T, et al. Sagittal alignment of cervical flexion and extension. Spine 2002;27:E348-E355.

Tao Y, Niemeyer F, Galbusera F, et al. Sagittal wedging of intervertebral discs and vertebral bodies in the cervical spine and their associations with age, sex, and cervical lordosis: A large-scale morphological study. Clin Anat. 2021 Oct;34(7):1111-1120. doi: 10.1002/ca.23769. Epub 2021 Aug 2. PMID: 34309067.

Taylor JAM, Clopton P, Bosch E, Miller K, Marcelis S. Interpretation of abnormal lumbosacral spine radiographs. A test comparing students, clinicians, radiology residents, and radiologists in medicine and chiropractic. Spine. 1995;20(10):1147 – 1154.

Thompson DG. Viewpoint: A need for lateral; full spine x-ray as a diagnostic complement to the A-P full spine view in chiropractic postural study. J Canad Chiropr Assoc. 2001;45(1):9-10.

Thompson EA. Text on chiropractic spinography. 4th edn. 1923. https://centerforinquiry.org/wp-content/uploads/sites/33/quackwatch/thompson_spinography_1923.pdf. 426pps

Throp I,, Shaw Y, Cade A. Improvement in developmental delay and hypotonia in a 15-month-old female following chiropractic care for reduction of vertebral subluxation: a case study. J Pediatric, Maternal & Family Health, Chiropractic. 2020; Jan;144-147

Townsend EH, Rowe ML. Mobility of the upper cervical spine in health and disease. Pediatrics 1952;10(5):567-563.

Treleaven J. Dizziness, unsteadiness, visual disturbances, and sensorimotor control in traumatic neck pain. J Orthop Sports Phys Ther. 2017 Jul;47(7):492-502. doi:10.2519/jospt.2017.7052. Epub 2017 Jun 16. PMID: 28622488.

Troyanovich SJ, Harrison DE, Harrison DD. Structural rehabilitation of the spine and posture: rationale for treatment beyond the resolution of symptoms. J Manipulative Physiol Ther. 1998 Jan;21(1):37-50. PMID: 9467100.

Tuchin PJ. A twelve-month clinical trial of chiropractic spinal manipulative therapy for migraine. Australas Chiropr Osteopathy. 1999 Jul;8(2):61-5. PMID: 17987194; PMCID: PMC2051091.

Uchida, S., Budgell, B. Somato-autonomic reflex. In: Binder, M.D., Hirokawa, N., Windhorst, U. (eds) Encyclopedia of Neuroscience. Springer, Berlin, Heidelberg. 2009. https://doi.org/10.1007/978-3-540-29678-2_5500

Uchikado H, Nishimura Y, Hattori G, Ohara Y. Micro-anatomical structures of the lumbar intervertebral foramen for full-endoscopic spine surgery: review of the literatures. J Spine Surg. 2020 Jun;6(2):405-414. doi: 10.21037/jss.2019.10.07. PMID: 32656378; PMCID: PMC7340827.

Udit S, Blake K, Chiu IM. Somatosensory and autonomic neuronal regulation of the immune response. Nat Rev Neurosci. 2022 Mar;23(3):157-171. doi: 10.1038/s41583-021-00555-4. Epub 2022 Jan 7. PMID: 34997214; PMCID: PMC9539447.

Vaňásková E, Dolina J, Hep A. Swallowing disorders related to vertebrogenic dysfunctions. New advances in the basic and clinical gastroenterology In Brzozowski T. The basic and clinical gastroenterology. In Tech. 2012. 175-184. https://cdn.intechopen.com/pdfs/35448/InTech-Swallowing_disorders_related_to_vertebrogenic_dysfunctions.pdf.

Vaňásková E, Hep A, Lewit K, et al. Cervical dysfunction with disturbed oesophageal motility – scintigraphic assessment. J Orthop Med 2001;23(1):9-11.

Velmahos GC, Jindal A, Chan LS. "Insignificant" mechanism of injury: not to be taken lightly. J Am Coll Surg. 2001;192(2):147-52.

Vernon H. Spinal manipulation and headaches of cervical origin. Man Med 1991;6:73-79. Vlachopoulos C, Geirgakopoulos, Pollalis D, Tousoulis D. Stable angina pectoris. In Coronary artery disease. London: Elsevier; 2018:157-200.

Wagner FM. Die somatische Dysfunktion der Halswirbelsäule und ihr komplexes klinisches Bild : Grundlagen der manualmedizinischen Diagnostik von Zervikobrachialgie und zervikozephalem Syndrom [Somatic dysfunction of the cervical spine and its complex clinical picture : The fundamentals of diagnostics of cervicobrachialgia and cervicocephalic syndrome through manual medicine]. Orthopade. 2022 Apr;51(4):263-273. German. doi: 10.1007/s00132-022-04228-7. Epub 2022 Mar 3. PMID: 35238967; PMCID: PMC8967759. (As translated)

Wang, L-H, Ding W-Q, Sun Y-G. Spinal ascending pathways for somatosensory information processing. Trends Neurosci. 2022;45(8):594-607.

Watanabe N, Nara M, Suzuki S, Sugie M, Yamamoto T, Hotta H. Effects of gentle mechanical skin stimulation on subjective symptoms and joint range of motions in people with chronic neck and shoulder discomfort. J Physiol Sci. 2023 Mar 29;73(1):4. doi: 10.1186/s12576-023-00862-8. PMID: 36991326. (Similar somatovisceral principles in acupuncture)

Whalen WM. Resolution of cervical radiculopathy in a woman after chiropractic manipulation. J Chiropr Med. 2008 Mar;7(1):17-23. doi: 10.1016/j.jcme.2007.10.002. PMID: 19674715; PMCID: PMC2647101.

Whang PG, Patel AA, Vaccaro AR. The development and evaluation of the subaxial injury classification scoring system for cervical spine trauma. Clin Orthop Relat Res. 2011 Mar;469(3):723-31. doi: 10.1007/s11999-010-1576-1. PMID: 20857247; PMCID: PMC3032869.

White AA 3rd, Johnson RM, Panjabi MM, Southwick WO. Biomechanical analysis of clinical stability in the cervical spine. Clin Orthop Relat Res. 1975;(109):85-96.

White AA, Panjabi MM. Clinical biomechanics of the spine. Philadelphia: JB Lippincott Co.1978.

Whitley JE, Forsyth HF. The classification of cervical spine injuries. Am J Roentgol. 1960;83(4):633-644.

Whitley JE, Forsyth HF. The classification of cervical spine injuries. Am J Roentgenol Radium Ther Nucl Med. 1960 Apr;83:633-44. PMID: 13844465.

WHO guidelines on basic training and safety in chiropractic. 2005:4. https://apps.who.int/iris/handle/10665/43352

Wilson RL. Chiropractic radiography and quality assurance handbook. CRC Press. 1999.

Winterstein JF. Chiropractic spinography. Self-Published. 1970, 88pps.

Wu Y, Loaiza J, Banerji R, Blouin O, Morgan E. Structure-function relationships of the human vertebral endplate. JOR Spine. 2021 Sep 13;4(3):e1170. doi: 10.1002/jsp2.1170. PMID: 34611592; PMCID: PMC8479528.

Wyatt LH. Facet syndrome in the cervical spine. J Am Chiropr Assoc. 2004;41(3):32-37.

Yochum L, Rowe L. Essentials of skeletal radiology. Vol I & II. 2nd edn. Baltimore: Williams & Wilkins. 19Yochum TR, Rowe LJ. (b) Essentials of skeletal radiology. Vol 2. 2nd ed. Baltimore: Williams & Wilkins.1996.

Young KJ. Joseph W. Howe DC, DACBR. and the development of modern chiropractic radiology. Chiropr Hist. 1999 Dec;19(2):27-47. PMID: 11624125.

Young KJ. A Tale of specialization in 2 professions: comparing the development of radiology in chiropractic and medicine. J Chiropr Humanit. 2019 Dec 10;26:3-18. doi: 10.1016/j.echu.2019.09.001. PMID: 31871435; PMCID: PMC6911919.

Zegarra-Parodi R. Could joint hypomobility alter optimal proprioceptive information? AAOJ, 2004;Dec:25-30.

Zhao X, Wu ZX, Han BJ, Yan YB, Zhang Y, Lei W. Three-dimensional analysis of cervical spine segmental motion in rotation. Arch Med Sci. 2013 Jun 20;9(3):515-20. doi: 10.5114/aoms.2013.35325. Epub 2013 May 27. PMID: 23847675; PMCID: PMC3701975. Available from: https://www.researchgate.net/publication/248706670_Three-dimensional_analysis_of_cervical_spine_segmental_motion_in_rotation

Appendices

Appendix 1

A radiological structural analysis of signs of cervical spine dysfunction with potential for sensory and autonomic reflex implications: All comprise elements of a Vertebral Subluxation Complex

Specific cervical segmental radiological findings often indicate potential sites of altered function (dysfunction) with or without evidence of displacement. If recent, evidence of disturbances will register noxious sensory input in varying degrees as is their physiological role. Older or healed sites of previous disruption have the potential to be reactivated once disturbed.

