We are IntechOpen,
the world's leading publisher of Open Access books
Built by scientists, for scientists

3,900
Open access books available

116,000
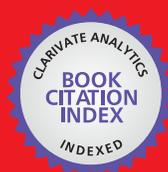International authors and editors

120M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Chapter

Physical Rehabilitation in the Management of Symptomatic Adult Scoliosis

Shu-Yan Ng, Tsz-Ki Ho and Yin-Ling Ng

Abstract

Scoliosis is prevalent in elderlies over the age of 60. Of the different curve types, the thoracolumbar curve is the most common curve type operated upon, as it is associated with marked trunk shift and disability. Current physiotherapy treatments consist of electrotherapy, aquatic exercises, core-strengthening exercises, and dry needling. Outcome of these treatments has not been satisfactory. Long-term successful rate of conservative treatment of symptomatic adult scoliosis is low, as the treatment addresses symptoms but not the biomechanics involved in adult scoliosis. Recent studies have shown that physiotherapeutic scoliosis-specific exercises (PSSE) and bracing stabilized the curves in 80% of the subjects. Thus PSSE and bracing should be added to the standard physiotherapy care in the management of symptomatic adult scoliosis. For asymptomatic patients with thoracolumbar curve that has an increased risk of progression, PSSE should be considered as preventative exercises. Patients who do not respond to conservative treatments and have significant spinal stenosis should be referred for surgery.

Keywords: degenerative lumbar scoliosis, adult scoliosis, scoliosis-specific exercises, physical rehabilitation

1. Introduction

Adult scoliosis refers to spinal curvature in excess of 10° after skeletal maturity. Common causes include adult idiopathic scoliosis (ADIS) and degenerative lumbar scoliosis (DLS). ADIS has its onset in childhood or adolescent. Degenerative lumbar scoliosis (DLS) is an adult-onset scoliosis brought about by degeneration of facet joints.

The prevalence of adult scoliosis varies with age and studies, ranging from 8.3 to 68% [1–5]. Xu et al. evaluated 2395 subjects over the age of 40 and reported that 13.3% had degenerative lumbar scoliosis (DLS) [5]. The prevalence increases with age. For subjects over 80 years of age, the prevalence is 27.1% [5]. Kobayashi et al. evaluated 60 elder normal subjects over 12 years and reported the prevalence of adult scoliosis to be 36.3% [1]. Schwab et al. reported the highest prevalence of 68% in 75 patients over the age of 60 [4].

The curve prevalence is inversely proportional to the curve magnitude. Majority of the curve is less than 10°. The prevalence of 10°, 10–20°, and >20° curves was reported to be 64, 44, and 24%, respectively [6].

Of the different curve patterns, the thoracolumbar scoliosis is associated with a higher prevalence of low back pain and functional impairment [7]. Also, these curves tend to progress. The rate of progression for lumbar or thoracolumbar single curve was 0.82/year (0.34–1.65°) for adult idiopathic scoliosis patients [8]. The rate of progression is higher for curve in excess of 30° [9–11]. This was supported by a recent study on the radiographic parameter risk factors of rapid progression in adolescents with Lenke V and VI idiopathic scoliosis [12]. The study showed that apical vertebral rotation ≥ III (according to the Nash-Moe classification), deviation of the apical vertebra ≥40 mm from the central sacral line in the lumbar curve, and a L5 tilt angle ≥10° (**Figure 1**) are associated with an increased risk of curve progression in adolescents [12].

Likewise, DLS tends to progress but irrespective of the Cobb angle (**Figure 2**) [8]. For patients with DLS, the rate of progression was 1.64°/year (0.77–3.82°) [8]. A study which followed up 200 subjects over 50 years of age for 5 years showed that 73% of the
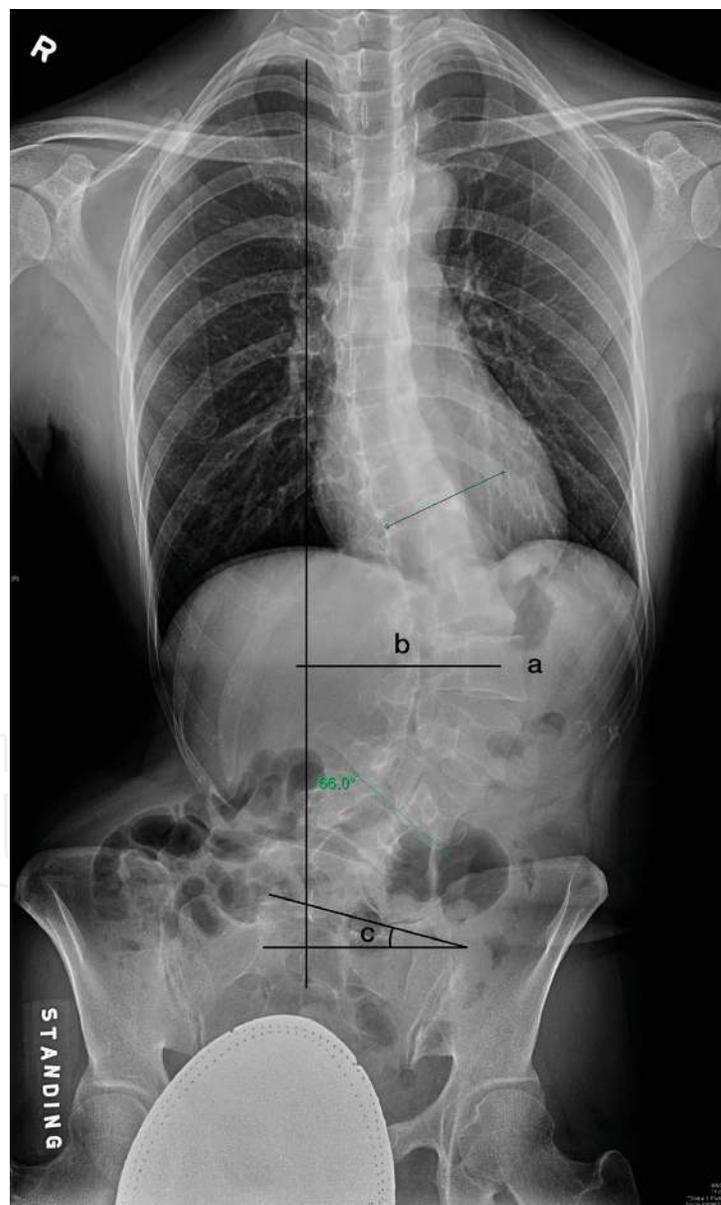

