An Introduction to Chiropractic BioPhysics® (CBP®) Technique: A Full Spine Rehabilitation Approach to Reducing Spine Deformities

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Chapter

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Abstract

Chiropractic Biophysics® (CBP®) technique is a full-spine and posture correcting method that incorporates mathematical principles into a unique approach to treat spinal disorders. It considers that the identification of postural rotations and translations of human postures are first evaluated and compared to the radiographic assessment of the spine alignment. Mirror image® postural positions and movements are utilized including spinal extension positions to improve the spine and posture towards a normal/ideal alignment. Specifically, corrective exercises, corrective traction and chiropractic adjustments are performed encompassing a multimodal rehabilitation program with the goal of improving the posture and spine alignment. CBP Rehabilitation programs are typically performed in-office with supportive at-home measures. Repeat assessment including radiographs are used to quantify and monitor structural improvements. CBP technique is an evidence-based approach to treat spine deformities and is supported by all forms of clinical evidence including systematic literature reviews, randomized controlled trials, non-randomized controlled trials, case reports/series as well as is supported by biomechanical posture-spine coupling validity, radiographic and posture analysis reliability/repeatability and use of a validated biomechanical spinal model as the outcome goal of care. CBP technique is a proven method to improve pain, disability and quality of life in those with structural deformities.

Keywords: spine deformity, structural rehabilitation, traction, exercise, chiropractic

1. Introduction

Chiropractic Biophysics® (CBP®) technique is a full-spine and posture correcting method that incorporates engineering and mathematical principles into a unique approach in the treatment of spine disorders [1–5]. CBP technique is best described as a 'structural' rehabilitation approach as opposed to 'functional' rehabilitation that typically encompasses physiotherapeutic modalities, stretching and exercises to regain function. The goal in structural rehabilitation is to restore the spine alignment and posture to as near normal as possible.

CBP operates on three main premises: 1. There is a normal/ideal static spinal configuration; 2. Abnormal alterations of the spine/posture result in abnormal function disrupting homeostatic balance; 3. Altered static spine/postural alignment results in abnormal dynamics [1]. The contemporary spine literature supports all three of these premises (See Section 4). CBP technique has published research on many facets of the technique including defining what normal/ideal spine alignment is, how to measure spine alignment parameters with reliable and repeatable methods, how to correct/re-align spinal displacements, and evidence proving correcting spine and postural displacements correlates with improvements in pain, disability and quality of life (QOL) measures (These studies are detailed later).

Herein, an overview is given of the scientific approach to treating spine disorders (i.e. subluxation) by the unique approach of CBP technique. A review will be given of the historical beginnings of CBP, rotations and translations of posture, the Harrison normal spinal model, radiographic analysis, posture and spinal coupling, the CBP protocol, clinical evidence of efficacy as well as the safety of the use of X-rays (The term 'X-rays' imply the use of plain radiographs throughout this chapter).

2. Historical beginnings

Donald D. Harrison, who had a Master's degree in Mechanical Engineering and a Doctorate degree in Applied Mathematics developed a devote urgency to bring contemporary science to chiropractic. In the late 1970s, Harrison was the main instructor for the chiropractic technique named 'Pettibon.' Dissatisfied with the failure to produce spinal correction, he often incorporated his own methods in certain cases to better attain spine and posture improvements. It was in the treatment of one particular case (circa 1980) where he discovered that the body must be treated using the principles of mathematics; the term 'mirror image®' adjusting he later coined to describe these new approaches [1].

A 1974 paper by Panjabi et al. describes a Cartesian coordinate system for use in the description and study of joint biomechanics (**Figure 1**) [6]. Harrison was the first to apply this system of analysis to upright human posture (**Figures 2** and **3**). Harrison began discovering the rotations and translations of human posture in 1980. During the early 1980s, the analysis system evolved to incorporate a full spine analysis of the

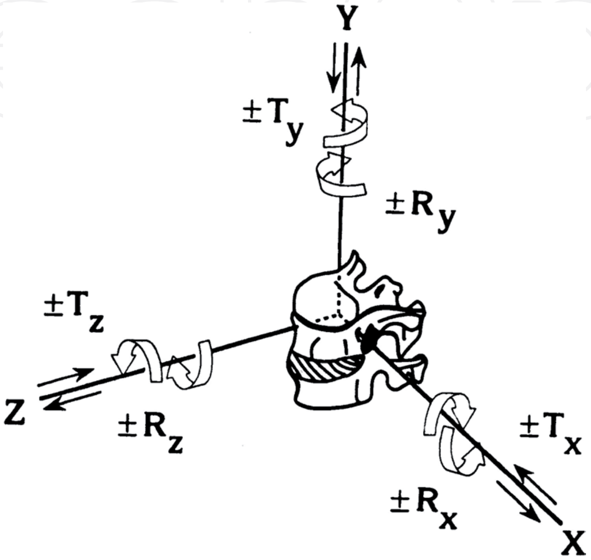

Figure 1.
A vertebra described in terms of rotations about and translations along the x, y, and z-axes on a cartesian coordinate system as proposed by Panjabi (courtesy CBP seminars).

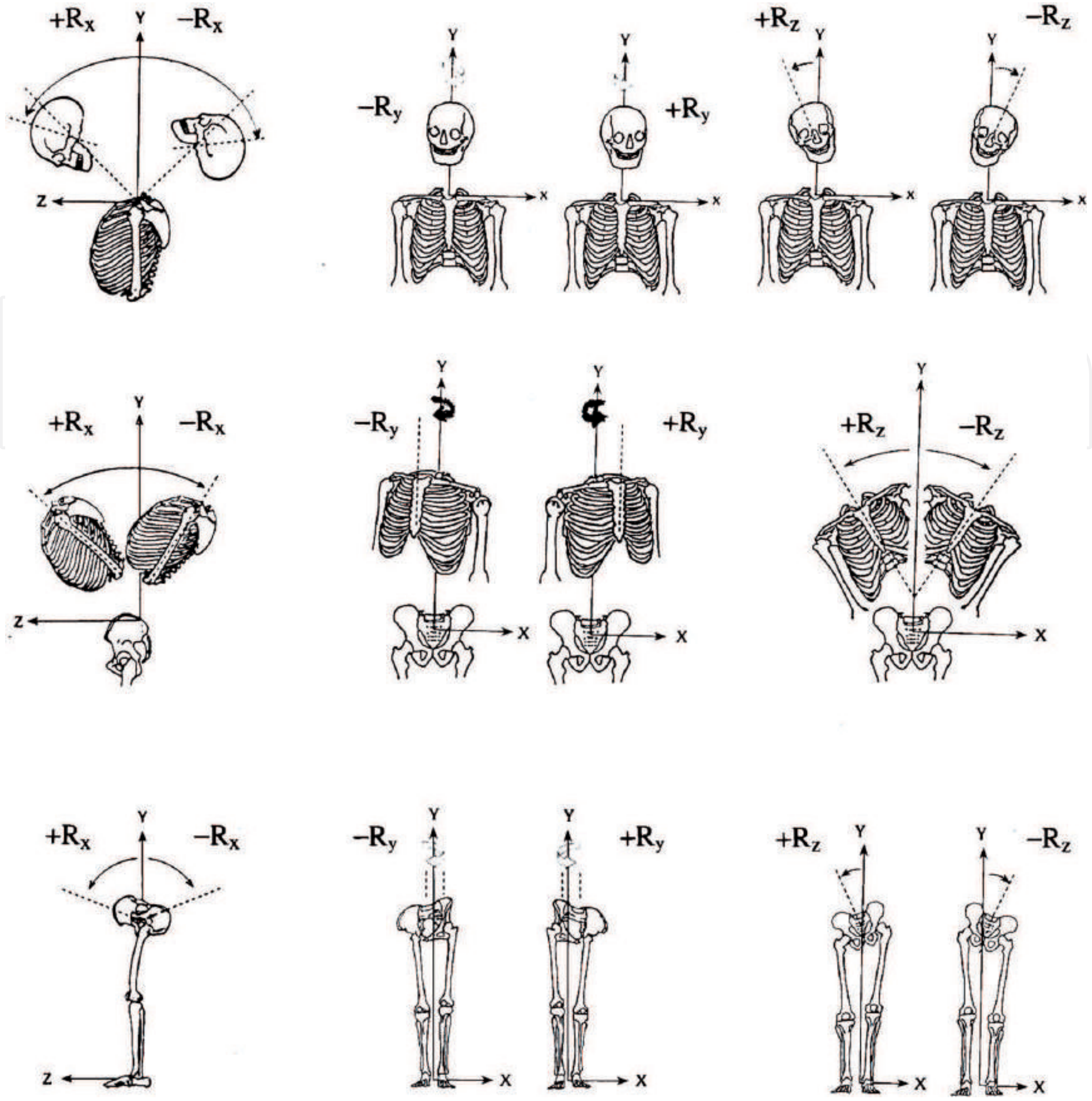

Figure 2.
If the head, thoracic cage, and pelvis are considered rigid bodies, then the possible rotations in three-dimensions are illustrated. Flexion and extension are rotations on the x-axis, axial rotation is about the y-axis, and lateral flexion is rotation about the z-axis (courtesy CBP seminars).

head, rib cage and pelvis in three-dimensions. The technique methods continued to evolve with intellectual contributions from early practitioners of CBP including among others, Drs. DeGeorge, Gambale, Pope and Deed Harrison (founder's son).

One of the unique methods within CBP is the use of 'extension traction' to restore the normal cervical or lumbar lordosis (**Figures 4** and **5**). The first cervical extension traction was with use of an inclined bench that utilized a camlock and pulley system to hyperextend the neck by pulling on the forehead [7]. This is the traction used in the first CBP non-randomized controlled clinical trial (nRCT) that showed that no traction either by no treatment or only cervical manipulation but no traction resulted in no improved alignment, while the traction group (also receiving cervical spinal manipulation) achieved improved lordosis [7].