NORMAL

A range of mensuration lines have evolved (Appendix 2) to establish normal criteria for a range of spinal postural and intersegmental relationships. Giles provides a detailed study by Penning on normal cervical kinematics. (Penning, 2005)

While a normal posture may be optimal, it does provide a base from which deviations may be noted and measured. (Haldeman (a) p395-397) (Gatterman(a) p124)

In essence an ideal should stand close to the following:-

Sagittal – A gentle lordosis (Gatterman (a), p101)

The head vertically above the body with a gravity line passing from the apex of the odontoid process down to the anterior-superior edge of the body of C7. (Gatterman (a), p101)

Coronal – The spine should be straight with the spinous processes in alignment with the centre of the odontoid, mandible, nasal septum, and external occipital protuberance

Motion - The concept of maintaining a mobile, supple, and flexible spine with segments that move freely and independently within their own physiological ROM.

Correction – Is essentially the release of functionally fixated, hypomobile, aberrant motion, or subluxated articulation(s). This would be conducted in a corrective direction if required. (White & Panjabi p313,314) Such segments may also be found in a compensating role to hypermobile or unstable segments. It also involves the

postural correction of the cervical spine. (Harrison 1996 x 2) (Harrison et al, 1997) Jutkowitz, 1997) (Morgan, 1987) (Troyanovich et al, 1998)

Adjustment – Is a specific correction and controlled mobilisation of a hypomobile motor segment, to obtain restoration or optimisation of physiological function. (Schmörl & Junghanns, p185). It is also intended to moderate noxious sensory input. This takes place in a restorative direction called a line of drive. Specific neural signs and symptoms are a part of the preparatory analysis.

Manipulation – A general, non-specific form of mobilising joints of the body.

Age at time of injury is one of the considerations regarding the radiological findings. In relation to compressive injuries of the facet surfaces, vertebral body end plates and epiphyseal rings should also be considered. Suspicion is aroused when the patient injures a segment when pre-pubescent as the vertebrae are largely cartilage and yet to ossify. (Ruch, p58,60) The plastic property of this cartilage tissue could suggest that a form of moulding of the vertebral body may take place depending on the severity of forces involved. Rather than fractures, questions arise as to whether the compressive effect results in indentations or small notches in the end plates or laminas or a 'rounding off' of the vertebral bodies. Disruption of the vertebral immature epiphyses is a noted possibility eg. Persistent epiphysis (Kattan, p212) - Epiphyseal ring) It is hypothesised that these may then be evident in the mature osseous tissue with the mature vertebral body slightly rounded or misshapen, and possibly vulnerable to dysfunction.

Whitely and Forsyth (1960) differentiate the epiphyseal margins noting that the anterior-superior margin is disturbed in a flexion injury which sometimes appears as though it has been an indentation from the anterior inferior rim of the suprajacent vertebra. They note this as an *impaction*. Further, they state it is the anterior inferior margin that is disrupted in a hyperextension injury.

CONSIDERATIONS AND FINDINGS ASSOCIATED WITH CERVICAL SUBLUXATIONS

Activity at time of onset

Age at onset or suspected cause

Comparisons with adjacent segments (Nordoff p139)

Comparison with normal lateral (Jackson p13)

Infant birth trauma (Kattan et al, p 229-231) (Ritzmann, 2004) (Sacher, 2004)

Ligaments. With many of these injuries and in consideration of segmental strains and sprains, the ligamentous tissue must be considered. Not only the symptoms of damaged ligamentous tissue, but also the possibility of vertebral instability and range of motion at affected levels.

Patient history (Kattan, p23)

Physical, neurological, spinal examination

Range of motion – segmental and regional

COMMON CLINICAL SYMPTOMS ASSOCIATED WITH CERVICAL SUBLUXATIONS

Cervicogenic disorders - other (Rome & Waterhouse, Pt 7, 2021) (Rome & Waterhouse, Pt 8, 2021)

Cervicogenic headaches & migraine (Rome & Waterhouse, Pt 9, 2021) (Tuchin, 1999)

Muscle tone, hypertonicity, hypotonicity (Liebeson, 1989) (Read, 2011) (McDowall et al, 2017) (Throp et al, 2020)

Neck pain – site of pain (Schmörl & Junghanns, p44)

Nerve root irritation vulnerability/ (Jackson p44)

Paediatric cervical findings (Biedermann 2004) (Kattan p 206-241) (Davies, 2000)

Palpation vertebral (static)– one of the diagnostic aids (Schmörl & Junghanns, p44)

Palpation –segmental motion (Schmörl & Junghanns, p39,44) (Motion palpation)

RADIOLOGICAL FINDINGS OF CERVICAL GLOBAL AND SEGMENTAL DYSFUNCTION AND DISPLACEMENT – ELEMENTS OF THE VSC with potential to activate a cascade of sensory input.

Depending on the case history, findings may be congenital, developmental, or traumatic in origin.

ARTICULAR PILLARS (SEE ALSO UNDER SUBLUXATION)

Alignment (Hadley(a), p128-9, C5) (Yockum & Rowe, p272) (Ames, 203)

Alignment of in A-P view (Short, NSW.gov.)

Displaced articular pillar processes may also be posterior (Kattan 1975 pp108)109

Rhomboid shape- normal (Kattan et al, p50-51) (Yockum & Rowe – C3, p272,678)

Subluxation of (Hadley(a), p142)

ARTICULAR SURFACES

Articular surfaces should be parallel (Kattan et al p51)

Articular notch (Yockum & Rowe, p266)

Depressed (Kattan, p98)

Subluxation (Kattan, p65)

Wedged (Kattan et al p166)

ATLAS See Suboccipital

BODY OF VERTEBRA

(See also: Body' under Subluxation, Listhesis)

Alignment of posterior margins (Hadley(a), p128-9) (Kattan, p98)

Anterior compressive wedging (White & Panjabi p225,226) (Hadley(a), p129F,E,)

Anterior displacement of body (Hadley(a) ,p128-9,EF-C5) (Ruch p36 C4)

Anterolisthesis, Anterior segmental subluxation, Forward subluxation (Hadley(a), p 127)

[C4 (Yockum & Rowe, p687)]

Anterior listhesis (Curtin P, McElwain, 2005)

Anterior stair 'step off' (Kattan, p227) (Appendix 4)

Anterior weightbearing (Rich (a), p155) (Ruch, pps40,66)

Avulsion of the ring apophyses (Jonsson et al 1991)

Compression of the anterior epiphyseal ring of a cervical vertebral body: While the usual diagnosis is for this secondary ossification centre to be a 'persistent epiphysis' the possibility of a dysfunction due to a hyperflexion compression injury before puberty may be a possibility in explaining associated symptoms.

Displaced (Less than a Grade I spondylolisthesis) (See spondylolisthesis)

Anterior (Hadley(a) p136,137) (Schmörl & Junghanns, p140)

Degenerative -v- traumatic (Lee et al, 1986)

Laterally (Hadley(a), p130) (Schmörl & Junghanns, p140)

Lateral tilt (about the 'Z' axis) Kattan C5/6, C6/7, p110)

Posteriorly (Nordoff , p146) (Schmörl & Junghanns, p140)

Rotation (2005,p56)

End plate compression (Gentle end plate "arcuate depression" at a stage before greater force of compression fracture or Schmorl's node formation. (Schmörl & Junghanns, p80) Indentation of end plates (Yockum & Rowe, p272)

Epiphyseal ring compressed particularly pre-ossification. (Ruch, p58,60) (Kattan, p166)

Epiphyseal ring fails to ossify (Hadley(a), p 128,129) (Kattan, 1975, 226,7) (El-Feky, 2023)

It is suggested here that another possibility or variant, that of a hyperflexion cervical injury prepuberty compressing the anterior of the cervical body. At times, this may explain the appearance in the mature cervical spine rather than a persistent epiphysis. (Schmörl & Junghanns, p353)

Epiphyseal ring separation ‘Teardrop’ ‘Chip’ (Rim epiphysis) (Kattan, p63,78) (El-Feky, 2023) Separation of vertebral edge (Schmörl & Junghanns, p169-172)

Teardrop fractures can be evidence of extreme flexion or extension injuries to the cervical spine. They are mentioned here to recognise the extremes of this type of spinal injury. These may not be as extreme as those causing teardrop fractures. However, they would constitute cervical strains of a lesser degree. They may still lead to less severe segmental disturbances of which VSCs would be a major outcome.

Epiphyseal rim ‘rounded off’ (Foreman & Croft p226) (Schmörl & Junghanns, p271) (Factor also in Scheuermann’s Disease?)