Figure 1.
The radiographic parameters that have been found to increase the risk of progression in adolescents with Lenke 5 and 6 scoliosis. It is likely that the parameters also increase the risk of curvature progression in adults. (a) Refers to the magnitude of apical vertebral rotation. (b) Refers to the distance between the central sacral line and the center of the apex of the lumbar curve. (c) Refers to the tilt angle of L5. When (a) is ≥III (based on the Nash-Moe method of measuring vertebral rotation), (b) is ≥4 cm, and (c) is ≥10°, the risk of progression of the curve increases.
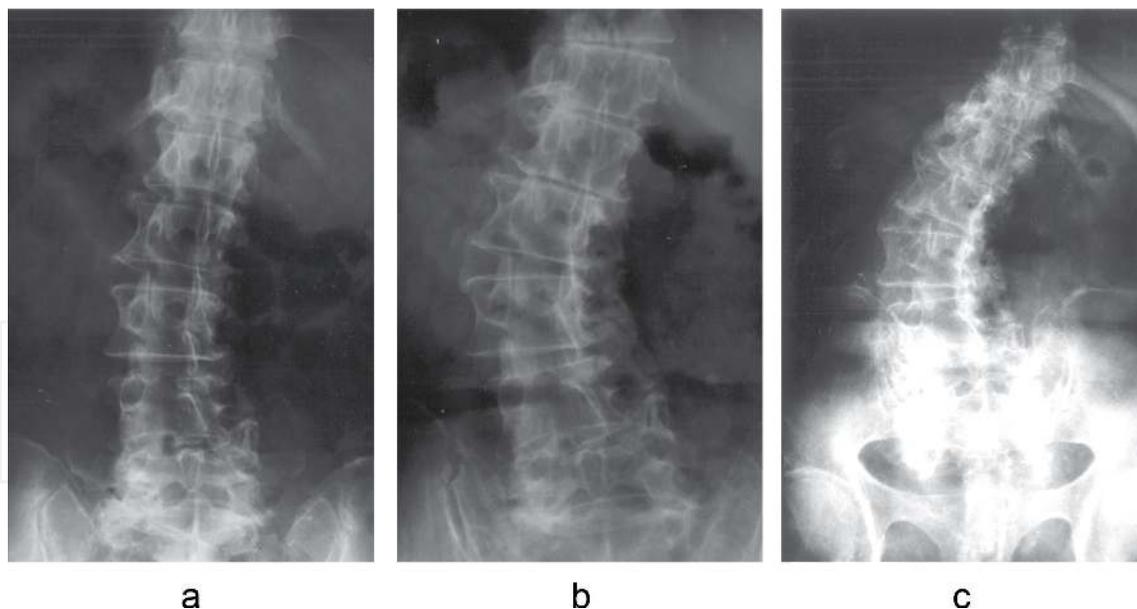
Figure 2.
The progression of degenerative lumbar scoliosis can be dramatic. The scoliosis in the frontal lumbar film of this woman 66 years of age was mild, with Cobb angle of 18° and the apex at L3 (a). The scoliosis progressed markedly 7 years later, with Cobb angle measuring 30°. Laterolisthesis of L1 to the right and L3 to the left could be seen (b). Arthrotic changes were apparent in the right in an attempt to stabilize the curvature, which, nevertheless, progressed to 44° 2 years later with marked rotation of L2–L4 vertebrae (c).

curves progressed 3° per year [13] and that apical vertebral rotation ≥ III (according to the Nash-Moe classification), a Cobb angle >30°, lateral vertebral translation >6 mm, and L5 above the intercristal line predict curve progression [13, 14]. Osteoporosis, a coronal Cobb angle <30°, lumbar lordosis, and degenerative spondylolisthesis are not risk factors for curve progression [14].

With increase in life expectancy of the population [2, 15], it follows that the prevalence of adult scoliosis increases [2, 15] and with it the morbidity.