Further development in cervical traction involved the addition of a posterior-to-anterior (PA) pull through the mid cervical spine with simultaneous extension and distraction of the head while sitting in a chair, so-called 'Pope's 2-way' traction (**Figure 4**) [8]. A slight modification of this traction involves the use of a chin-forehead strap to add weight directly to the patients head as an extension-compression 2-way traction (**Figure 4**) [9]. More recently, a cervical extension

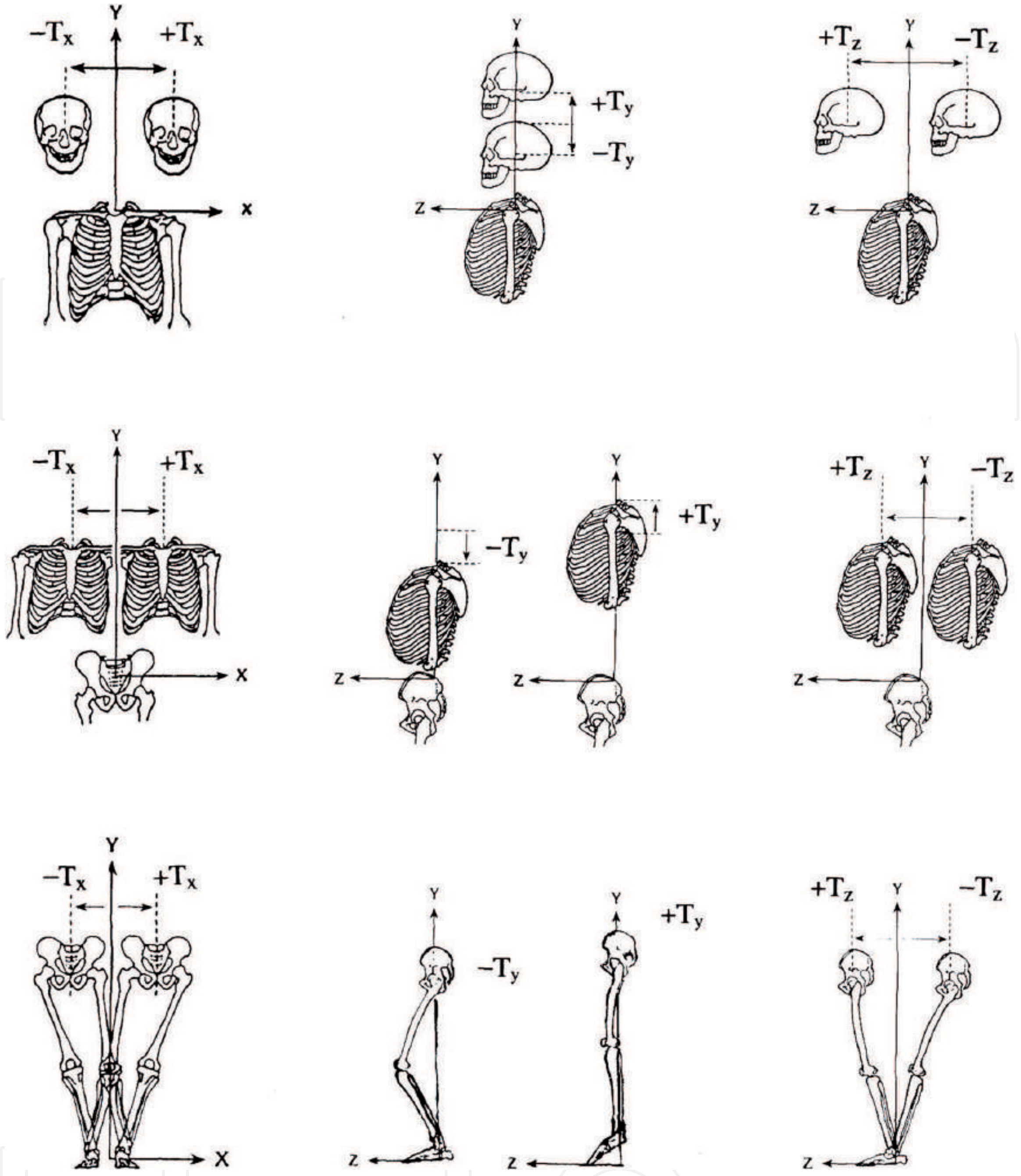

Figure 3.
If the head, thoracic cage, and pelvis are considered rigid bodies, then the possible translations in three-dimensions are illustrated. Lateral translations occur along the x-axis, vertical translations occur along the y-axis, and anterior–posterior translations (protraction-retraction) occurs along the z-axis (courtesy CBP seminars).

orthotic (Denneroll) has been shown to be effective at increasing cervical lordosis (**Figure 4**).

In the mid 1990s, Deed Harrison helped to develop precision vectors for lumbar extension traction (**Figure 5**), where the first nRCT showing lumbar curve restoration was published in the *Archives of Physical Medicine and Rehabilitation* in 2002 and concluded: “This new method of lumbar extension traction is the first nonsurgical rehabilitative procedure to show increases in lumbar lordosis in chronic LBP *(low back pain)* subjects with hypolordosis” [10]. A lumbar extension orthotic device by Denneroll is also used for lumbar extension traction (**Figure 5**).

Figure 4.
Cervical extension traction (courtesy CBP seminars).

Figure 5.
Lumbar extension traction (courtesy CBP seminars).

CBP technique is one of the most scientifically based posture and spine correcting techniques. There are many randomized controlled trials (RCTs), nRCTs, and well over 100 case reports/series documenting the improvement of diverse spine deformity patterns with concomitant reduction of pain, disability and increased QOL measures [11].

3. Rotations and translations of posture

The main strength of CBP technique is its fundamental underpinnings in engineering and mathematics [1]. It is a general theorem that any object can be decomposed as a rotation, a translation and a deformation [12]. Acknowledging that deformation of living tissues occurs, as in compressing of discs, ligaments, muscles etc., we divert attention to rotations and translations of posture. The main masses of the body, namely the head, thorax and pelvis can be described in relation to the body mass below within a Cartesian coordinate system (**Figures 2** and **3**). That is, the head is described in relation to the thorax, the thorax in relation to the pelvis, and the pelvis in relation to the feet [1, 13].

Any rotations or translations of the body masses as seen in neutral posture via external observation or internally by X-ray is acknowledged as abnormal. Therefore, no offset of the masses equates to the normal postural alignment (i.e. un-subluxated position). It is important to note that in the assessment of a patient, it is the presence of a rotation or translation in the neutral standing position that is abnormal. When Harrison first applied this method of analysis, the treatment became apparent with the postural diagnosis. That is, for any rotation or translation apparent in neutral standing posture, the opposite position would need to be the treatment as applied during exercises, spinal traction or spinal adjustments, as this is the mathematical solution, "the exact reversing of the patient's abnormal posture." [1] In fact, because the soft tissues require a significant magnitude of stress and strains to attempt to correct the spinal position via mirror image methods, Harrison suggested that postural reflections (i.e. 'mirror image' adjustments) need to be applied in "twice the negative of the translation distances and rotation angles." [1].

It should be noted when Harrison finally developed the full spine analysis of rotations and translations of posture in the mid 1980s, he discovered that virtually

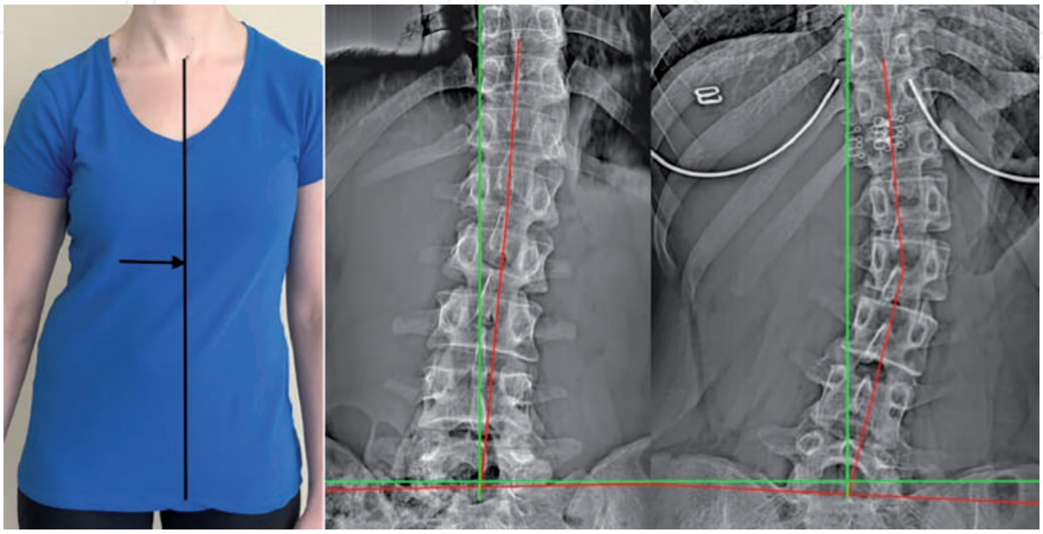

Figure 6.
Posture image and antero-posterior lumbar radiographs depicting a left lateral thoracic translation (side shift). Both patients in the radiographs have a 20 mm left lateral shift of T10 off midline. Left patient has a pure left lateral thoracic translation posture, aka 'pseudo-scoliosis.' Right patient has a true left lumbar scoliosis (vertebral rotation). Green line is vertical; red line highlights patient alignment (courtesy CBP seminars).

50% of all human movements had never been studied (except forward head posture). Thus, the Harrison research group performed several studies to evaluate the normal range of motion for several translation postures including lateral head and thoracic postures as well as anterior and posterior thoracic translation postures (Discussed in Section 6). [2, 3] Clinically, the spinal coupling patterns as discovered to be associated with these common postural positions are of utmost importance in the treatment of these spinal disorders.

Importance of the study of these never previously studied translation postures can be highlighted in the distinction between true scoliosis and 'pseudo-scoliosis' (**Figure 6**) [14] Pseudo-scoliosis is a lateral thoracic translation posture that characteristically features little to no vertebral rotation (simple to correct) [15, 16], whereas, true scoliosis characteristically features significant vertebral rotation (and is typically much more difficult to treat). X-ray screening of the spine is the only way to differentiate true scoliosis from pseudo-scoliosis.

As mentioned, the absence of rotations and translations of the body masses in standing posture is normal. However, the shape of the spine position, particularly in the sagittal plane has traditionally been debated.