Fracture – as there are degrees of fracture, healed fractures may result in misshapen vertebral bodies which may be the site of dysfunction and noxious sensory input. An active fracture is a red flag at that site, and along with findings of advanced osteoporosis are usually contraindications to manipulative intervention.

SUBLUXATIONS

Glide sign of instability (Hadley(a) p126)

Lateral displacement (Jackson p 9)

Microsubluxation (Kim 2022)

Nuclear depression (Yockum & Rowe p272) (Not Schmörl’s node or notochordal remnant but compression induced) sufficient to reduce facet interspace.)

Olisthesis (Listhesis) (Bell, 2018) (Goel et al, 2023)

Osteophytes (Hadley(a), p422-438) (See also separate heading below)

Posterior (Hadley(a), p438,9)

Posterior body displacement (Nordoff,, p146)

Posterior stairstep - multiple segments (Nordoff, p146)

Pseudosubluxation’ (Pate, 1993, 1998) (Curtin, McElwain, 2005)

Retrolisthesis (Rich, p270) (Ruch, p48)

Rotation about Y-axis. (Penning, 2005, p56)

Shape – normally rhomboid in lateral view. (Kattan, et al p51)

Spondylolisthesis (Rich, p201) (Jiang, 2011) (Fedorchuk & Lightstone, 2016) (Rowe & Steiman, 1987)

‘Anterior spondylolisthesis tended to occur at the level adjacent to the stabilized level, where the disc space was narrowed due to degeneration, or at the cervicothoracic junction, where the thoracic spine is naturally stiffened.’ (Aoyama, 2018)

Stair step of vertebral bodies – anterior (Keats & Anderson, p224/5) (Foreman & Croft, p227)

Stair-step of vertebral bodies – posterior (Ruch, p32,38)

‘Step-off’ (Kattan, p227)

Subluxation – anterior (Hadley(a), p128) “Slight subluxation” (Schmörl & Junghanns, p251)

Translation (Foreman & Croft, p53)

Wedging (Kattan, et al p166)

Whole vertebra rotation about ‘Y’ axis (Kattan, p27,91,98,100,101)

DEGENERATIVE

All cervical joints susceptible - atlantoaxial, uncovertebral, (von Luschka, neurocentral) apophyseal (facet) and intervertebral discal joints. (Yockum & Rowe, p807 (b)) (Rowe, p89) (Gatterman (b), pp243-5)

Articular surfaces ‘*mechanical imbalances*’ – dysfunction (Jackson, p104-5)

Decreased disc height (Yockum & Rowe, p807)

‘Degenerative aging should be uniform in all the joints of one individual and not in one or two specific joints’ (Jackson, p 110)

Differentiating aging from wear and tear (Schmörl & Junghanns, p142) (Jackson, p110,132)

Differentiating wear and tear from induced trauma injury (Jackson, 132)

Most common C5/C6 (Yockum & Rowe, p807)

Osteophytes – articular (Rowe, p89)

Osteophytes (Vertebral body) (Rowe, p89)

DISC - INTERVERTEBRAL

Appears thicker on side of unilateral forward subluxation (Hadley(a), p130)

Bulging discs may bulge anteriorly, posteriorly, or laterally although lateral is less likely in the cervical spine due to the uncinate processes (Jackson, 128-9).

Degeneration -v Aging 'wear and tear' due to heavy manual work especially with neck strain, e.g. painters, mechanic, noted effect on apophyseal joints – weight bearing. (Schmörl & Junghanns, pps14-21. 141-151, 299-300). Factor in facet motor function, vascular and nerve (IVF)compromise (pps37,38). The change indicates an alteration to its function prior to disturbance - dysfunction. - '*Joint function is altered*.' (Jackson, p129)

Disc height may be related to adjacent levels in order to compare likely respective levels of function. (Ruch, p40)

Multiple levels may be degenerative wear and tear while one or two isolated disc levels implies trauma, e.g. whiplash.

Disc degeneration (Maigne p17, Chapter 3, p22)

Disc height/space increase with endplate depression (Schmörl & Junghanns, p139)

Height – comparison with adjacent discs can indicate either bulging disc (posterior, anterior, or lateral), inflamed -increased height), degenerated disc thinner that neighbouring discs. Reasonable indication of altered function and sensory feedback.

Loss of turgor alters mechanical motor unit (Navone et al, 2017) "bounce" (Schmörl & Junghanns, p279)

Swollen disc C4/C5(White & Panjabi p227) *('The inappropriate increase of the height of disc space will result in facet joint subluxation.'* (Liu et al, 2006)

Thinning of the disc (Ruch, p42,44) (Kattan, p75)

Can be a normal process of aging but at an even rate for the region. (Hadley(a), p124, 265)

If isolated to one or two discs likely to be due to a particular injury Trauma (Hadley(a), p264) (Jackson, p110)

Particularly noted when compared to thicker nearby discs – except for an unrelated swollen disc (discitis).

Can lead to telescoping of the posterior joints - 'subluxation'. (Hadley(a), p422)

The superior articular processes tend to subluxate posterior and inferior. (Hadley(a), p 422)

Vacuum phenomena (Kattan, et al p78) (Nordoff, p139) (Yockum & Rowe, p687)

Variation in disc heights can be informative (degenerative, disc damage, wedged, swollen. (Nordoff, p143)

Wedging anterior-posterior narrower anteriorly) (Maigne, p17) (Foreman & Croft, p51,53)

Wedging of disc P-A (Lewit, p70 – C4/5) (Foreman & Croft, p51,53)

Wedging lateral – (also with scoliosis) (Tao et al)

Wedging. - posterior-anterior (Maigne, p17)

Widening of anterior disc (Nordoff, p138-9)

DISPLACEMENT COMPONENT OF VERTEBRAL SUBLUXATION COMPLEX

'Encroachment (of the IVF) also results from a decrease in the anterior-posterior diameter of the opening when the vertebral body above becomes displaced backward.' (Hadley(a) p432)

Alignment (Lin et al, 2001) (Scheer, et al, 2013) (Lewit, p36)

Anterior flexion of vertebral segment (Hadley(a), p127) ((Schmörl & Junghanns, p140)

Innate articular 'attempt to maintain the functions of the neck.' (Jackson, p111)

Lateral displacement (Schmörl & Junghanns, p140)

Posterior displacement (Schmörl & Junghanns, p140,390)

Rotational (Hadley(a) p128,130) (Schmörl & Junghanns, p47) (Jackson, p181) (Kattan, p100)

DYSFUNCTION COMPONENT of the VERTEBRAL SUBLUXATION COMPLEX

'The normal physiological movements are of diagnostic value and may be utilized in evaluating or eliciting the symptoms of nerve pressure.' (Hadley(a), p432)

One of the key elements of a vertebral subluxation complex, dysfunction is proposed as a prime initiator of noxious sensory input with ultimate autonomic reflex association depending on severity and/or prolonged duration

Aberrant movement - cervical segment (Nordoff, p144)

Anterior stair step (Keats & Anderson, p224,225) (Pate, 1993)

Asymmetry of motion (Hadley(a), p124)

Cervical facet dysfunction. (Kirpalani & Mitra, 2007)

Disturbed mechano-dynamics (Jackson, p130-1)

Fixation segmental ('Fixation of movement' Hadley(a), p127,130) (Nordoff, p146) Gatterman (a), pps233-4,270-1,382) (Schmörl & Junghanns, p376 – locking; incarcerated) (Leach, various)

Fixation – global (Hadley(a), p127)

Functional inactivity' (Jackson, p121)

Functional pathology (Schmörl & Junghanns, p39)

Functional segment fixation (Hadley(a), p131)

Hyperextension (Cailliet, p62,63) (Gatterman (a), p403)

Hyperflexion (Cailliet, p62,63) (Gatterman (a), p403)

Hypermobility – segment – C2/3 segment (Hadley(a), p132,133) (Maigne, p17,207-209) (Gatterman,(a) p173,5,382,7) (Gatterman(c), p47)

Hypomobility global/regional (Hadley(a), p126,127) (Gatterman (b), p139)

Immobilisation of the motor segment Schmörl & Junghanns, p213)

'Improper increased motion' (Schmörl & Junghanns, p213) (Hypermobile)

Inefficient motor segment (Schmörl & Junghanns, p213)

Instability segmental- cervical (Nordoff, p145-6) (Schmörl & Junghanns, p216-220) (Foreman & Croft, p51) (Yochum & Rowe, p687) (Physiopedia, online)

Intervertebral insufficiency (Schmörl & Junghanns, p213)

'Limitation of motion' (Schmörl & Junghanns, p251)

'Locking of the vertebrae' mobility (Schmörl & Junghanns, p213)

'Loosening of the motor segment (Schmörl & Junghanns, p213)

Malfunction (Schmörl & Junghanns, p213)

'*Mechanical imbalances* ' (Jackson, p104-5)

Mobility block (Schmörl & Junghanns, p213)