2. Etiopathogenesis

There are many different causes of adult scoliosis. Majority of the adult scoliosis are adult idiopathic scoliosis (ADIS) and degenerative lumbar scoliosis (DLS). Other causes include neuromuscular conditions such as cerebral palsy, syringomyelia, and spinal dysraphism and congenital anomalies such as block vertebrae. Adult scoliosis may also arise from trauma, neoplastic disease, as well as iatrogenic causes such as simple decompression (laminectomy) or lumbar fusion procedures [16]. The following discussion will be limited to the commonly seen ADIS and DLS.

Idiopathic scoliosis, as its name implies, does not have any identifiable cause. When juveniles and adolescents who have idiopathic scoliosis reach adulthood or skeletal maturity, the scoliosis is then referred to as adult idiopathic scoliosis (ADIS).

The etiology of DLS is multifactorial and is related to progressive degeneration of the lumbar spine, compression fracture, and reduced bone density and quality [16]. The asymmetrical disc degeneration, facet degeneration, and ligamentous laxity all contribute to laxity in the spinal column [7, 17], with resultant asymmetrical deformities of the lumbar spine in the axial, coronal, and sagittal planes [18, 19]. The sagittal imbalance is accentuated in the presence of osteopenia or osteoporosis [16].

The mechanisms by which the scoliotic curves cause low back pain have not been clearly established. Pain can result from muscle overload, joint irritation, as well as nerve tension or compression. Initial complaints on the apex of the curvature are

possibly a result of muscle overload, when the paravertebral muscles have to contract to maintain the spinal balance. With curve progression, joints become involved and the compressive, shear, and torsional forces concentrating in the concavity of the curve increase. Junctional segments are subjected to increased shear, favoring degenerative changes at these levels. When the shear force exerted on the junctional segments exceeds that of the restraining force, laterolisthesis may occur [20]. It is noteworthy that laterolisthesis is present even in mild lumbar scoliosis. In a study of 91 adults with lumbar idiopathic scoliosis, 9.75% of the patients were found to have laterolisthesis, despite the average lumbar Cobb angle being 16.5° [20]. The presence of lumbar laterolisthesis is associated with a higher frequency of back pain than do other curve patterns [10, 21]. When, however, osteophytes and traction spurs develop in those segments, the unstable segments may become stabilized with reduction in pain.

Depending on the level of involvement and anatomical configurations, nerve root entrapment may occur with radicular distress in the lower extremity. The nerve entrapment is usually present in the concavity of the curve, though it may also occur in the side of convexity. It is generally secondary to foraminal compression
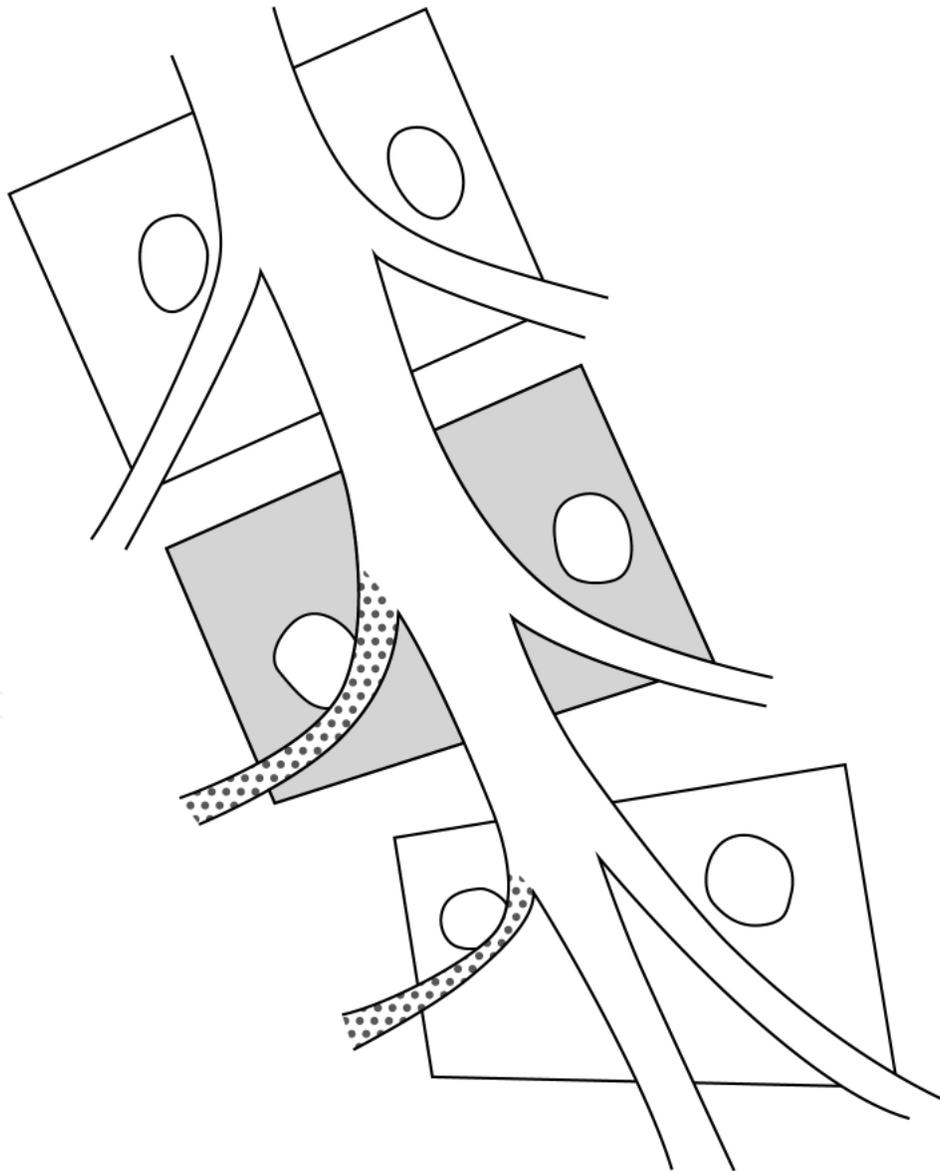