4. The Harrison normal spine model

In the mid 1990s to the mid 2000s, the Harrison research team performed a series of spine modeling studies of the sagittal spinal curves (**Figure 7**) [17–24]. To

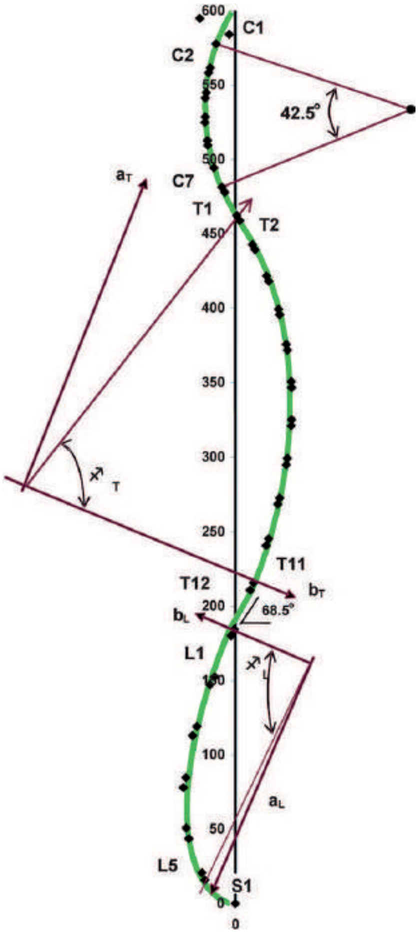

Figure 7.
The Harrison normal sagittal spine model as the path of the posterior longitudinal ligament. The cervical, thoracic and lumbar curves are all portions of an elliptical curve having a unique minor-to-major axis ratio. The cervical curve is circular meaning the minor and major axes are equal (courtesy CBP seminars).

this day, this seminal work serves as the treatment outcome goal (i.e. gold standard) for providing structural rehabilitation by CBP methods (**Figure 8**). In a series of systematic studies, elliptical shape modeling of the path of the posterior longitudinal ligament was performed as it could be easily compared to the posterior vertebral body margins on X-rays, the same anatomical region used for measuring the sagittal spinal curves (i.e. Harrison posterior tangents (**Figure 9**) [25–28]).

Computer iterations of spine shape modeling were applied to determine the best-fit geometric spinal shapes by fitting ellipses of varying minor-to-major axis ratios to the digitized data points from the posterior vertebral body corners from X-ray samples for each of the three regions of the spine (cervical [17–19], thoracic [20, 21], and lumbar spine [22–24]). As shown in **Figure 7**, the Harrison normal spinal model features a circular cervical lordosis, an elliptical thoracic curve featuring greater curvature cephalad with a straightened thoraco-lumbar junction and an

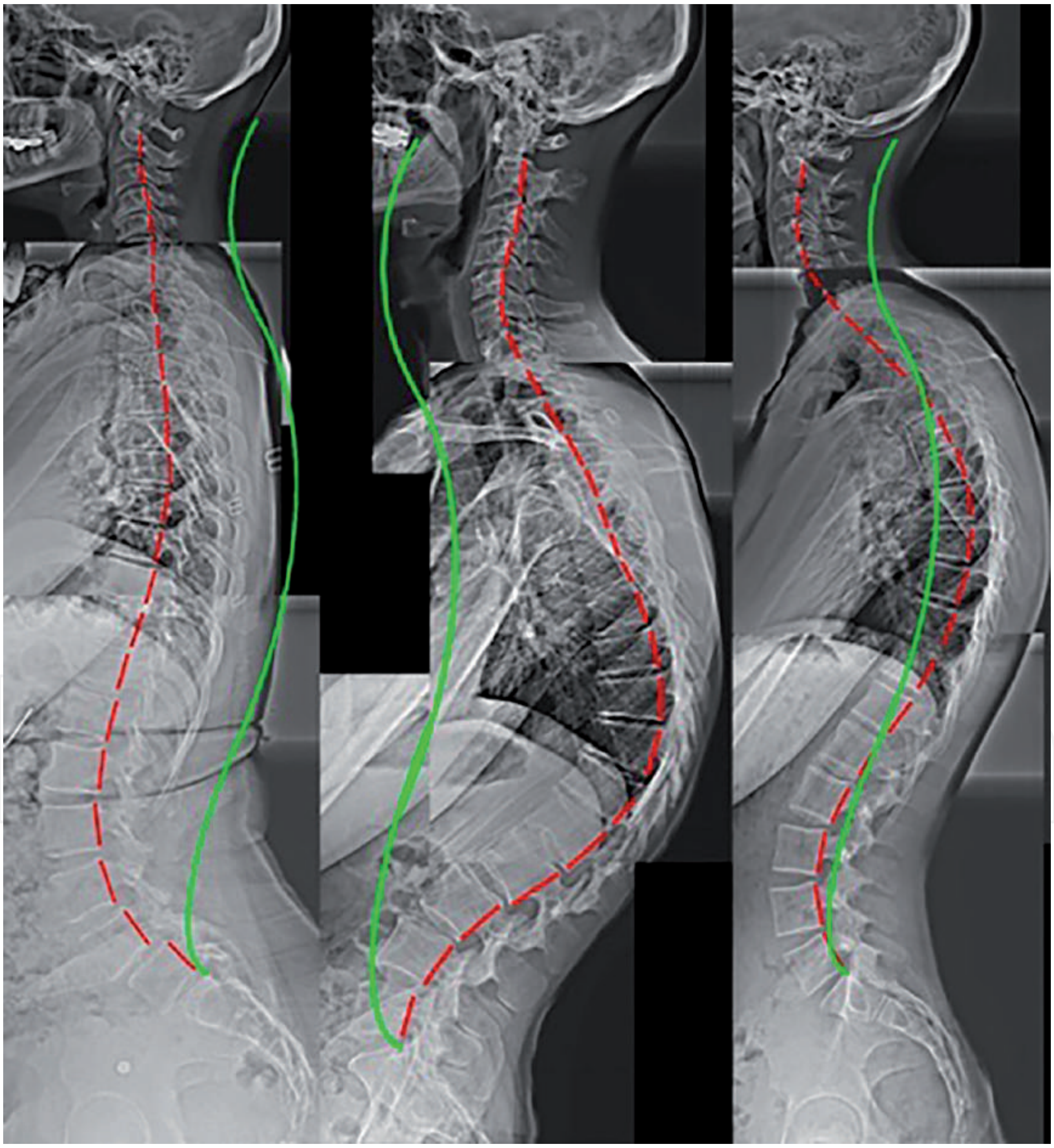

Figure 8.
Three patients demonstrating dramatically different spine alignment patterns. Left: excessive lumbar hyperlordosis, L4 anterolisthesis, and excessive anterior sagittal balance in a mid-aged female with disabling low back pain; middle: excessive thoracolumbar kyphosis and early degenerative changes in a mid-aged male; right: excessive thoracic hyperkyphosis in a young male with Scheuermann's disease. Red line is contiguous with posterior vertebral body margins; green line represents Harrison normal spinal model (courtesy PAO).

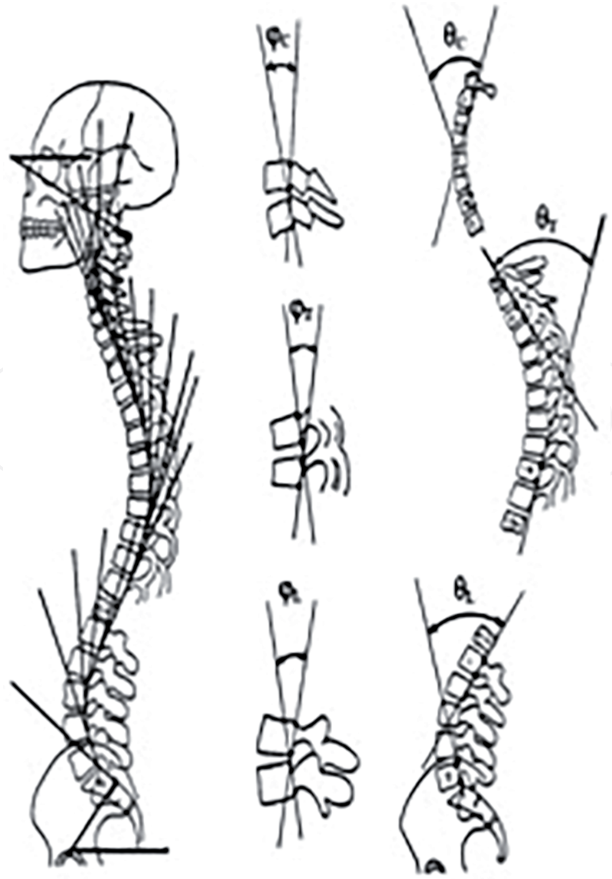

Figure 9.
Harrison posterior tangent method involves lines drawn contiguous with the posterior vertebral body margins. Intersegmental as well as regional sagittal curves are easily quantified having a standard error of measurement within about 2° (courtesy CBP seminars).

elliptical lumbar lordosis showing a greater distal lumbar curvature. The spine is assumed to be vertical in the front view.

Although some have attempted to criticize the Harrison normal spinal model, it is important to acknowledge that it has been validated in several ways. Simple analysis of alignment data on samples of normal, asymptomatic populations have been done [17–24]. Comparison studies between normal samples to symptomatic samples have been performed [17, 29]. Comparisons between normal samples to theoretical ideal models have been done [17, 18, 20, 23]. Statistical differentiation of asymptomatic subjects from symptomatic pain group patients based on alignment data has been performed [19, 24].

In subsequent biomechanical modeling studies, the Harrison group used a validated postural loading model to verify that sagittal spinal balance and the sagittal curves of the spine are critical biomechanical parameters for maintaining postural load balance in healthy subjects [30]. Keller et al. [30] stated "because the pattern of [intervertebral disc] IVD postural stresses mirrored the sagittal curvatures and sagittal displacement of the spine, a failure of the IVD's hydrostatic mechanism under these sustained loads could occur". In a similar biomechanical modeling study, Harrison et al. determined that anterior sagittal thoracic posture (anterior thorax translation relative to the pelvis) resulted in significant increases in disc loads and stresses for all vertebral levels below T9 and that the extensor muscle loads required to maintain static equilibrium in upright anterior posture increased almost five times that of normal [31]. In another study Keller et al. [32] determined that "postural forces are responsible for initiation of osteoporotic spinal deformity in elderly subjects".