Performance inefficiency (Schmörl & Junghanns, p213)

Range of motion (Schmörl & Junghanns, p39)

Rigidity of the motor segment (Schmörl & Junghanns, p213)

Segmental limitation of movement' (Jackson, p187)

Segmental vertebral fixations – cervical (Gelley, 2021)

'Stiffening of the involved segment' (Schmörl & Junghanns, p251)

'Traumatic functional disturbance' (Schmörl & Junghanns, p251)

END PLATE

'Alterations of vertebral endplates have long been a subject of interest, but are of unclear clinical significance.' (Rothschild& Masharawi, 2014)

'…many of the apparent-level mechanical properties, including modulus, yield stress, and in the case of the inferior vertebral endplate, failure strains.' (Wu et al, 2021)

End plate depression – minor compression fracture - – depending on degree of compression. (Ruch, p65)

Minor compression fracture of end plate cartilage

Schmörl's Nodes – compression or notochord. Not necessarily central (Lipson et al, 1985)

FACETS (See also under subluxation)

'Constriction of the intervertebral foramen may be caused by a posterior joint telescoping and by wedging of the superior articular processes forward.' (Hadley(a), p432)

In extension - compression 'contusion of the articular cartilage.' (Jackson, p84)

Articular surface indentation (Ruch p34)

Asymmetry of facet surfaces possible (Hadley(a), p123)

Compression (Foreman & Croft p78) (Jackson, p84)

Degeneration (Ruch, p34)

Derangement of opposing joint surfaces. (Cailliet, p62)

Displacement (Hadley(a), p127, 144)

Displaced 'forward' (Kattan, et al p166)

Divergence or convergence of articular planes (Nordoff, p144)

Facet Notch due to inferior tip of suprajacent facet (Yockum & Rowe, p266) (Ruch, p8)

Facet separation (Jackson 1966, p179 (Hadley(a), p176)

Facet syndrome – cervical. (Wyatt, 2004)

Fixation – functional (Hadley(a), p125) C5/6 - (Hadley(a), p139-40) '*Sudden arrest of mobility*'- (Schmörl & Junghanns p203)

Flaring (Tipping – Hadley, p127, 139,140,144) ('Separated')

Gliding anterior (Hadley, p126) Mid-cervical in adults, more superior in children)

Hypermobility – instability (Schmörl & Junghanns, p203,213-228)

Hypomobility (Hadley(a), p125-127)

Imbrication (Hadley(a), p 144)

Incomplete dislocation – subluxation (Hadley(a), p127)

Indentation (compression) of facet surface (not fracture) (Hadley(a), p70,142,181) (Kattan, et al p202,249,258) (Ruch, p34,52;46,54, C7; p60 - C6)

Indentation of superior articular facet surface of cervical vertebrae between C3- C7. (Yockum & Rowe, p266)

Inflammation, cervical facet inflammation provides a base for noxious sensory input. (Jackson, p119Also includes juvenile epiphysitis. (Hadley(a), p244-5)

Narrowed interarticular space (Rich, p184)

Normally parallel facet surfaces segmentally (Kattan, e p90)

Notch (Yockum & Rowe, p266) (Hadley(a), p70 – Superior facet, C3)

Osteophytes (See own heading)

Overlapping of facet apices (imbrication) (telescoping) (over-riding facets) If less than 50% joint considered unstable. (Schleicher et al, 2018)

Over-riding facets (Jackson, p52)

Posterior facet separation (Hadley(a), p127) (Ruch, p66,C4/5)

Sprain or strain (Cailliet, p61) (Gatterman(b), p242-3)

Subluxation (Facet) (Hadley(a), p34,127,142) – See also definition Vertebral Subluxation Complex (VSC) – dysfunction, displacement, noxious sensory input, autonomic reflexes and soft tissue elements.

Anterior subluxation (Kattan et al, p62,92,95,98,151)

'Backward' subluxation (Kattan et al, p 60,108,152)

'Minor degree of subluxation' (Kattan, et al, p37

'Subluxation (Kattan et al, p46,51,67,83,90,91,160,166)

(Jackson, p53,95-96,165,168,177,179,184,187,190,195,286,287)

(Schmörl & Junghanns, pps222,249-250,376)

Subluxate (Jackson,52)

Superior facet – displaced anterior-superior. Hadley(a), p127)

Symmetry of motion (Hadley(a), p 124) (Bryner, p1986) (Robinson et al, 1987)

Telescoping (Hadley(a), p422)

Unilateral subluxation (Hadley(a) p128-129) (Kattan et al p83)

Wedging of interarticular space (Hadley(a), p127) White & Panjabi, p123)

Wedging of pillar (C4,C6. (Ruch, p68)

Widening of interarticular space (Hadley(a), p127) (Chu, 2022 - Figure 1) (Foreman & Croft p53) (Ruch, C4 p46,62; C3/4 p54,58; C5 p74)

FIXATION

C2/C3 Functional Fixation (Hadley(a), p127,132-133)

IMAGING

Kattan lists 17 possible imaging techniques for the cervical spine. (p311), 14 by Jackson (p330), and 9 by Nordoff (p134-5).

Advantage of functional views (Davis series) (Kattan et al, p37) (Schmörl & Junghanns, p50) (Lewit, p35,60,61) (Nordoff, p135) (Foreman & Croft, p51) (Penning, 2005, p53) (Yockum & Rowe, p28) (Gatterman (a)-p124,125 &various, (b), p95-7) (c) 139) (d) 143-145, (Gay, 1993)

Advantage of erect films (weight-bearing) (Hadley(a), p135) (Kattan, et al, p35)

Aid to diagnosis of 'minor intervertebral derangement'. (Maigne p95,105)

Functional mensuration (Lewit p62-82)

Importance of lateral view (Lewit, p35,57-82)

Segmental fixation/Functional fixation (Note: surgical fixation involves the insertion of plates or rods to permanently stabilise vertebral segments.)

Overlay tracing of neutral and functional views (Gatterman (a), 128-130) (Gatterman(c) p145)

INTERVERTEBRAL FORAMINA

'There are various ways in which intervertebral foramen encroachment may occur.'

'Constriction of the intervertebral foramen may be cause by a posterior joint telescoping and by wedging of the superior articular process forward…and by 'backward displacement' of the vertebral body.'

'The extremes of lateral flexion, dorsal extension or rotation may normally decrease the size of the foramen by as much as one-third' ipsilaterally. (Hadley(a), p430-2)

'Not all patients who exhibit foramen encroachment radiographically experience radiculitis; (Hadley(a) p438)

- Physiological in spinal extension
- Increased lordosis
- Dorsal kyphosis exaggerates cervical lordosis
- Lateral flexion – decrease IVF by ⅓ unilaterally
- Rotation - – decrease IVF by ⅓ unilaterally

'In the IVF '*important contact takes place between the nerves (and blood vessels) and the motor segment* (however this relationship may change), ' *if the motor segment id altered in space or direction'* (Schmörl & Junghanns, p38)

Change in size and shape with segmental movement (Hadley(a), p430-32)

Compromise of IVF. (Hadley(a), 128-9) (Kattan et al, p46,47,109) (Lewit p 63)

Encroachment (Jackson, p51)

Enlarged (Kattan p167)

IVF diminish contralaterally to side of rotation (Hadley(a), p128)

Ligaments occupying foramen (Uchikado et al (2020)

Radiculitis (Hadley(a), p 432)

LAMINAE

Interlaminary proximation. (Rich, p155)

Notch at the '*back of the articular process*' mostly C7 seldom C6.'normal variant' (Kattan et al, p 249,258) (Rich, p182 Fig 595)

Lamina notch (Hadley(a), p265)

LISTHESES

Listheses may be asymptomatic, however when first disrupted the sudden onset may exhibit signs or symptoms. They can be red or orange flag so management would be particularly conservative with radiological assessment an imperative.

Anterior listhesis C3 (Hadley(a), p144)

Anterolisthesis. (Ruch, p11,12)

Atlas – lateral listhesis

Microsubluxation (Bourdeinyi & Plotkina, 2020)
"Minimal Retrolisthesis" cervical, Case 32 – C6, 1-1.5mm (Grin, et al, 2019)
Olisthesis (Goel et al, 2023) Generic term

Posterior body (Hadley(a), p440-441)

Pseudospondylolisthesis (Hadley(a), p409)

Retrolisthesis (C4 'Retrosubluxation' – Hadley(a), p440) (Ruch C5, p40)

MOBILITY OF SEGMENT` (See also under 'Dysfunction'.

Determined on flexion/extension series. (Hadle, p121-124)

Motion palpation. (Schafer, 2013) (Nyberg & Smith, 2013) (Humphreys et al, 2004)

NEURAL ARCH

Symmetry 'distorted' on lateral and oblique views. (Hadley(a), p 128)

OSTEOARTHRITIS (Spondylosis Deformans) (Degenerative arthritis)

It is noted that in the early stages spondylosis deformans was initially spondylitis, an inflammatory stage with somatosensory activation.