Figure 3.
The possible mechanism of nerve root entrapment in the concavity of the scoliotic curve. The laterolisthesis of the shaded vertebra to the left causes a downward migration of the left pedicle and exerts a pull on the nerve root. Owing to the lateral movement of the nerve root, the nerve root below is being stretched by the left pedicle. Thus a scoliosis can cause entrapment of nerve roots at two levels.

and pedicular kinking. With laterolisthesis, the pedicle migrates toward the side of concavity. The higher nerve root is thus stretched by the migrating pedicle (**Figure 3**); the lower nerve root similarly is stretched over the pedicle as it shifts laterally with the vertebral body above [22].

3. Clinical features

Many studies have shown that both ADIS and DLS may present with low back pain and radiculopathy. Yet, their characteristics differ [23]. ADIS patients usually have mechanical low back pain at an earlier age, at or around the age of 30. The pain is mechanical and seldom involves the leg [23].

In contrast, DLS patients have different pain patterns (**Table 1**). They are usually in the 50–60 years of age [24]. Those under 50 years of age with lumbar scoliosis are rarely subjected to significant pain and disability. Onset of the low back pain may be sudden but is usually progressive. Most commonly, the patient complains of low back pain at the end of a strenuous day or after some unusual activities. Rest reduces the pain. Pain is usually present at the apex of the curve, the lumbosacral junction, and the concavity of the scoliotic spine [25–27]. Very rarely is the pain brought about by impingement of the lower ribs upon the iliac crest [25].

	Degenerative lumbar scoliosis (DLS)	Adult idiopathic scoliosis (ADIS)
Age range at presentation (years)	55–57	25–56
Male/female incidence	41:59	4:96
Symptoms	Stenotic	Mechanical

Table 1.
The main difference in clinical presentation in patients with DLS and ADIS [24].

With progression of the condition, the patient may complain of radiating pain deep into the buttock and distally down the lower extremity, involving more than one dermatome with poorly defined boundaries [24]. Definite root entrapment is uncommon, and the incidence reported is 2.2% [26]. The severity of the complaint was found to be statistically significantly correlated with age. The older the patient, the more severe are the symptoms. A study of subjects over 50 years of age with DLS showed that 45 out of 200 patients (22.5%) had severe pain and neurological deficits [13].

3.1 Relationship between lumbar curve and low back pain

The relationship between the degree of lumbar curve and low back pain, however, has been controversial. Some authors [26, 27] reported that the greater the degree of scoliosis, the more is the pain. This is especially so for a curve that exceeds 45° [26]. In an analysis of pain pattern, Jackson and Simmons [27] found that the severity of low back pain varies with the level of scoliosis, the type of curve, and the degree of the curve. Lumbosacral, lumbar, and thoracolumbar curves were found to be more painful than thoracic curves. Comparing all curves, compensatory half curves are less painful, with one exception, viz., the left compensatory lumbosacral half curve. In the presence of a major and a compensatory curve, the pain usually

localizes in the lower junctional segments and in the compensatory curve below the major deformity. In the presence of double major curves, however, the pain primarily affects the junctional areas below and between the major curves, with the lower one being more symptomatic [27].

Recent studies have shown that a coronal imbalance of more than 4–5 cm is associated with deterioration of pain and function scores in unoperated patients [28, 29]. Trunk shift is a predictor of surgery for patients with thoracolumbar and lumbar curvatures [29].

Yet, other authors did not concur with this view [9, 30]. They found no correlation between the degree of scoliosis and back symptoms. Lafage et al. reported no correlation between clinical outcomes and coronal global balance [30]; the magnitude of the coronal deformity did not impact pain and disability [30].

Recently, it has been shown that sagittal spinal balance is more important than coronal curves in relation to clinical outcomes [31–35]. The severity of the symptoms in adult scoliosis patients is linearly related to the magnitude of the sagittal spinal imbalance [36]. A spinal vertical axis (SVA) in excess of 70 mm is associated with an increase in clinical symptoms [30, 36].

4. Physical signs and physical examination

The patient usually walks with a typical antalgic list, with forward flexion of the spine and flexion of both knees. This is more evident as weakness with ambulation increases. Also, the patient is noted to sit obliquely, maintaining weight on one buttock and twisting away from the panful side [24]. Loss of height can occur. It was reported that a loss of height from 4 to 24 cm in 1–22 years may occur [37].