The Harrison group also used an elliptical shell model to evaluate the loads and bending moments on the cervical vertebrae in varying cervical spine deformity alignments [33, 34]. They found that in normal lordosis the anterior and posterior vertebral body stresses are nearly uniform and minimal, whereas, in cervical deformity configurations having kyphosis (S-shape kyphosis high or low, total kyphosis), the vertebral body stresses are 'very large' and opposite in direction compared to normal lordosis [33]. They concluded "This analysis provides the basis for the formation of osteophytes (Wolff's Law) on the anterior margins of vertebrae in kyphotic regions of the sagittal cervical curve. This indicates that any kyphosis is an undesirable configuration in the cervical spine" [33]. Anterior head translation and a 'military' neck also displayed significantly increased vertebral body stresses that are reverse in direction from C5-T1 and are also proven to be "undesirable configurations in the cervical spine" [34].

5. Radiographic analysis

All radiographs should be taken in the 'neutral' standing position with the feet positioned with the heels at hips width apart. This is to avoid any induced postural deviations due to foot position. Also, to ensure a reproducible neutral (i.e. natural) body position, the subject should close their eyes and nod the head back and forth a couple times to where the subject should stop in their preferred position and then open their eyes while maintaining this adopted stance. Any postural misalignments seen in the subject should not be corrected. The lower body mass on the particular view being taken should be centered to the bucky. All X-rays should be taken without footwear.

It should be mentioned that the measurement of different sagittal spinal contours including regional curves or absolute rotation angles (ARAs) (i.e. cervical/lumbar lordosis; thoracic kyphosis) and intersegmental relative rotation angles (RRAs) between adjacent vertebrae can be easily quantified by use of the Harrison posterior tangent (HPT) lines (**Figure 9**) [25–28]. The HPT method is preferred for three main reasons, 1. The posterior margins of the vertebral bodies are less affected by osteoarthritic changes as compared to the anterior margins which makes anatomical measurements more reliable and valid; 2. The posterior tangents are contiguous with the slope of the spinal curves and represent the first derivative in an engineering analysis and therefore, their intersection accurately depicts the sagittal configuration; 3. The HPT method has a small standard error of measurement (SEM) of approximately 2° versus higher SEMs with the Cobb (4.5–10°) [25–27]. This is why the HPT method is superior to other methods of sagittal spine mensuration including the popular Cobb method.

Generally, the global curves are measured as C2-C7, T1-T12, and L1-L5, however since the inflection of the cervical lordosis to thoracic kyphosis occurs at T1, some clinicians prefer to measure the cervical curve from C1-T1, and the thoracic curve from T2-T11 or T3-T10. Anterior sagittal translation distances are simply measured by the horizontal displacement offset between comparison vertebrae such as C2-S1, C2-C7 or T1, T1-T12, etc.

The anterior-to-posterior (AP) or PA X-rays are taken using the same postural positioning. The modified Risser-Ferguson method is employed to measure coronal plane alignment (**Figure 10**) [28]. On the AP/PA cervicothoracic view an upper angle is created as the angle between the best fit line of the upper cervical segments and intersection with the bite line, and a lower angle is formed between the best fit lines of the upper to lower spine segments [28]. The Rz angle is the angle formed by a vertical axis line (VAL) drawn from T4 and the lower cervicothoracic best fit line. Normal upper angle, lower angle and Rz cervicothoracic angles are 90°, 0° and 0°, respectively. The AP/PA thoracic view may show an angle. The lumbopelvic view has an upper angle, the angle between the best fit line of the upper versus lower lumbar segments, and a lower angle, the angle between the best

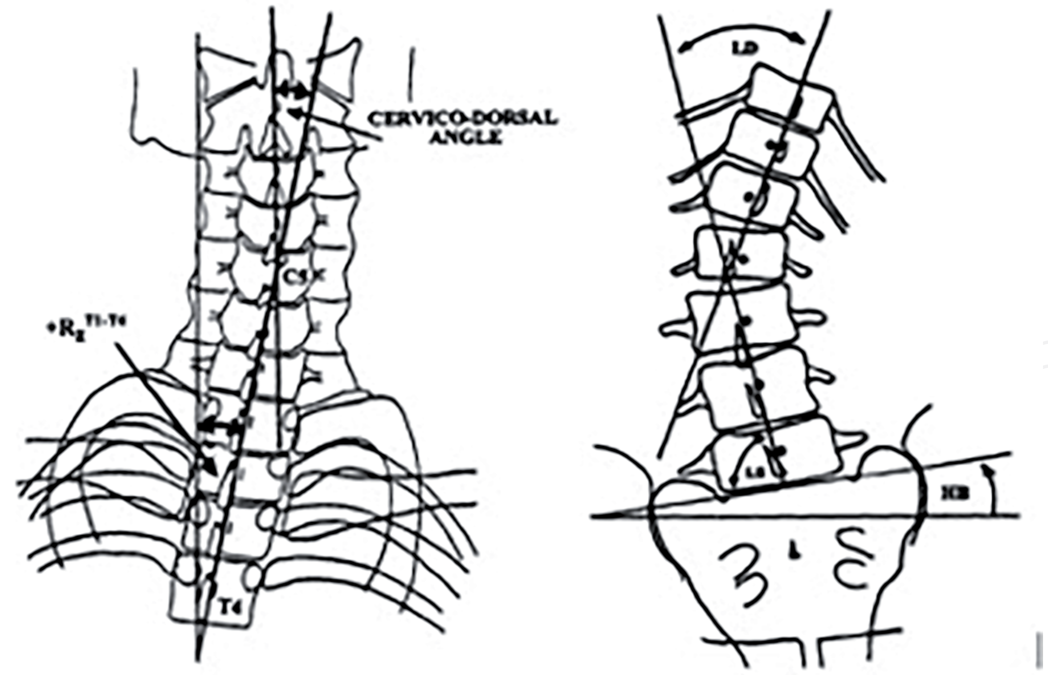

Figure 10.
AP radiographic line drawing by modified Risser-Ferguson method.

fit line between the lower segments and the horizontal pelvic line [28]. The upper angle and lower angle should be 0° and 90°, respectively. Any regional or full-spine coronal balance offset (i.e. imbalance) can be easily quantified as the horizontal distance between the uppermost segment to the lowermost segment (e.g. C2-T2, T1-T12, T12-S1, C2-S1).

6. Posture and spinal coupling

Postural rotations and translations as described by Harrison (**Figures 2** and **3**) are understood as 'main motions' and the corresponding spinal displacements to accommodate the postural positions are termed 'coupled motions' [2, 3, 35–38]. In CBP, a considerable clinical significance is placed on the correlation between the patient's three-dimensional postural presentation (posture displacement in terms of rotations and translations) and the two-dimensional X-ray coupled motion (spinal rotations and translations) [2, 3, 38].

Of prime importance is the appreciation that unless there is buckling, anomalies or ligament damage, standing neutral postural rotation and translation displacements of the head or thorax *cause* the vertebral spinal coupling patterns as seen on X-ray. If a patient's rotations and/or translations of posture 'match' the associated spinal coupling pattern as expected (i.e. normal coupling), then it is considered an 'easy' or typical case and the intuitive mirror image application of CBP methods would apply. When the patient's rotations and/or translations of posture do not match the expected spine coupling pattern (i.e. spinal coupling does not match postural displacement), then it is considered an atypical case where the clinician needs to consider alternative (i.e. more complicated) strategies for spine rehabilitation.

A classic demonstration of the 'matching' versus 'mismatching' of rotations and translations of posture and spine coupling patterns can be illustrated with forward head posture, aka, anterior head translation (AHT) (**Figure 11**). The natural and expected spine coupling with a forward translated head posture involves lower cervical spine flexion and upper cervical spine extension. As seen in **Figure 11**, many

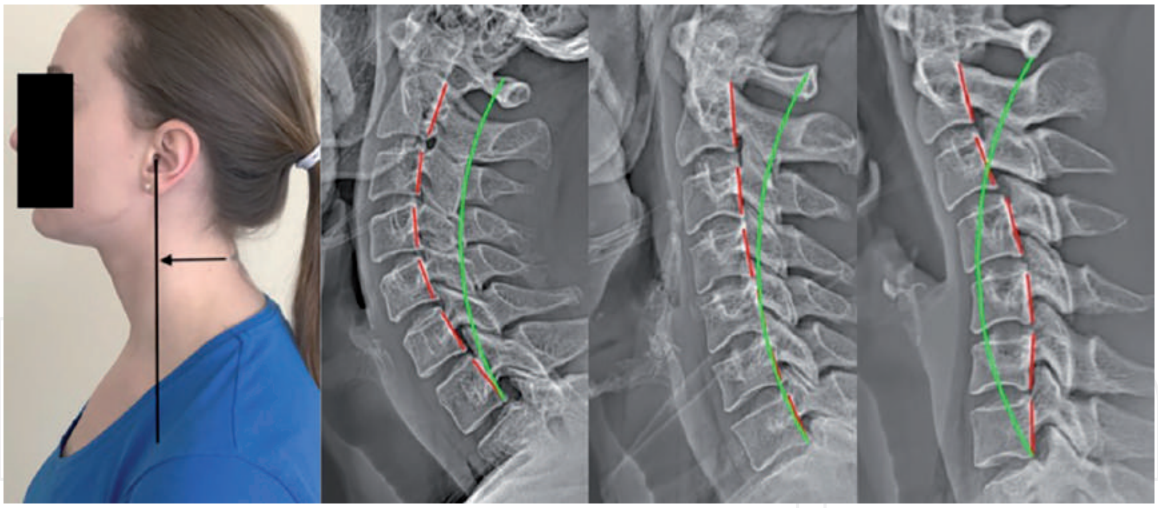

Figure 11.
Forward head translation as shown in posture and in three unique lateral cervical radiographs. All three X-ray images have about 25 mm of forward head translation. Left: hyperlordosis; middle: hypolordosis; right: kyphosis. Green line is normal alignment; red line highlights patient alignment.

spine different vertebral coupling patterns are possible including hyperlordosis, hypolordosis, or kyphosis and accordingly, each cervical configuration requires its own unique application of CBP methods for its ideal correction.