Compression on posterior articulations with possible sclerosis, eburnation, and erosion. (Hadley(a) p265)

Limitation of motion. (Hadley p265) Motion restoration or improvement indicated- Auths)

Nerve root changes (Hadley(a) p265)

Telescoping/imbrication of posterior joints (Hadley p265)

Thinned discs (Hadley(a) p265)

Tips of articular pillars impinge on pedicle above or lamina below. (Hadley, 1935) (Hadley(a) p265)

OSTEOPHYTES

It can be noted that that the presence of osteophytes is not necessarily the immediate cause of symptoms when the spurs would have existed well before the more recent appearance of symptoms. Even before that, the soft tissue scarring would have existed for the ossification to occur and be visible. As such, it is possible that a segmental physical-mechanical disturbance or dysfunction (VSC) and ligamentous damage may be contributing to the patient's symptoms. (Jackson, p105,129,133)

However, not all vertebral osteophyte formations with foramen encroachment result in radicular symptoms. (Hadley(a), p438)

Bridging calcification begins some 2-months after injury to the anterior longitudinal ligament. (Hadley(a), p128)

No osteophytic formation ('bridging') if subluxation recent. (Hadley(a), p128)

These formations or osseous anomalies may however indicate dysfunction or displacement at particular segmental levels, or nearby adjacent compensatory segments. (Jackson 110-111)

May develop at any of the cervical articulations (Jackson, p54) (Gatterman(a), p176-179)

Articular (Schmörl & Junghanns, p203,276)

Anterior body (Ruch p 30) (Hadley(a), p139,414)

Lateral (uncovertebral joints) These spurs may 'affect the sympathetic plexus surrounding the vertebral artery possible contributing to symptoms of Barré Lieou syndrome and vasomotor disturbance about the head. (Hadley(a) p422, 424) (Maigne, p192-206)

POSTURE – CERVICAL - Postural deviation (Appendix 5)

'Any mal-alignment in this curve or irregularity in the spacing of the sections indicates a disturbance in the structure or the articulation of the cervical units.' (Hadley(a), p430)

Orthopaedic surgeons Goldthwait et al (1952) identified the importance of posture to health as early as 1934. (Protopsaltis et al, 2015) They discuss a range of nerve-related symptoms associated with irritation from cervical sprains and postural changes.

Angular kyphosis – anterior weight bearing of head - regional (Hadley(a), p127a-129 Fig F,135-6,138-40,142-3) (Nordoff, p43) ('Arcual' -Yockum & Rowe, p684,5)

'*Bend between C5 and C6*' (Schmörl & Junghanns, p49)

Angular lordosis (Hadley p 127b-8) with spinous approximation (Kattan et al, p88)

Possible damage to holding elements if angulation occurs at a single segmental level with spinous approximation. This may suggest subluxation, disc damage or degree thereof, and instability. (Ruch, p50)

Spinous approximation. (Ruch, p50)

Anterior weightbearing of head (Hadley(a), p127-9) (Lewit, p70,81) (Ruch, p48,66) (Cailliet, p12)

Average lordosis 40º (35º -45 º) provides optimal shock absorption. (Nordoff, p142)

Arcual lordosis (Yockum & Rowe, p685)

Bracket cervical spine (Ruch, p65)

Centre of gravity anterior (Hadley(a), p128)

Deviation cervical postural (Nordoff, p143)

Forward head posture (Mahmoud et al, 2019) (Mostafee et al, 2022) (Norton et al, 2022) (Kamel et al, 2023)

The observation is made here that a cervical spine that is relatively flexible should respond more effectively to corrective postural exercises than exercises alone. (Au)

Functional characteristics/dysfunction with functional views (Hadley(a), p 124)

Hyperkyphosis. (Harrison et al, 1997)

Hyperlordosis cervical (Ruch, p34) (Rich, p258,259)

Hypolordotic cervical spine (Hadley(a), p126,128) (Lewit, p70) (Rowe, p89) (Ruch, p46) (Harrison et al, 2004), Military cervical spine (Ruch, pps 46,48,72)

Hypermobility cervical spine (Yockum & Rowe, p687)

Hypomobility cervical spine (Ernst & Niedeggen, 2005)

Kyphotic cervical spine. (Eriksen p31) (Lewit, p71) (Yockum & Rowe, p685) (Jackson, 252)

Kyphosis – angular (Hadley(a), p 127) (Eriksen, p31) (Ruch, pps52,54)

Lordosis – alignment. (Gay, 1993) (Harrison (a) et al, 1996) (Harrison (b) et al, 1996) (Jutkowitz, 1997) (Morgan, 1997) (Lin et al 2001) (Sheer et al 2013)

Lordosis – Angular (Hadley(a), p127), Symmetry (Hadley(a), p124) (Grob et al, 2007)

Military spine cervical (Eriksen p31) (Ruch p72)

Posterior cervical weight bearing (McAviney et al, 2005) (Harrison et al, 2003)

Posture and the cervical spine. (Oakley et al, 2022) (Smith et al, 2019)

Sagittal balance. (Lee et al, 2015) (Ling et al, 2018)

Scoliosis Rich, p238) (Extreme – Idiopathic rotary Scoliosis –(Rich, p235,236)

It is noted that scolioses are gross spinal misalignments. There is a case for managing the function and symptoms through spinal manipulation in order to minimise noxious sensory input.

S-spine Combined lordosis and kyphosis within the 7 cervical segments

Stair step (See Appendix 4)

Swan neck- lordosis and kyphosis. (Ruch, p70)

Symmetry of anterior curve – lordosis. (Hadley(a), p124, 128)

RADICULITIS

Abnormal compromise of the IVF may result in radiculitis oedema, haemorrhage, additional disc pressure, disc degeneration, trauma or movement of adjacent structures may be sufficient to produce radicular symptoms. (Hadley(a), p432)

'Some unusual movement of the neck may be the added stimulation which triggers an attack of radicular symptoms.' (Jackson, pps51-76,106)

'*Cervical radiculitis may be confused with angina.*' (Vlachopoulos et al. 2018)

Case report (Apfelbeck, 2005) (Whalen, 2007)

Cervicogenic radiculitis (Maigne, p210-222)

SEGMENT

Anterior tilt (Hadley(a) p127, 135,136)

Anterior translation 1-2mm (Foreman & Croft [53)

Disalignment (Cailliet p69)

Flexion - C4/C5 flexion subluxation C4/C5 flexion subluxation (Hadley(a), p135,136) kyphotic angulation (Foreman & Croft [53)

Fixation (Hadley, p125) (Antos et al, 1990)

Hypermobility (Hadley, p122) (Lauridsen. 2003)

Hypomobility (Rey-Eiriz G et al, 2010)

Instability (Lauridsen,. 2003)

Retrolisthesis (Figure 1 - Chu, 2022)

Segment displacement – 'gliding' - anterior to posterior (Hadley(a), p126)

Spondylolisthesis (C6) (Rich, p201)

Pseudospondylolisthesis (Hadley(a), p432)

SOMATOSOMATIC REFLEXES

'alteration of the tendon reflexes anywhere along their segmental distribution.' (Jackson, p51)

SOMATOVISCERAL (Non-musculoskeletal)

Respiration (Hadley(a), p450)

Various symptoms pain in head, face, ear, throat, or sinuses (Hadley(a), p438)

Ocular imbalance (attributed to atlantoaxial rotatory subluxation)

Sensory disturbances in pharynx

Vasomotor disturbances, hyperhydrosis, flushing, lacrimation, salivation

Vertigo, dizziness, tinnitus, diminished hearing (Treleaven, 2017) (Kristiansson, 2009)

Cranial nerves blood pressure, (Jackson p,158,159)

See also (Gatterman, p334) (Schenk et al, 2006) (Grgić, 2013) (Leach, 108-115) (Lewit , p281-287) (Maigne, p164, 192-206), (Schmörl & Junghanns, p216-218) (Vaňásková et al, 2012) (Vaňásková et al. 2001) (Mann et al, 1984) (Sato et al, 2020) (Wagner 2022) (Sato et al, 2022)

SPINAL CANAL

Compromise subluxation (Hadley(a) **128-9)** (Schmörl & Junghanns, p212)

SPONDYLOLISTHESIS

Under the Meyerding classification of this condition, the displacement element of a VSC may be technically considered a Grade 1 which, by definition is a displacement of 0%-25% of the base vertebral endplate. (Green et al, 1981) (Koslosky & Gendelberg, 2020) (Curtin, McElwain, 2005) However, chiropractors would generally consider displacements under 3mm for possible amelioration. Even then, the degree and type of dysfunction would also need to be considered. (Scher,1979) (Kent 1992) (Pate 1998)

Bilateral pars defects are integral to Grade 2 and above spondylolistheses. Grade I spondylolistheses are commonly attributed to disc degeneration.