Examination in standing position permits assessment of the deformities as well as the sagittal and coronal imbalance. Adult scoliosis patients are often seen with trunk shift in the coronal plane together with positive sagittal imbalance. Reduction in lumbar lordosis is generally evident as the pelvis is retroverted to compensate for the positive sagittal malalignment. In severe deformity when the pelvic retroversion is insufficient to compensate for the sagittal imbalance, hip and knee flexion may be required to restore the sagittal balance. In the long term, contractures of hip flexors may result, when they can be assessed by Thomas leg raise test [38].

Inspection from the back may reveal the lumbar scoliosis. Generally, the pelvis shifts contralateral to the side of lumbar convexity. In the presence of left lumbar curvature, the pelvis shifts to the right and superiorly. The right pelvis is higher than the left. Conversely a right lumbar curvature is associated with shifting of the pelvis to the left [39]. This was confirmed by a study, which showed that 79% of patients with a single lumbar curve had the apex of the scoliosis opposite the side of high iliac crest [40]. The apparent leg length discrepancy that this created was reported in 87% of patients with degenerative lumbar scoliosis [40].

Assessment of the deformity may also be made in the sitting position to eliminate the confounding apparent leg length discrepancy or hip flexor contracture [38].

To determine the coronal balance, the distance from the gluteal cleft to a plumb line dropped from C7 is measured. When the head and trunk are not centered over the gluteal cleft and the measurement (coronal balance) is in excess of 4 cm, the scoliosis may be poorly compensated and more likely to progress [28].

Palpation may or may not elicit tenderness in the low back [9]. When tenderness is present, it is generally found in the concavity of the curve and at the junction between the two curves [27].

Neurological examination generally shows that there is reduced sensation in poorly defined areas. The reflexes of the lower extremities, however, are generally within normal limits. With increase in pain and disability, however, paresthesia over the posterolateral thigh and leg in areas of L5 and S1 dermatomal distribution becomes more evident, and reflexes in the lower extremities may reduce and become absent [41]. Straight leg raising is rarely restricted.

5. Clinical imaging

5.1 Radiography

Posteroanterior (PA) and lateral full spine radiographs are generally required. These enable assessment of global and regional spinopelvic alignment and assessment of the severity of the condition and the risk of curve progression.

To determine the coronal balance, a central sacral line (CSL) is drawn vertically from the center of the sacrum. The distance from C7 to the CSL is a measure of the coronal balance. From the PA film, the Cobb angle and the pelvic obliquity can also be determined. To measure the coronal Cobb angle, the upper and lower most tilted vertebrae (end vertebrae) are determined. Tangent lines are then drawn on the superior end plate of the upper end vertebra and the inferior end plate of the lower end vertebra, respectively. Perpendicular lines are then drawn to these two lines. The angle of intersection is the Cobb angle. The location of the curve is determined by the level of the apex, which is defined as the disc or vertebra maximally displaced from the midline and is minimally angulated. When the apex is located at T12 or L1, the curve is termed thoracolumbar curve; when the apex is inferior to L1, the curve is known as lumbar curve.

In DLS, the apex is generally located at the level of L2 and L3, with an associated distal fractional curve between L4 and S1. Compensatory curve when present is generally not structural and involves the thoracic and thoracolumbar areas [6]. Traction spurs and osteophytes are usually evident and are relatively large, situated on the concavity of the curve. Not uncommonly, laterolisthesis is present. In a long-term follow-up study, Weinstein and Ponseti [9] found that with time, marked translatory shift occurs between two vertebral segments in some lumbar and thoracolumbar curves. More severe structural deformities are characterized by laterolisthesis and rotatory subluxation, often at L3–L4 [20]. The shift took place at the lower end of the curve or at the transitional vertebra and is usually responsible for curve progression, which averages 3.3° in 10 years for both the thoracolumbar and lumbar curves [9, 20]. In mild curves with pelvic obliquity and more than 9 mm difference in hip levels, Giles and Taylor found an increased prevalence of L5 wedging in anteroposterior view, when compared with controls [42].

Vertebral rotation can be determined clinically using the Nash-Moe method or more accurately using the Raimondi or Perdriolle methods (**Figure 4**), both of which have low intra- and inter-observer errors [43–45]. The measurement is important as studies have shown that vertebral rotation >33% is associated with an increased incidence of back pain [9].

Figure 4.
Measurement of the apical vertebral rotation using the Raimondi method. The distance from the edge of the convex side of the apical vertebra to the center of the convex pedicle (x) is determined. The width of the vertebra (x + y) is then measured. From these two readings, the vertebral rotation can be determined using a Raimondi torsiometer.

Many recent studies have shown the importance of sagittal profile in relation to clinical outcome [30, 36, 46]. Many spinopelvic measurements have been found to correlate with the pain and disability. Schwab et al. showed that sagittal vertical axis (SVA), pelvic incidence minus lumbar lordosis, and pelvic tilt are related to disability and pain scores [46].