These cervical spine patterns have been termed harmonics and their presence can only be determined by radiography [2, 39]. Importantly, in CBP treatment approaches, each cervical spine coupling pattern (harmonic) requires its own unique treatment protocol. This is why many manual therapy approaches (e.g. Mackenzie head retractions) are inadequate at correcting posture and spine alignment as these are prescribed universally (i.e. ‘blackbox treatment’) resulting in many patients receiving treatment protocols that are contraindicated. A patient with a hyperlordotic cervical spine should never be prescribed neck extension exercises as this would dynamically hyperextend the cervical joints. A patient with a complete cervical kyphosis should never be prescribed head retraction exercises as this often ‘buckles’ the spine into further kyphosis.

Also, as mentioned and illustrated in **Figure 6**, ‘pseudo-scoliosis’ or pure lateral translations of the thorax (or head) must be distinguished from true scoliosis by examination of the spinal coupling patterns [14]. If there is minimal or no vertebral rotation then this represents a typical case requiring CBP mirror image postural correction [3]. If there is vertebral rotation then it is considered true scoliosis and a completely different application of CBP methods (i.e. non-commutative properties of finite rotation angles [40, 41]). Case examples of the special application of CBP methods in the treatment of scoliosis is described later.

7. CBP protocol

The CBP patient management protocol [2–4] involves all typical initial patient examination procedures including the consultation, examination as well as pain, disability and quality of life questionnaires (**Figure 12**). In addition, CBP treatment consideration requires, without exception, a full-spine posture assessment as well as full-spine AP and lateral standing radiographs. Posture needs to be either qualitatively, but ideally quantitatively assessed as rotations and translations of the head, thorax and pelvis in three-dimensions (**Figures 2** and **3**). The X-rays need to be digitized and quantified, ideally with the Harrison posterior tangent method for the sagittal images and with the modified Risser-Ferguson on the AP images.

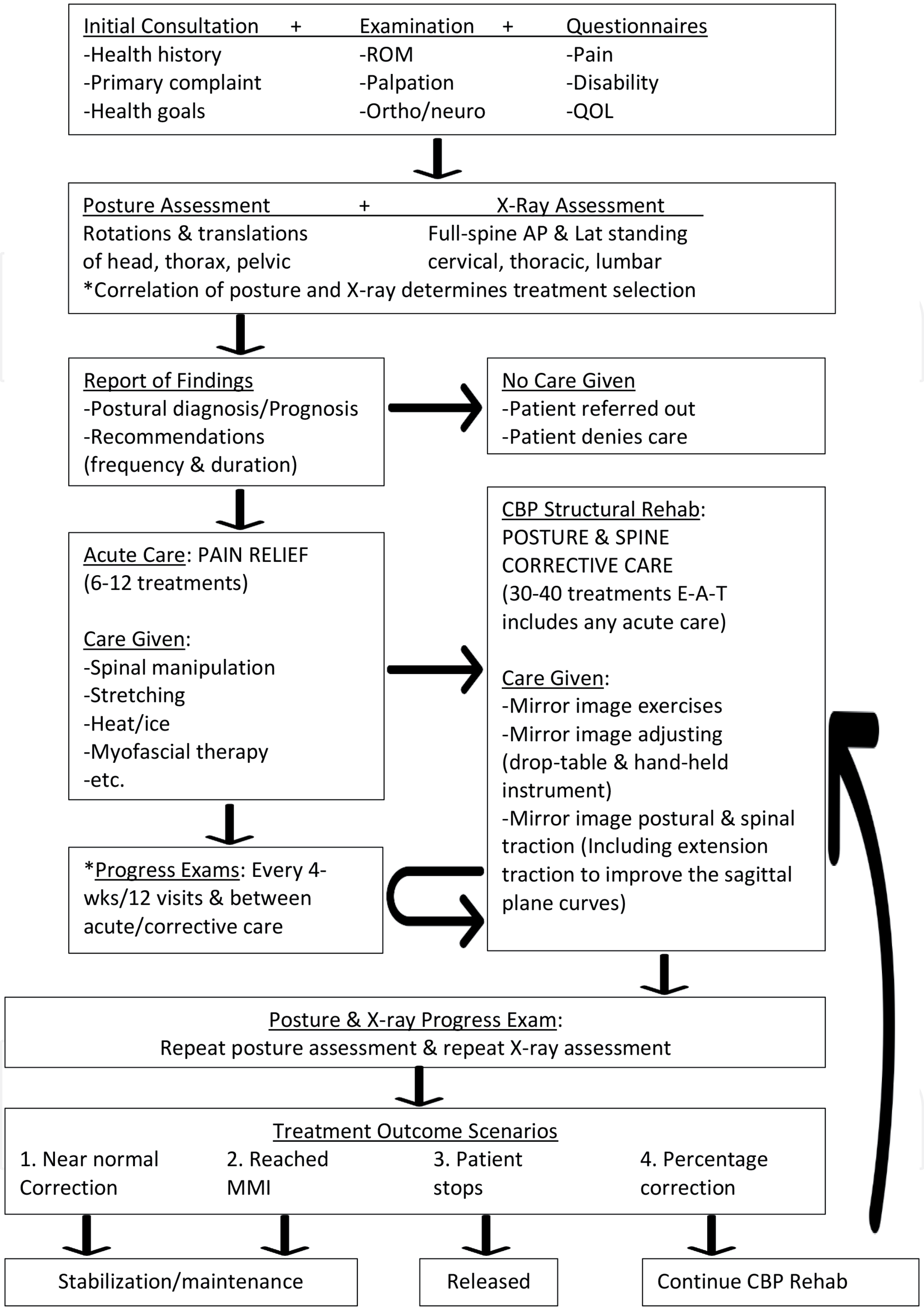

Figure 12.
CBP protocol treatment algorithm.

As seen in **Figure 12**, if appropriate, a new patient should be treated for their acute pain that is distinct and separate from CBP methods. It is recommended that the acute 'pain care' treatment include spinal manipulation, stretching (e.g. proprioceptive neuromuscular facilitation (PNF), Yoga, etc.), heat/ice, soft tissue myofascial therapy (e.g. transverse friction, Nimmo-receptor tonus technique, etc.). Once the patient

Study	Journal	Traction method	Traction time	Number of treatments	Change (*)	Change/txt (*)	Theoretical treatment extrapolation		
							Hypolordotic -20°	No curve 0°	Kyphotic +20°
RCTs									
Moustafa	Sci Reports	Denneroll	20m	30	13.9	0.46	32	76	119
Moustafa	Heliyon	Denneroll	15–20m	30	13.4	0.45	34	78	123
Moustafa	J Athl Train	Denneroll	20m	30	14.7	0.49	31	71	112
Moustafa	APMR	Denneroll	20m	30	13.1	0.44	34	80	126
Moustafa	EJPRM	Denneroll	20m	30	13.7	0.46	33	77	120
Moustafa	BFPTCU	Denneroll	20m	36	12.8	0.36	42	98	155
nRCTs									
Harrison	JMPT	Pope 2-way	20m	38	17.9	0.47	32	74	117
Harrison	APMR	2way	20m	35	14.2	0.41	37	86	136
Harrison	JMPT	Ext-comp	10m	60	13.2	022	68	159	250

**Note: Correction is estimated to achieve -35 of cervical lordosis.*

Table 1.
Summary of cervical lordosis improvement by number of treatments, magnitude correction/treatment and the extrapolation to typical sagittal cervical curve subluxation types and the theoretical treatment number required for their correction to -35° C2-7 ARA.

Study	Journal	Traction method	Traction time	Number of treatments	Change (*)	Change/ txt (*)	Theoretical treatment extrapolation		
							Hypolordotic -30°	Hypolordotic -15°	No curve 0°
RCTs									
Moustafa	JBMR/JMPT	LET	20m	30	6.2	0.21	48	121	194
Moustafa	Clin Rehab	LET	20m	30	8.7	0.29	34	86	138
nRCTs									
Harrison	APMR	LET	20m	36	11.3	0.31	32	80	127

**Note: Correction is estimated to achieve -40 of lumbar lordosis.*

Table 2.
Summary of lumbar lordosis improvement by number of treatments, magnitude correction/treatment and the extrapolation to typical sagittal lumbar curve subluxation types and the theoretical treatment number required for their correction to -40° L1-5 ARA.

Study	Journal	Traction method	Traction time	Number of treatments	Change (mm)	Change/txt (mm)	Theoretical treatment extrapolation		
							Mild offset ±10mm	Moderate offset ±20mm	Severe offset ±30mm
nRCTs									
Head trans Harrison	JRRD	Lat trans	20 m	37	6.9	0.19	54	107	161
Thorax trans Harrison	Eur Sp J	Lat trans	20 m	36	7.7	0.21	47	94	140

Note: Correction is estimated to achieve 0mm of offset.

Table 3.
Summary of AP head and thorax lateral translation reduction by number of treatments, magnitude correction/treatment and the extrapolation to larger coronal plane offset subluxations and the theoretical treatment number required for their correction.

experiences some initial pain relief (e.g. 6–12 treatments) they can be re-assessed and graduated to CBP structural rehabilitation. The decision to first treat a new patient with 'acute' pain care is a clinical decision that is mainly for patients that have either never seen a chiropractor previously or they have not been previously treated for their acute condition. For patients who have received recent previous treatment without relief, CBP rehabilitation care is recommended from the start of treatment [2–4].

CBP structural rehabilitation is suggested as either three times per week for 12-weeks (36 treatments) or four times per week for 9-weeks (36 treatments), however, the controlled trial data support treatment blocks of 30–40 treatment sessions [7–10, 15, 42–55]. An initial patient who has acute or chronic pains and who has not been treated recently or at all for their current spine issue should be treated for an initial 6–12 sessions to provide pain relief. After signs of relief have occurred, a progress exam should be performed and the patient should be transitioned or 'graduated' to CBP corrective care.

CBP treatment occurs in 'blocks of care.' Numerous CBP controlled clinical trials (RCTs [43–55] and nRCTs [7–10, 15, 42]) provide evidence for spine altering changes to occur in the range of 30–40 treatment sessions; thus, it is the practitioners' choice to set their protocol within this range (i.e. treatment blocks). The end of each 'block' of CBP care requires a progress exam which includes all of the typical assessment procedures as well as a posture and X-ray assessment. Exam results may either dictate the need for further CBP treatment or the recommendation for 'supportive' or maintenance care. An initial block of CBP structural rehabilitation will include any acute care provided in the first 2–4 weeks. It is always recommended that ongoing 'progress exams' be performed regularly, at either 4-week or 12 treatment intervals, or as frequently as recommended by each practitioner's regional regulatory board requirements.