There appears to be inconsistency in terminology regarding dislocation (p97,157,178), displacement (p238), minor degrees of subluxation (p37), and spondylolisthesis (p156) when these terms appear seemingly interchangeably. (Kattan, 1975)

C6 (Rich, p201) (C3, Grade 4, p200)

Case report. (Bennett & Hayde, 1991)

Degenerative -v- traumatic (Lee, 1986)

See also anterolisthesis, retrolisthesis, olisthesis.

SPINOUS PROCESSES & Lamina

Acrostealgia of the tips of the spinous processes. (Schmörl & Junghanns, p251)

Alignment (Hadley(a), p122, 438[A]) (Kattan p57)

Approximation of two spinous processes (Hadley(a), p121,125) (Nordoff, p138)

Deviation – lateral 'towards side of subluxation' (Hadley(a) p128,130) (Schmörl & Junghanns, p47) (Jackson p 181) (Kattan, p100)

Fanning of spinous interspace, Separation, Flaring- (Hadley(a), p121,127, 139,140,326,438-9) (Foreman & Croft p53,227) (Jackson, p181) (Yockum & Rowe p684) (Nordoff p138)

Fixation of spinouses - spinouses not fanning on cervical flexion. (Hadley(a), p125-7,139,140,326)

Kissing spinouses – see over-riding spinouses (Jackson, 52)

Lateral spinous deviation to side of subluxation (Hadley(a), p128)

Notch in lamina – C6/C7 (Keats & Johnstone, 1982)

Possible avulsion of interspinous ligaments (Hadley(a), p136)

Separation – see Fanning (Cailliet, p57)

Straight (Kattan, p57)

SUBLUXATION - SEGMENTAL POSITIONING

Atlas fixations (Gatterman (a)138-148, (b)101,))

Anterior slippage' (Schmörl & Junghanns, pp49)

Anterior subluxation (Gatterman(b), p107) (Kattan, p89)

Anterior subluxation (most common) (Hadley(a), p128) (Foreman & Croft, p53)

Apophyseal subluxation (Hadley, 1936)

Axis subluxation (Gatterman(c), p101)

C1 laterality. (Lewit p 72)

Cervical spine laterality fixation – hypomobility (Lewit, p 74)

Dynamic joint disrelationship (Foreman & Croft p50)

Facet subluxation (Kattan, p29), 'Apophyseal' – (Hadley, 1935)

Insufficient displacement (to be appreciated on x-ray) (Kattan et al p91)

Malalignment of posterior arches (Hadley(a), 142)

May occur if head rotated at time of an impact. (Hadley(a), p128)

Posterior (Kattan p60,108)

Pseudosubluxation (Pate, 1993) (Curtin et al, 2005)

Referred to as a sprain (Hadley(a), p127)

Rotary fixations – 4 types. (Foreman & Croft, p43) (Kattan, p29,98)

Segmental disrelations (Nordoff p138)

Segmental translation – suggests replacement of normal pivotal motion (Nordoff p145,'Slight')

Slight posterior displacement (Schmörl & Junghanns, p49)

Spontaneous subluxation due to inflammatory foci (Schmörl & Junghanns, p250)

Subluxation. (Gatterman (a),(b),39-49, (c)139-140, (d)139-149) (Kattan, p37,83,162

Subluxation (incomplete dislocation) (Hadley(a), p127, 128)

Subluxation (partial displacement (Hadley(a), p128)

Vertebral subluxation complex. The evidence indicates that there are a number of elements in a subluxation other than just minor displacement, hence the VSC designation. This has led to a more inclusive term as recognised by the WHO.

In addition, in view of the conventionally recognised radiological findings, it appears that only a limited number in some 6 health professions (including the medical profession) have adopted an appreciation of the wider ramifications of the VSC.

Further, it may be said that the allopathic model of health management being focussed principally on pharmaceutical and surgical models of care which would seem inappropriate for a physical-mechanical model despite the plethora of pathoanatomical evidence recognised in allopathic radiology.

SUBOCCIPITAL (Atlanto-occipital, Atlantoaxial)

Aberrant motion (functional imaging) (Gatterman (a), p267)

Atlas **subluxation** (Hadley(a) p130,132)

Atlas flexion subluxation (Rich, p263)

Asymmetry of periodontoid space (Nordoff p138) (Gatterman (a) p256) (Eriksen p25-7)

Atlanto-odontoid space not even (Hadley(a) p130),

C0/C1 fixation – lateral flexion (Lewit p74,75)

C1 anterior *en masse* (White & Panjabi p210)

C1 anteroflexion/flexion (Lewit p 70)

C1 lateral subluxation C1 (Kattan et al p54) (Jackson p 165)

C1 retroflexion/extension (Lewit p66, 70)

C1 posterior rotational fixation (Yockum & Rowe, p691)

C1/C2 Rotational (Kattan et al p51,139-44)

C2 rotation (Jackson p 167)

C2 rotational fixation (Yockum & Rowe, p691)

Differences in the position of the lateral masses of atlas (Hadley(a), p149)

Displaced lateral mass (Hadley(a), p130-133)

Fixation (Hadley(a), p130) (Kattan et al p54,91) (Lewit p66)

Hypermobility C1 (Lewit p77)

Lateral displacement of atlas (Nordoff, p141) (Kattan, et al p54)

(Hadley(a), p130,149) (Yockum & Rowe, p691) (Jacobson & Adler, 1953)

Malalignment (Hadley(a), p412)

Normal lateral tilting (Jackson, p9)

Normal rotation (Jackson, p7)

Odontoid normally centrally located in A-P view (Kattan, p52)

Rotational C1 subluxation (Hadley(a), p,148) (Kattan, et al p29,91,144,173) (Yockum & Rowe, p691) (White & Panjabi, p208-9).

Subluxation 'minor degree of' – (Kattan, p 37,62,166)

Subluxed (Cailliet, p62)

Unilateral posterior 'rare' (White & Panjabi, p208)

Unilateral subluxation C1('anterior most common', p205) (White & Panjabi, p205-7)

UNCINATE PROCESS, lunate process, eminentia costaria, processus uncinatus,

Covertebral joint, Joints of von Luschka. Uncovertebral joint, Neurocentral joint, Intervertebral half joint (Hadley(a) 422 citing von Luschka)

(As with 'subluxation', there is often nomenclature for essentially the same thing. (Auths)

Osteophytes (Hadley(a), p422)

VISCERAL DISTURBANCES – 'NON-MUSCULOSKELETAL'

A range of non-musculoskeletal symptoms are noted as being associated through the textbooks mentioned in this section.

(Jackson p 140-144) (Lewit p27-9, 282-7) (Maigne p164,192) (Cailliet p69),

Schmörl & Junghanns, state that inefficient motor segments (intervertebral insufficiency '*may affect inner organs*' (p213). They then go on to cite numerous studies involving non-musculoskeletal conditions considered to be vertebrogenic in association. (p213-227).

Barré Lieou syndrome and vasomotor disturbance about the head. (Hadley(a) p422, 424) (Maigne, p192-206)

WHIPLASH

Whiplash has been described as a sudden acceleration or a deceleration-acceleration injury. (Jackson p83-90). Lateral whiplash is also possible. (Jackson p88)

These types of injuries often result in mechanical disturbance of the cervical spine [and lumbar spine -(Jackson p89) in varying degrees and termed whiplash associated disorders (WAD). The more minor disturbances often remain undetected and can result in a diagnosis of functional overlay. (Myrtveitet et al 2012) (Kim et al, 2022)

Many of the radiological findings discussed in this paper can be identifiable indications of these disturbances as dysfunctional subluxations.

Head position at time of injury (Jackson p. 87)

Radiological evidence as to time of injury. (Nordhoff, p. 175)

Earlier injury (Jackson p. 297)

A forensic guideline provides a grading of whiplash symptoms – see The Croft CAD Classification System (1992). (Foreman & Croft p. 61)

Appendix 2

MENSURATION

Breaches of these lines may indicate vertebral displacement or dysfunction, especially if associated with symptoms. Breaches may also indicate fracture or pathology. For these guidelines to be radiologically significant, it would seem reasonable that deviations would indicate forms of disruption which could activate noxious sensory impulses if associated with signs and symptoms.