SVA is a measure of the sagittal imbalance. It is the horizontal distance between a vertical plumb line from the body of C7 to the posterosuperior corner of S1. The mean SVA of asymptomatic subjects was reported to be 0.5 ± 2.5 cm, whereas an ideal SVA was defined to be ±5 cm [47]. A SVA in excess of 7 cm was shown to be associated with an increase in clinical symptoms [36]. The findings were confirmed by other independent studies [30, 46]. Lafage et al. reported a correlation between the SVA and Scoliosis Research Society (SRS) total scores and Oswestry Disability Index (ODI) scores [30].

The SVA requires calibration of radiographs for measurement. To avoid the inherent error in measuring the offsets in non-calibrated radiographs, the T1 spinopelvic inclination (T1-SPI) angle may be used instead of SVA [30]. It is the

angle subtended by a vertical plumb line from the center of T1 and a line drawn to bicoxofemoral axes (**Figure 5**). The angle has been shown to correlate with the health-related quality of life (HRQOL) scores [30]. Recently, Propopsalitis et al. (2014) proposed a novel radiographic measure of global spinal alignment, the T1 pelvic angle (TPA) [48]. It is the angle subtended by the lines connecting the bicoxofemoral axis to the center of T1 and the midpoint of the sacral end plate. Studies have shown that the measurement does not vary with pelvic retroversion or other postural compensatory mechanisms [48]. TPA was found to correlate with HRQOL scores. Treatment should attempt to reduce the TPA to <14°. Angle in excess of 20° corresponded to severe disability [48].

The pelvic incidence (PI) is also another important pelvic parameter that needs to be measured. It is a constant morphological parameter which has been shown to influence lumbar alignment. It is the angle subtended by the line connecting the midpoint of the bicoxofemoral axes and that of the sacral end plate and the perpendicular line to the latter. It should approximately match the lumbar lordosis (LL) (PI-LL = ±9°). A pelvic incidence-lumbar lordosis mismatch (PI-LL) in excess of 10° was reported to correlate with disability [46].

The PI is the sum of the pelvic tilt (PT) and sacral slope (SS) which are dynamic pelvic parameters that measure pelvic version, a compensatory mechanism to help maintain an upright posture in the setting of sagittal malalignment. The pelvic tilt is the angle subtended by the line connecting the midpoint of the bicoxofemoral
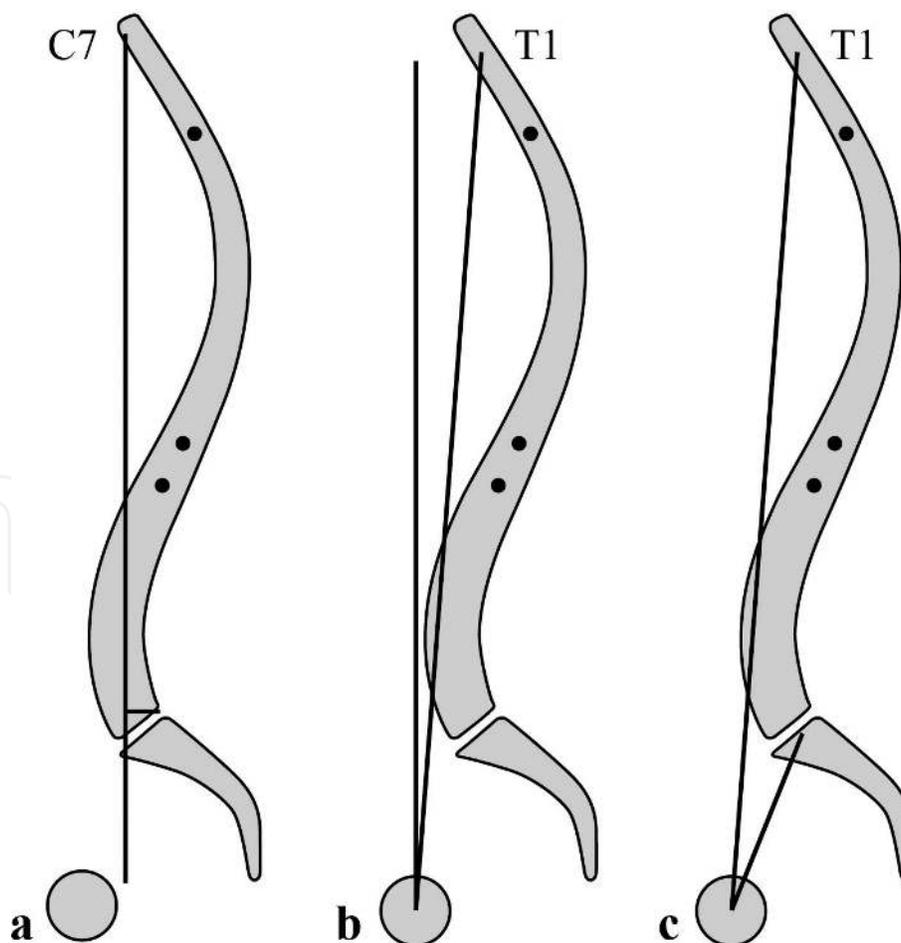

Figure 5.
The different methods of measuring global spinopelvic alignment. The sagittal vertical axis (a), the T1 spinopelvic inclination (T1-SPI) (b), and the T1 pelvic angle (TPA) (c).

axes and that of the sacral end plate and the vertical reference line extending upward from the femoral head axis. A positive sagittal imbalance as signified by an increased SVA is generally compensated by an increase in the pelvic tilt. A pelvic tilt of >22° is associated with disability [46].