CBP does not specifically support 'long-term' care plans. However, based on the data, an adult typically needs 6-months of corrective care (e.g. 72 treatments over 6-months at 3x/week) which is an evidence-based recommendation. Although, any given patient may require a shorted (i.e. 3-month) or longer treatment program based on their initial presenting postural parameters—approximate treatment extrapolations can be made by studying **Tables 1**–**3**. There is also support for supportive/maintenance care at a frequency of approximately 2×/month [8–10].

8. Clinical evidence of efficacy

As mentioned, CBP technique has an abundance of clinical evidence supporting its effectiveness in correcting spine deformity and posture [7–10, 15, 42–55]. Recently, systematic reviews have summarized the clinical evidence as reported in the published controlled trials on these methods [56, 57]. We summarize the evidence here in four parts: cervical lordosis, lumbar lordosis, lateral translation (pseudo-scoliosis) postures of the head and thorax, and finally, evolving evidence from case reports/series on other important spine deformities including lumbar spondylolisthesis, cervical spondylolisthesis, thoracic hyperkyphosis, thoraco-lumbar junctional kyphosis, thoracic hypokyphosis (straight back syndrome), anterior sagittal balance, lumbar kyphosis (flat back syndrome), lumbar hyperlordosis, post-surgical cervical spine fusion and scoliosis.

8.1 Cervical lordosis

A recent systematic review found that of the RCTs and nRCTs on CBP extension traction methods, a 12–18° improvement in cervical lordosis can be achieved in

10–15 weeks after 30–36 treatment sessions [57]. Most RCTs have used the cervical Denneroll [43–47, 49, 50], and the three nRCTs all used different CET methods (**Table 1**) [7–9].

Table 1 shows the improvement in degrees per treatment as well as theoretical numbers of treatments for various presenting cervical spine subluxations. On average, there appears to be just less than a half degree improvement per treatment session; obviously, there are patients that will have both more correction and less correction than this. Using this estimation as an initial guideline, evidence-based treatment numbers can be predicted. For example, a patient presenting with a cervical kyphosis of 20° would require over 100 treatments to restore the neck to a curve of 35°.

Figures 13 and **14** show the long-term outcomes in patients receiving cervical extension traction versus comparative groups not receiving the traction. The patients restoring lordosis via CBP traction methods show improved cervical alignment which is maintained at a years' follow-up (**Figure 13**) whereas, comparative groups receiving various physiotherapeutic treatments less the extension traction do not experience cervical improvement (**Figure 13**) and also show that any initial pain relief regresses back towards baseline levels after the cessation of treatment (**Figure 14**). Patient's with improved lordosis retain their initial pain relief a year later (**Figure 14**). This is alarming as it shows patients receiving various physiotherapeutic treatments who do not improve their cervical lordosis (in hypolordotic patients) will have a future regression of symptoms post-treatment and may be misled by 'apparent treatment efficacy' [5, 57].

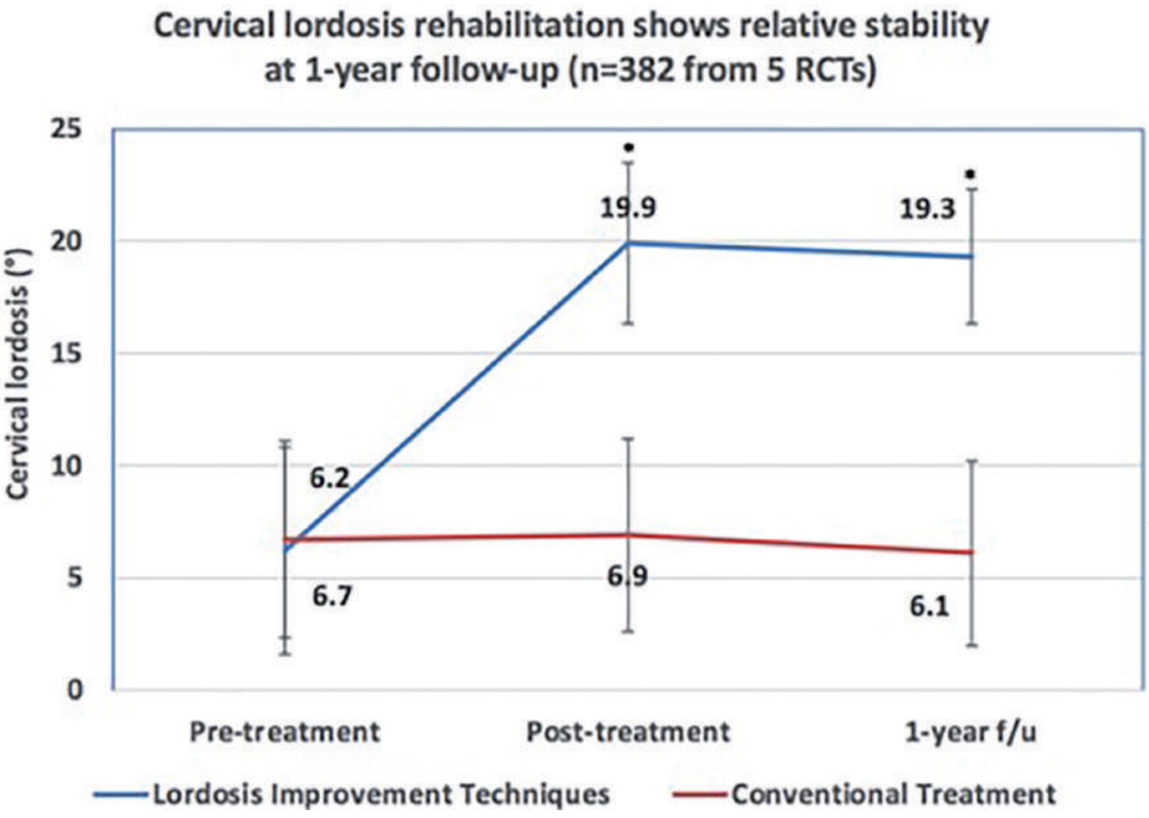

Figure 13.
*Data from five RCTs demonstrates patients achieving cervical lordosis improvement (via extension traction) as well as conventional treatments have lordosis improvements that are sustained for 1 year after stopping treatment versus the cervical curve of comparative groups (controls not achieving lordosis improvement) remain unaffected by conventional treatments (weighted averages from five RCTs [44, 45, 47, 49, 50]). * indicates a significant group difference as specified in each of the five trials; brackets represent weighted standard deviation.*

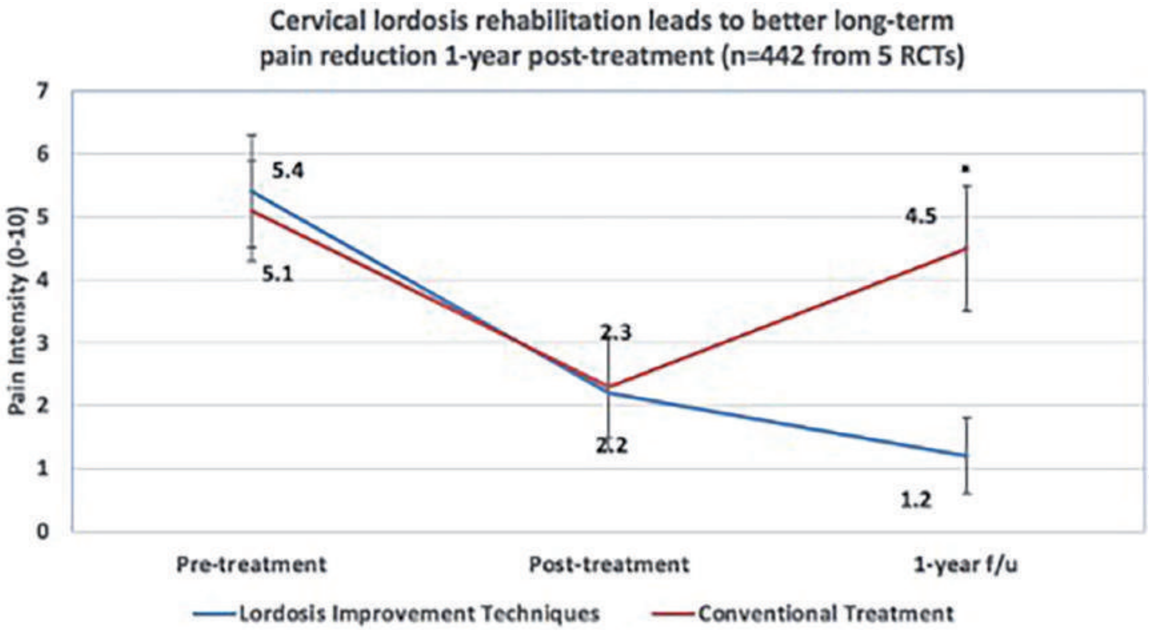

Figure 14.
*Data from five RCTs demonstrates patients achieving cervical lordosis improvement (via extension traction) as well as conventional treatments have pain reductions that are sustained for 1 year after stopping treatment versus comparative groups (controls not achieving lordosis improvement) who show a regression (increase) of pain intensity towards baseline after stopping treatment (weighted averages from five RCTs [45–47, 49, 50]). * indicates a significant group difference as specified in each of the five trials; brackets represent weighted standard deviation.*

8.2 Lumbar lordosis

A recent systematic review found "Limited but good quality evidence substantiates that the use of extension traction methods in rehabilitation programs definitively increases lumbar hypolordosis" [56]. The authors further stated: "Preliminarily, these studies indicate these methods provide longer-term relief to patients with low back disorders versus conventional rehabilitation approaches tested" [56]. On average, a 7–11° increase in lordosis can be achieved over 10–12 weeks after 30–36 treatment sessions (**Table 2**).

It must be mentioned that lumbar extension traction is necessary to increase the lumbar lordosis. Importantly, using the data from published trials [10, 53–55], one can extrapolate approximate treatment duration (**Table 2**). As seen, a mild hypolordotic lumbar spine of 30° (L1-L5 ARA) may only require 32–48 treatments, whereas, a flat lumbar curve would require 127–194 treatments to achieve a normal 40° lordosis.