LINES OF MENSURATION & BASELINES FOR 'NORMAL'

Anterior atlanto-occipital dislocation measurement (Yockum & Rowe, p147) (See rCCI)

Anterior arch of atlas/odontoid 2.5mm in adults 4.5 in children. (Kattan, p51)

Anterior border of vertebral bodies (Kattan, p48) (Foreman & Croft, p216)

Anterior Canal Line & intervertebral foramina & posterior foramen magnum (Kattan, p49) (Meschan, 1963)

Apophyseal joints spaces parallel (Kattan, p51)

Articular pillars, lateral view – regular rhomboid shape (Kattan, p50)

Atlantoaxial; alignment (Yockum & Rowe, p152)

Atlantodental interspace (ADI) (Yockum & Rowe, p148)

Basion-dens interval of 12mm (Harris et al, 1994)

C7 slope angle (Lee et al, 2013) (Núñez-Pereira et al, 2015)

Cervical Cobb Angle (Scheer et al,. 2013)

Cervical gravity line (Example of optimal cervical posture) (Yockum & Rowe, p152) (Gatterman (b, p263-4)(d), (124)

Cervical lordosis, (a) Depth measurement, (b) Method of Jochumsen, (c) Angle of cervical curve (Yockum & Rowe, p,152) (Gatterman, (a) p124) (d), p101)

Cervical stress line (Gatterman (b), p102-103)

Chamberlain's line – dens clearance. (Meschan, p220) (Nordoff, p140) (Yockum & Rowe, p144)

CO/C1 Instability (Fielding and Hawkins, 1977) into four types - (Schleicher et al, 2018):

1) Rotatory subluxation without any anteroposterior translation;

2) Rotatory subluxation with an anterior shift of 3 mm to 5 mm;

3) Rotatory subluxation with an anterior shift of more than 5 mm;

4) Rotatory subluxation with a posterior shift.

Cranio-vertebral angle (Kamel et al. 2023.

Dens-foramen magnum line (Meschan, p220)

Digastric line (platybasia) (Yockum & Rowe, p145)

Facet joint overlap. (Schleicher et al, 2018)

Harrison Cervical Curve Method (Scheer et al, 2013)

Jackson Stress Lines (Scheer et al, 2013)

George's line (Nordoff, p141)

Macrae's line (Yochum & Rowe, p144)

Macnab's line, lumbar spine (Gatterman (b), p104)

McGregor's line (Yockum & Rowe, p143)

Method of Bull (Yockum & Rowe, p149)

Posterior cervical line (Nordoff, p142) (Foreman & Croft, p216) (Yockum & Rowe, p150)

Posterior foramen magnum line (Meschan, p220)

Prevertebral soft tissue line (Nordoff, p142) (Yockum & Rowe, p155)

Retropharyngeal space at C2 3.5mm in children and adults (Kattan. p51) (Foreman & Croft, p220)

Retrotracheal space 14mm - range 9-22mm.adults, children 8mm - 5-14 range. (Kattan,. p51)

Revised cranio-cervical interval. (rCCI) (CO/C1 instability if >2,5mm) (Schleicher et al, 2018) (Citing: Provenzale and Sarikaya, 2009)

Rule of Spence (atlas lateral mass overlap in mm) (Schleicher et al, 2018)

Spinal canal (Yockum & Rowe p151)

Spinolamina line (Kattan, p49,97) (Foreman & Croft, p219) (Ruch, 36)

Spinous process line (lateral view) smooth, even, continuous (Kattan, et al. p57)

Stress lines of the cervical spine (Yockum & Rowe, p154)

T1 Slope line (Scheer et al, 2013) (Effect on cervical spine) (Knott et al, 2010) (Lee, 2013)

In what seems inconsistent, much emphasis in the medical literature is placed on postural and vertebral displacement yet the management of these conditions seems primarily directed at symptoms without addressing autonomic reflex aspects activated by disrupted physical dysfunction and displacements all of which can hardly be corrected by chemical means alone.

Appendix 3

HYPOLORDOSIS – A CORRELATION OF CLINICAL AND RADIOLOGICAL FINDINGS

HYPERLORDOTIC CERVICAL SPINE.

Findings noted in lateral cervical view.

('Lordotic angulation' or 'isolated extension' – (Penning; 1968)

NORMAL

In the lateral view, a normal cervical spine is a gentle forward 'C' or concave curve resulting in the odontoid process lying vertically above the centre of the body of C7 and the head sitting vertically symmetrically balanced over the centre of gravity

Cervical discs are normally twice as thick anteriorly as posteriorly. (Cailliet pp5)

RED FLAGS, ORANGE FLAGS AND CONTRAINDICATIONS

Possible fractures of posterior elements, or pathology.

DIFFERENTIAL DIAGNOSES

Congenital

Postural

Occupational

EFFECT ON FUNCTION

Flexion may be limited

Extension may be greater than average.

POSSIBLE ASSOCIATED IMPLICATIONS

The persistence of a cervical hyperlordosis indicates a disorder of the cervical spine. ('Backward angulation' (Jackson, p187)

Possibly postural in origin - acquired or hereditary.

Possibly associated hyperlordotic lumbar spine resulting in adaptation and compensation.

Possibly associated hyperkyphotic dorsal spine resulting in adaptation.

Possibly demonstrable legal evidence if traumatic factor involved as in an acceleration/deceleration type injury or hyperextension. (See 'Facet Indentation' - No 4).

May lead to anterior osteophytosis formation in later years. (Jackson, p54) This may lead to direct irritation or reflex stimulation of the sympathetic nerve supply. (Jackson, pp72)

Weight bearing transferred to posterior facets - possible predisposing to osteoarthritis in later years. Compression of the posterior interarticular motor units. (Whitley et al 1960)

Tiring posture of neck.

Anterior weight bearing usually associated with hypolordosis or kyphosis.

Irritation of those facets.

Restriction of motion of those facets.

Compression of posterior facets at that level.

Kissing spinouses.

In a neutral lateral view with anterior weight bearing of the skull (anterior inclination or anterior shift in weight bearing) look for facets riding superiorly upon the inferior vertebra

Possible radicular involvement.

Clinically manifested as a localised vertebral dysfunction at the sub-occipital level due to occipital extension compensation as well as at the C7/T1 transition level. This is a mechanical fixation component of a vertebral subluxation complex (VSC).

The findings will vary greatly and will largely depend on the position of the head at the time of impact.

POSSIBLE CLINICAL FINDINGS (SIGNS)

Posturally there is often an anterior shift in weight bearing of the head, that is the head is supported anterior to the normal neutral postural gravity line.

Hyperlordotic cervical spine would have hyperextension of the head with fixation at the upper cervical level C0/C1/C2

Hyperextension of head on active extension together with an anterior shift of head weight bearing to the centre of A-P gravity.

Increased wedging of discs posteriorly, ie. narrower posteriorly.

If longstanding, osteophytic spurs may appear at the anterior margins of the vertebral bodies involved. This is most common between C4-C6. (Jackson pp45,54)

Approximation of spinous processes.

Patient presents with a 'slumped' or 'rounded' posture

Possible headaches. (Jackson, p139)

Possible light headedness or dizziness. (Jackson, pp141)(Kristjansson & Treleaven 2009)

Tired dull aching neck.

On palpation spinous processes will be difficult to identify individually.

On palpation hypermobility in extension is likely.

Possible facet arthropathy or predisposition to arthropathy.

Possible neurological alteration on a segmental basis due to nerve root irritation. (Jackson, pp44,72,74) These include: venous congestion, sensory changes, muscle atrophy or spasm, altered tendon reflexes. (Jackson pp51)

POSSIBLE FUNCTIONAL FINDINGS (SYMPTOMS)

Patient describes a 'Heavy head' or that their 'head is too heavy for their neck'. or their 'neck is not strong enough to support their head' or the 'neck feels weak'.

Exaggeration of upper dorsal kyphosis - may be pseudokyphosis, that is the anterior inclination of the head exaggerates a normal dorsal kyphosis from the C7/T1 level.

If of lumbar aetiology there is likely to be a corresponding lumbar hyperlordosis with a dorsal hyperkyphosis.

Neck tires easily.

If occipital extension is present:

This is likely to be postural, the head will extend in compensation for the cervical kyphosis.

Possible headaches

Possible sub-occipital headaches

Possible posterior eye pain

Psychological stress and tension is likely to aggravate any associated symptoms, particularly muscle tone.

Probable cervicogenic headaches.

Possible radicular involvement.

POTENTIAL AETIOLOGY

Possibly hereditary or acquired through poor postural habits ('slumping') or traumatic in origin.

Hyperextension sprain (Giles & Baker, 2005, p10)

Hyperextension type injury such a being struck from the rear while waiting at an intersection.

Severe football injury.

Vertical impact onto the frontal or anterior vertex region of the head

Patient dumped in the surf hitting forehead on ocean floor.

Diving - striking head on impact of water, underwater object or bottom of pool. (One of the dangers of shallow water.)

High dive - impact of head on surface of water.

Hyperlordotic lumbar spine.

AGGRAVATING FACTORS

Desk work - looking down over keyboard – prolonged postural flexion.

Prolonged overhead work.

Sleeping supine.

High heel shoes.

Prolonged standing leading to postural fatigue.

Carrying loads with the weight 'dragging' the arms which in turn pull from the shoulders which in turn basically anchor from the trapezius muscles and therefore the head and neck.

Prolonged driving - with head anterior to the centre of gravity.

Reading - care with bifocals.

Posture - slumping in chairs.