5.2 Advanced imaging

In the presence of signs and findings of nerve root entrapment and intermittent claudication, referral for magnetic resonance imaging may be necessary to rule out the possibility of spinal cord impingement, spinal canal stenosis, lateral recess stenosis, or intraspinal lesions.

When osteoporosis is suspected, the patient should be referred for bone density assessment by dual-energy X-ray absorptiometry (DEXA) or the radiation-free echographic ultrasound [49], as reduction in bone density has been found to be lower in DLS patients when compared with normal controls with no scoliosis [5]. Also, bone mineral density (BMD) was found to correlate negatively with the scoliosis angle [50]. Furthermore, DLS patients with a lumbar curve in excess of 20° were found to have lower BMD than those with lumbar curves less than 20° [5].

6. Treatment

Treatment is generally conservative, particularly for patients who do not have rapidly progressive curves or significant neurological symptoms [6, 23, 51, 52]. Nonsteroidal anti-inflammatory drugs (NSAIDs), analgesics, manipulation, acupuncture, physiotherapy, and steroid injection were generally used to treat the low back pain and the accompanied radiculopathy [52, 53]. Outcome, however, was not satisfactory [52, 53]. A systematic review in 2007 showed that there was little evidence in support of these treatments in the management of adult scoliosis [52]. The studies identified level IV evidence for physical therapy, chiropractic care, and bracing and level III evidence for steroid injections [52]. Studies showed that the long-term successful rate of conservative treatment of symptomatic scoliosis was only 27% [33, 54].

The above treatments aim at pain reduction and stabilization of the curve, but not at the sagittal imbalance which is so often seen in patients with DLS. Recent studies have shown that physiotherapeutic scoliosis-specific exercises (PSSE), mirror image exercises, and chiropractic manipulation together with multimodal rehabilitation reduced pain and disability ratings in ADIS patients with thoracolumbar and lumbar curves [55–67]. Also, bracing is able to stabilize progressive curves in 80% of the adults with scoliosis [68].

6.1 Scoliosis-specific exercises and adult scoliosis

In the past 15 years, many different exercises and rehabilitation approaches to ADIS have been investigated. These include exercise, manipulation, and multimodal rehabilitation approaches [55–67, 69]. Exercises studied include yoga (side plank), Pilates, the side-shift and hitch exercise, the active self-correction, the Chiropractic BioPhysics® (CBP) mirror image, the FED, the Scientific Exercises Approach to Scoliosis (SEAS), and the Schroth Best Practice® (SBP®) program (**Table 2**). Other rehabilitation techniques investigated include the gravity traction, the weighting system, and manipulation [58, 62, 69]. These interventions have all been reported to reduce pain, disability, and the curves in ADIS.

Studies	Authors	No	Age	Types of scoliosis	Intervention	PI	Outcome
Case report/ series	Morningstar 2006 [26]	3	23–37	ADIS (TH)	Chiropractic and rehab	<12 weeks	Reduced curves (35 → 22°; 22 → 8°; 37 → 21°)
	Negrini 2008 [21]	1	25	ADIS (DM)	SEAS	1 year	Reduced curve (47 → 28.5°)
	Yang 2015 [22]	1	26	ADIS (TH)	Schroth + physio	8 weeks	Reduced curve (20.5 → 16.4°)
	Lebel 2016 [24]	1	23	ADIS (TH)	Schroth	More than 1 year	Reduced LBP and curve (70 → 58°; 48 → 43°)
	Harrison 2017 [18]	5	17–45	ADIS (TL or L)	CBP® + manipulation	18–84 visits	Reduced curves in 60%
	Haggard 2017 [25]	1	15	AIS (TL)	CBP® + manipulation	24 visits	Reduced LBP and curve after failure of chiropractic tx (27 → 8°)
Cohort	Barrios 2002 [15]	30	25–55	ADIS (MX)	FED device	20 = 60 sessions	Reduced back pain and curve (35 → 33°)
	Maruyama 2002 [17]	69	11–27	AIS and ADIS	Side shift and hitch	Mean 4.2 years	TL: (24.5 → 22.9°)
	Morningstar 2004 [20]	19	15–65	ADIS (MX)	Chiropractic and rehab	4–6 weeks	Reduced curve mean reduction 17°
	Morningstar 2011 [16]	28	18–54	ADIS (MX)	Chiropractic and rehab	6 months	Reduced curves and disability rating; TL (39.2 → 22°)
	Fishman 2014 [23]	25	14–85	ADIS; DLS (MX)	Side plank	3–22 months	Reduced 32% of the curve (37.2 → 25.3°)
	Negrini 2015 [13]	34	38 ± 11	ADIS (MX)	SEAS	2 years	Reduced curves in 69% TL (49 → 46°)
	Ng 2018 [19]	12	59 ± 15	ADIS and DLS	Schroth Best Practice	9 months	Reduced curves in 33%
RCT	Monticone 2016 [14]	130	51.6	ADIS (MX)	Self-correction and cognitive training	20 weeks	Reduced disability and curves

No, number of patients; PI, period of intervention; ADIS, adult patients with idiopathic scoliosis; DLS, degenerative lumbar scoliosis; MX, mixed curve types; TH, thoracic scoliosis; DM, double major curves; TL, thoracolumbar curve; L, lumbar curve; CBP®, chiropractic biophysics; SEAS, Scientific Exercises Approach to Scoliosis.