The same trend as observed in patients receiving cervical lordosis correction versus comparative groups not receiving lordosis improvement is seen in the trials on the lumbar spine [5, 56]. Lordosis increase in patients receiving lumbar extension traction is achieved and maintained at 6-months follow-up (**Figure 15**); these patients also retain their initial pain relief whereas, comparative patient groups not receiving lordosis improvement (**Figure 15**) lose their initial pain relief by 6-months after cessation of treatment (**Figure 16**). Again, this is alarming and shows how active low back treatment, although offering transient pain relief, will likely regress after treatment if not receiving concurrent lordosis correction in those suffering from hypolordotic-related LBP [5, 56].

8.3 AP head and thorax postures

Coronal plane lateral translations of the head and thorax also referred to as 'pseudo-scoliosis' each has an nRCT published [15, 42] and many case reports

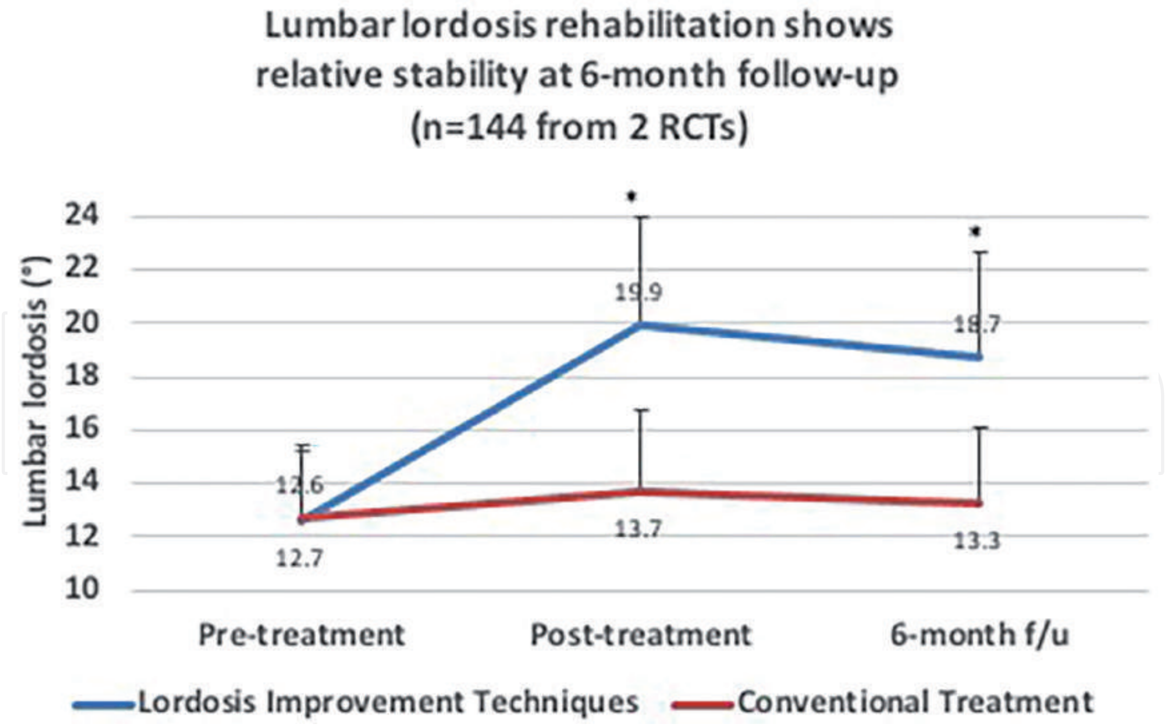

Figure 15.
*Data from two RCTs demonstrates patients achieving lumbar lordosis improvement (via extension traction) as well as conventional treatments have lordosis improvements that are sustained for 6-months after stopping treatment versus the lumbar curve of comparative groups (controls not achieving lordosis improvement) remain unaffected by conventional treatments (weighted averages from two RCTs [53, 54]). * indicates a significant group difference as specified in each of the two trials; brackets represent weighted standard deviation.*

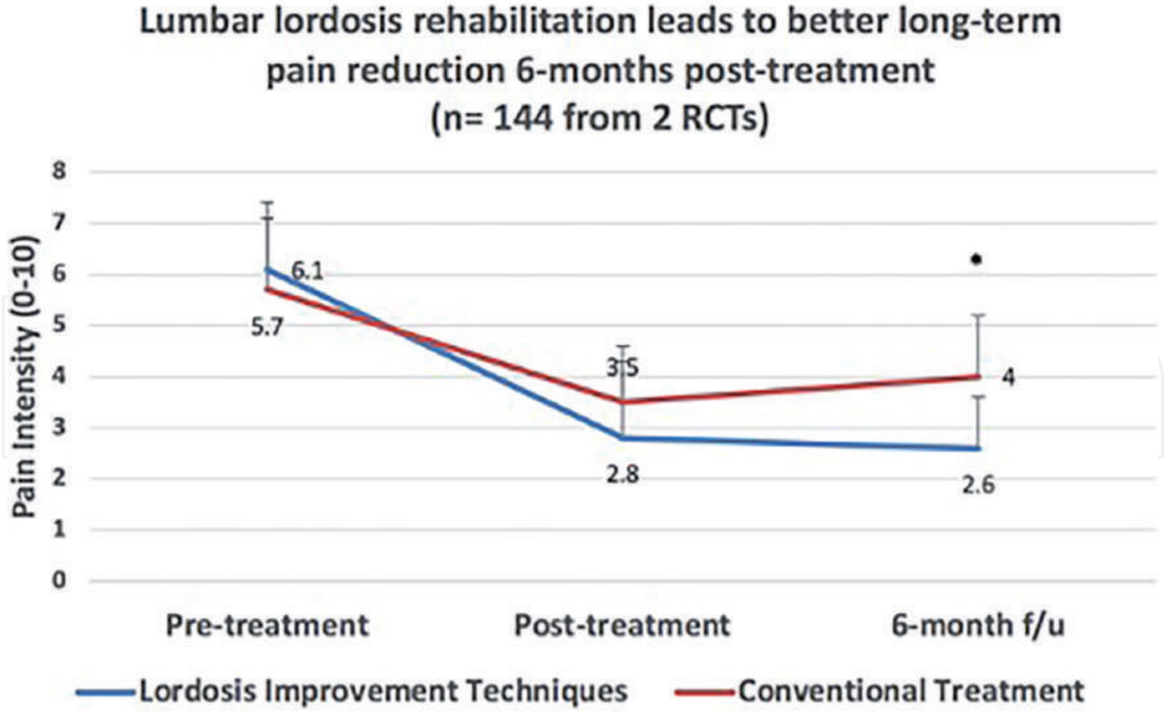

Figure 16.
*Data from two RCTs demonstrates patients achieving lumbar lordosis improvement (via extension traction) as well as conventional treatments have pain reductions that are sustained for 6-months after stopping treatment versus comparative groups (controls not achieving lordosis improvement) who show a regression (increase) of pain intensity towards baseline after stopping treatment (weighted averages from two RCTs [53, 54]). * indicates a significant group difference as specified in each of the two trials; brackets represent weighted standard deviation.*

demonstrating its reduction [16, 58–63]. As discussed earlier, the differentiation from true scoliosis is that the involved vertebrae have minimal to no rotation, whereas, true scoliosis has substantial vertebral rotation (**Figure 6**). Also, the spinal coupling pattern of a laterally translated body mass (head or thorax) will demonstrate the lower involved spinal region to laterally flex towards the side of the translation and the upper involved spinal region to laterally flex back towards the vertical [35, 36].

Based on the data, a laterally translated body mass can be reduced about 7–8 mm after about 35 treatments. On average, correction of a laterally translated head or thorax can be corrected at about 0.2 mm per treatment, or about 1 mm per five treatments. Extrapolations of treatment numbers to patient subluxation presentation are shown in **Table 3**. From the data in each of the nRCTs, an approximate 50% reduction of the initial laterally translated head and thorax postures occurred; therefore, an average patient having an approximate 15 mm translation posture (head or rib cage) requires 6-months of corrective care (approximately 72 treatments). It must also be mentioned that many case reports have demonstrated larger lateral translation postural corrections/reductions with CBP methods in similar time frames [16, 58–63], thus, these serve as approximate treatment extrapolations.

8.4 Other spine deformities

It is known that the science for manual therapies is lacking [64]. Therefore, lesser forms of evidence must be considered when evaluating various treatment approaches used to treat various spinal conditions by manual therapists [65, 66]; this includes treatment utilizing CBP methods. We now highlight more recent case studies and series showing structural spinal correction for a variety of relatively common disorders.

8.4.1 Lumbar spondylolisthesis

Fedorchuk et al. [67] reported on an 11 mm reduction (13.3–2.4 mm) of an L4 anterolisthesis in a 69-year old suffering from LBP and leg cramping. Pain relief was achieved after 60 treatments over 45 weeks. This was the first documented report of a reduction of a Grade 2 lumbar spondylolisthesis by CBP methods, as well as any other non-surgical method.

Oakley and Harrison reported on the reduction of multiple retrolistheses from L1-L4 ranging from 4.5 to 5.9 mm in a 32-year old male with LBP [68]. These were all reduced to within normal (<4.5 mm) after approximately 36 treatments over 14-weeks. A 13-month follow-up indicated the patient remained well and reported no back pain and the corrections had remained stable.

Fedorchuk et al. [69] reported on the reduction of L1 (−6.6 to −1.7 mm) and L2 (−6.1 to −2.0 mm) retrolistheses and an L5 anterolisthesis (+6.8 to −2.5 mm) in a 63-year old female bodybuilder with severe LBP and osteoarthritis. Thirty treatments were given over 10-weeks which resulted in normalizing all spondylolistheses as well as a dramatic reduction in pain and an ability to leg press 60 more pounds in the gym.

Fedorchuk et al. reported the complete reduction of an L3 retrolisthesis and L4 anterolisthesis after 50 treatments over a 7-month period [70]. The patient was 57-years old with severe LBP and sciatica. The L3 retrolisthesis reduced from −5.3 to −1.7 and the L4 anterolisthesis reduced from +5.4 to +1.0 mm. After treatment the patient was able to return to playing hockey and experienced full resolution of the back pain which had forced him to retire from sport. A 1-year follow-up showed the patient had remained well and maintained the corrections.