RELIEVING FACTORS

Needs high pillow as a low pillow leads to further extension when supine.

Rests head or chin in hands while sitting.

Raise or tilt surface of desk.

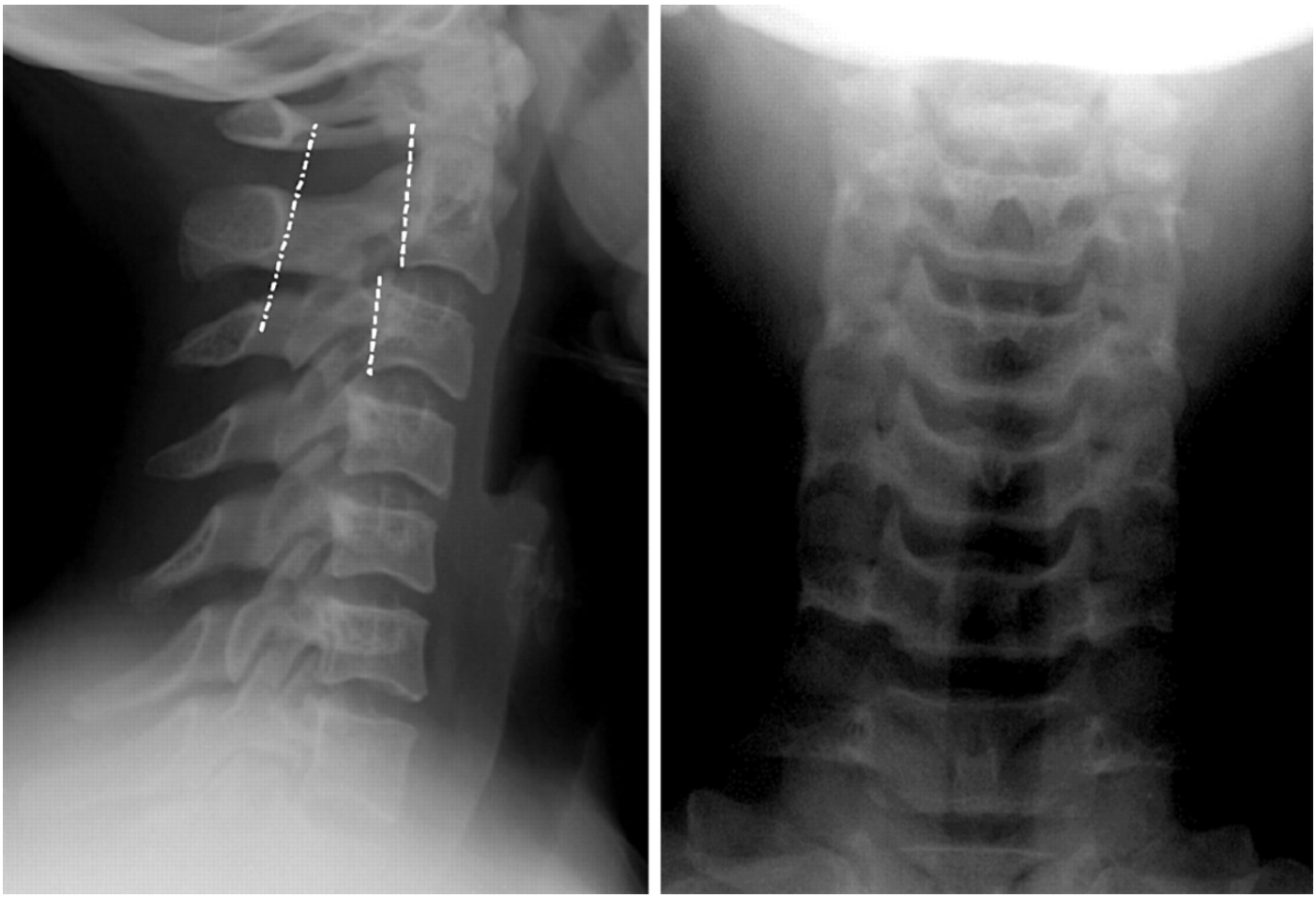
ADJUNCTIVE EXERCISE OR THERAPY.

Isometric - resisted head flexion with head retracted.

Isometric lumbar flexion exercises if hyperlordosis evident.

Appendix 4

‘Stair step’ subluxation

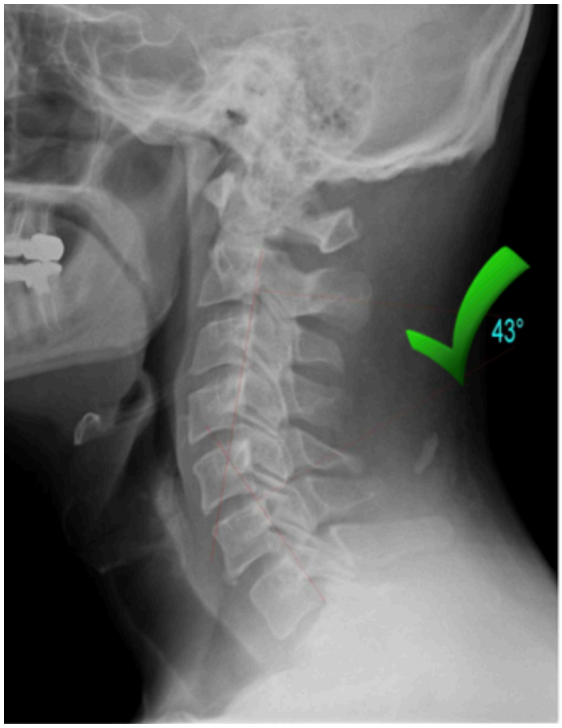


Curtin P, McElwain J. Assessment of the ‘nearly normal’ cervical spine radiograph: C2-C3 pseudosubluxation in an adult with whiplash injury.

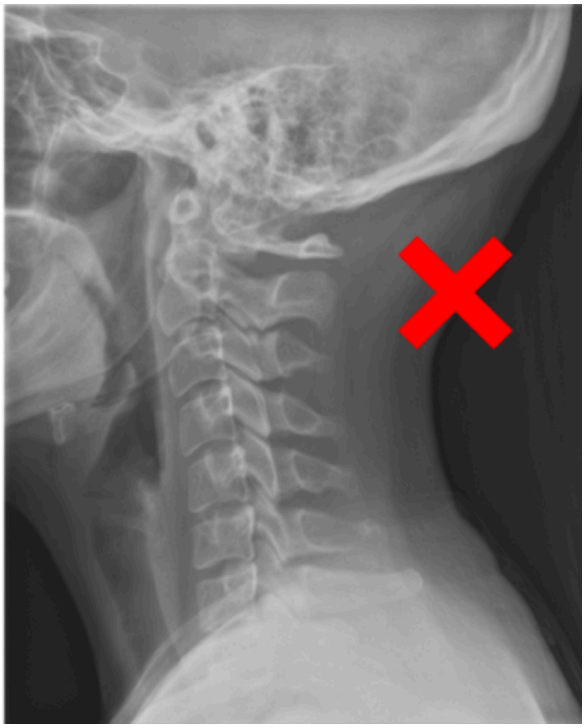
Ref: Emerg Med J. 2005 Dec;22(12):907-8. DOI 10.1136/emj.2004.020115. https://pubmed.ncbi.nlm.nih.gov/16299212/

Appendix 5

Comparison of cervical postures indicating functional differences activating different proprioceptive input.

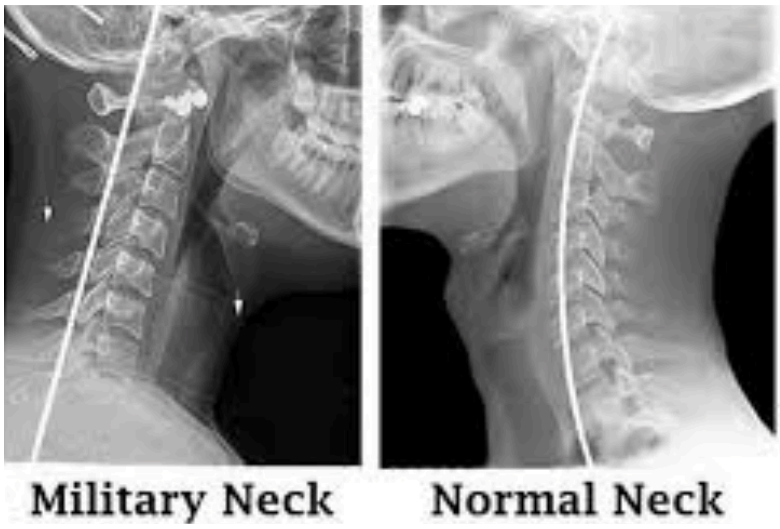


Normal



Slight kyphosis
Note: C4 flexion on C5
Alignment of articular apices C5/C6

From: https://stronglifechiropractic.com/neck-alignment-whats-normal-3/



Anterior weight-bearing