8.4.2 Cervical spondylolisthesis

Recently, Fedorchuk et al. present a case series of eight female patients with concomitant cervical hypolordosis, forward head translation and spondylolistheses [71]. All were in motor vehicle collisions, each having at least one, and at most four simultaneous cervical vertebral spondylolistheses ranging in magnitude from >2 mm up to 4.5 mm. All cases experienced a reduction in translational offset of the spondylolistheses, and increase in cervical lordosis and a decrease in forward head translation as well as an increase in spinal canal diameter at the location of the spondylolisthesis after 30 treatment sessions that included cervical extension traction over a duration of 12-weeks. On average, the spondylolistheses reduced by 2.6 mm and there was an average drop in neck disability by 30%.

In another case, Fedorchuk et al. presented a single case of a 52-year old with chronic neck pain [72]. The patient had a C4 anterolisthesis of 2.4 mm which was reduced to 0.7 mm as well as an increase in cervical lordosis and reduction in forward head translation after 30 treatments over 12-weeks. The patient reported a resolution of their neck pain and stiffness.

8.4.3 Thoracic hyperkyphosis

Thoracic hyperkyphosis is a relatively common subluxation pattern in the aging. Although there is one RCT on CBP methods showing reduction of the deformity, it is yet to be formally published [52]. A systematic review of CBP methods used to reduce thoracic hyperkyphosis was published [73] and summarized the outcomes of several case reports and series [74–79]. In **Table 2** of the Oakley and Harrison review an average 12° reduction in thoracic kyphosis occurred after 32 treatments over 14.5 weeks from a total of 17 patients [52]. The improved posture correlated with reduced pain, disability and improved QOL [52]. **Figures 17** and **18** show various CBP mirror image spinal exercises and traction, respectively.

8.4.4 Thoracolumbar junctional kyphosis

Thoracolumbar kyphosis is the forward angled spine at the junction of the thoracic and lumbar spine and is associated with chronic LBP (CLBP). Gubbels et al.

Figure 17.
CBP recommended mirror image exercises for patients with thoracic hyper-kyphosis.

Figure 18.
CBP mirror image traction for patients with thoracic hyper-kyphosis.

presented a case of the minimization of pain in a 16-year old female after a 22° reduction of thoracolumbar kyphosis, a 48 mm reduction of posterior sagittal balance, an 11° increase in lumbar lordosis and a 10° increase in sacral inclination [80]. Twenty-four in office treatments were given over an 8-week period with daily home traction resulting in a minimization of back pains.

8.4.5 Thoracic hypokyphosis (straight back syndrome)

Thoracic spine hypolordosis is termed straight back syndrome (SBS) and is associated with back pains and exertional dyspnea. Fortner et al. [81] reported on an 18-year old male suffering from back pains and exertional dyspnea. Twenty-four treatments over a 9-week period resulted in a 15° increase in thoracic kyphosis, a decrease in pain and improved exertional dyspnea symptoms. A 4-month follow-up showed the patient remained well.

Betz et al. [82] reported the improvement in a 19-year old male who suffered from exertional dyspnea and back pain. Over 12-weeks a 14° increase in thoracic curve was achieved resulting in relief of exertional dyspnea and pain, as well as increases in both the antero-posterior thoracic diameter and the ratio of antero-posterior to transthoracic diameter, both measures critical to the wellbeing of patients with SBS. A 2.75-year follow-up showed the patient remained well.

Fedorchuk et al. [83] reported on a 13° increased thoracic curve in a 26-year old male with back pains and type 1 diabetes. Treatment over 7-weeks included 36 sessions. Back pains reduced and importantly, there was also improvement in blood glucose immediately following the onset of each visit. An improvement in blood glucose averages, percentage of time of blood glucose in a healthy target range, and glycosylated hemoglobin occurred and the patient was able to reduce their basal insulin need by approximately half after the 7-weeks of care.

Mitchel et al. [84] reported a 10° increase in thoracic curve over 16-weeks in a 33-year old male suffering from exertional dyspnea and back pains. The measured lung capacity improved by 2L, the back pain diminished and the exertional dyspnea resolved. A 7-month follow-up indicated the patient remained well.

8.4.6 Anterior sagittal balance

Anterior sagittal balance (ASB) is the forward displacement of the upper body over the pelvis. Haas et al. reported on the dramatic 110 mm reduction in ASB in an 87-year old female with CLBP and sciatica [85]. Treatment consisted of 24 in office sessions over an 8-week period. The patient achieved a dramatic reduction of symptoms, improvements in flexibility and orthopedic testing.

Anderson et al. [86] reported on a 91 mm reduction in ASB in a 59-year old male patient suffering from a variety of symptoms associated with Parkinson's disease. Initial treatment involved 38 treatments over 5 months. The patient experienced significant improvements in multiple postural parameters, gait, balance, hand tremors, low back and knee pains and SF-36 values. A 21-month follow-up showed the patient remained essentially well and most of the initial postural improvements were maintained.

8.4.7 Lumbar kyphosis (flat back syndrome)

Flat back syndrome (FBS) is the anterior translation of the upper body and gross loss (or kyphosis) of the lumbar spine and is associated with high pain and disability. In a case series, Harrison and Oakley describe the significant restoration of lumbar lordosis in two patients suffering from debilitating CLBP from flat back syndrome [87]. One patient had a 50° lordosis improvement in 100 treatments over 20 weeks, the other had a 26° lordosis improvement in 70 treatments over 16.5 weeks. In the discussion section of the report, it was calculated that the treatment costs of the patients receiving CBP treatment versus the projected costs for the surgical procedures recommended to the two patients equated to only 1–8%; the authors stated "at first 70 or 100 treatments may be criticized as 'over-treatment,' however, considering the overall cost-effectiveness and positive patient outcomes, it certainly is not" [87].

8.4.8 Lumbar hyperlordosis

Although lumbar hypolordosis is the most common lumbar misalignment in those presenting with chronic LBP [10], lumbar hyperlordosis is also seen clinically. CBP methods can be directed at decreasing lumbar lordosis and its typically associated anteriorly rotated pelvis. In a recent case, Oakley et al. [88] presented a case demonstrating the relief of CLBP and hip pains after an 8° reduction in lumbar hyperlordosis, a 5° reduction in pelvic tilt and an accompanying 17 mm reduction of forward sagittal balance. This occurred over a period of 13 months and 73 total treatments.

8.4.9 Post-surgical cervical spine fusion

Post-surgical cervical spine intervertebral fusion is not a common finding in clinical practice however, it is occasionally encountered. Many of these patients continue to suffer years after the intervention. Harrison et al. [89] presented a case showing improvement in sagittal postural parameters which corresponded with improved clinical outcome in a 52-year old male. Over a 6-month period, a 6° increase in cervical lordosis was achieved as well as a 13 mm reduction in anterior head translation (AHT). These improvements were maintained at a 2.5-year follow-up.

Fedorchuk et al. [90] also presented a successful outcome in a 43-year old with a C5-6 intersegmental fusion. After 36 treatments over 3-months, there was a 13° increase in cervical lordosis, a 9 mm decrease in AHT and a 5 mm reduction in lateral head translation.

8.4.10 Scoliosis

Although too large of a topic to address in this chapter, CBP technique has a unique approach in the treatment of scoliosis [3]. CBP methods incorporates the 'non-commutative property of finite rotation angles under addition' to ascertain the order of postural movements to be prescribed in the mirror image treatment of this disorder. Harrison and Oakley described reductions in curve magnitude in five lumbar or thoracolumbar scoliosis patients ranging from 5° to 24° after 18–84 treatments [40]. All patients were female and ranged in age from 19 to 45 years.

Haggard et al. reported a 19° reduction in a thoracolumbar curve in a 15-year old female patient after 24 office treatments over 15-weeks. The patient also performed 45 at home spine blocking sessions as prescribed by the attending chiropractor [41]. The patients LBP and headaches were dramatically improved, and the curve was reduced to 8°.

9. Use of X-ray

Use of X-ray for spine analysis is essential for treating spine deformities, including with CBP technique methods. Historically, there has been concerns of carcinogenicity associated with X-ray use. Recently, however, new evidence has come to light showing that anti-X-ray sentiment stemming from the supposed carcinogenicity is based on flawed science [91–93]. The bottom line is the linear no-threshold (LNT) model used to support radiation risk analysis is not scientific as it is not consistent with current radiobiological data [94–98].

X-rays and CT scans deliver low-dose radiation doses (<200 mGy), and because of this they cannot cause cancer. This is because low-dose (versus high-dose) radiation exposures stimulate the adaptive repair systems of the body to repair any damage done [99–101]. Although this topic is important, it is a much larger issue than the scope of this chapter but many recent reviews have found that X-rays (and CT scans) are not harmful [103]. In fact, after a substantial and critical review of higher quality studies on radiation exposure, Schultz et al. concluded: "The evidence suggests that exposure to multiple CT scans and other sources of low-dose radiation with a cumulative dose up to 100 mSv (approximately 10 scans), and possibly as high as 200 mSv (approximately 20 scans), does not increase cancer risk." Thus, there should be no hesitation or misunderstanding surrounding X-ray risks. Doctors and patients need to become updated on X-ray safety and not succumb to the traditional carcinogenicity misinformation.

10. Conclusion

CBP technique is a well-studied approach to the structural improvement of spinal disorders. Many spinal disorders with associated pain and functional syndromes have either well characterized or evolving evidence for their treatment by the mirror image approach that underpins CBP methods. The correlation of the spine alignment and postural rotations and translations of posture are of critical importance and unique in the CBP approach.

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Conflict of interest

D.E.H. teaches spine rehabilitation methods and sells products related to the treatment of spine deformities; P.A.O. is a paid consultant to CBP.

Nomenclature

AHT	anterior head translation
ASB	anterior sagittal balance
AP	anterior-to-posterior
ARA	absolute rotation angle
CBP	Chiropractic BioPhysics®
CLBP	chronic low back pain
HPT	Harrison posterior tangent
IVD	intervertebral disc
LBP	low back pain
LNT	linear no-threshold
nRCT	non-randomized controlled trial
QOL	quality of life
PA	posterior-to-anterior
PNF	proprioceptive neuromuscular facilitation
RCT	randomized controlled trial
RRA	relative rotation angle
SEM	standard error of measurement
SBS	straight back syndrome

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