Table 2.
Studies on exercises and rehabilitation on the curves and pain in adult scoliosis patients.

6.1.1 Pain reduction

A number of studies have reported a reduction of pain after scoliosis-specific exercises intervention [60, 64]. Yang reported a reduction in pain in a young female with ADIS with a thoracic curvature using the SBP®, together with the standard physiotherapy care [64]; the pain scale (visual analogue scale, VAS) of the patient reduced from 5 to 1. Lebel and Lebel reported a severe case of thoracic scoliosis treated by Schroth exercises [66]. After 9 months of exercises, the thoracic curve of the 23-year-old female patient with adolescent idiopathic scoliosis reduced from 70 to 58° and the lumbar curve from 48 to 43° [66]. There was a significant reduction in low back pain after 1 month of exercise [66]. Harrison and Oakley reported similar findings in five ADIS with thoracolumbar or lumbar curves, using the CBP® mirror image method [60]. All the five cases reported a reduction of VAS, with the most significant one dropping from 6 to 0 [60]. The findings agreed with the results of a randomized controlled trial which showed that stabilization exercises which included active self-correction, task-oriented activities, and cognitive behavior therapy improved the Oswestry Disability Index (ODI) of ADIS when compared to standard physiotherapy treatment [56].

6.1.2 Cobb angle reduction

Many studies similarly showed that rehabilitation and specific exercises improve curves in ADIS and patients with DLS [58, 60, 61]. Some studies have shown that manipulation together with multimodal rehabilitation reduced scoliosis curves. In a retrospective review, Morningstar et al. showed that chiropractic treatment together with multimodal rehabilitation for 4–6 weeks reduced the curves in all of the 19 adult patients with idiopathic scoliosis [62]. This was confirmed by a subsequent study, which reported that 6 months of multimodal treatment together with manipulation reduced scoliosis curves and disability ratings in 28 ADIS aged 18–54 [58]. Non-specific exercises and physiotherapeutic scoliosis-specific exercises (PSSE) have also been found to improve curvatures in ADIS [55, 65, 66]. Fishman et al. reported that performance of side plank exercises daily for as long as tolerable (around 2 minutes) on the side of scoliosis convexity reduced the curves in ADIS and DLS patients [65]. Daily side plank exercises for 3–22 months reduced curves significantly in 30% of the adult scoliosis patients [65]. Yet, the study included adolescents aged 14 as well as patients with a Cobb angle less than 10°, which is strictly speaking not scoliosis [65]. Negrini et al. reported the outcome of SEAS intervention in a 25-year-old female adult with progressive double major curve, which progressed by 10° in 6 years [63]. In the follow-up 1 year later, the curvatures were found to reduce significantly from 47 to 28.5°. The authors attributed the positive change to an improvement in postural collapse [63]. The results were supported by a retrospective cohort study conducted by the same group [55]. SEAS intervention for 2 years resulted in an improvement of the Cobb angle in 68% of the 34 ADIS aged 38 ± 11 [55]. The mean reduction in the Cobb angle was 4.6 ± 5.0°, with no differences based on the location of the curve, gender, and length of treatment [55]. Monticone et al. compared the outcome of stabilization exercises using self-correction, task-oriented activities, and cognitive behavior therapy with standard physiotherapy care, which consisted of active and passive mobilizations, stretching, and strengthening exercises of the spinal muscles in the treatment of ADIS [56]. In the randomized controlled trial which involved 130 patients with a mean age of 51.6, they found that the experimental group had a reduced Cobb angle after 20 weeks of intervention as compared to the control group. Schroth exercises have also been found to reduce curves in adult scoliosis patients [64, 66]. Ng et al., in a prospective study, showed that home-based SBP® program for 9 months reduced

the thoracolumbar or lumbar curvature in over 30% of the ADIS and DLS patients [61]. Harrison and Oakley reported the outcome of CBP® mirror image method in the treatment of thoracolumbar and lumbar curves in five patients with ADIS. In 18–84 visits, the treatment improved the curvatures in 60% of the patients, when a reduction of ≥6° is regarded as an improvement [60]. The CBP® mirror image method was regarded as similar to Schroth exercises [60].

6.1.3 Sagittal profile

While there were many studies addressing the coronal curves in ADIS and DLS patients, there were very few studies addressing the impact of PSSE on the sagittal profile of the patients [61]. The effects of PSSE on the sagittal profile of this group of patients are thus uncertain.

6.2 Other physical interventions

Hanging exercises should not be included as they have not been found useful [70]. Periodic axial spinal unloading using the LTX3000 lumbar rehabilitation system did not permanently affect the scoliosis; unloading of the spine temporarily reduced the scoliosis angle in adult scoliosis subjects, but with cessation of the intervention, the curves reverted back to the baseline level [70].

As thoracolumbar and lumbar curves are frequently associated with pelvic shift and obliquity, with secondary apparent leg length discrepancy, it is tempting to apply sole lift on the side of the low pelvis. Lehnert-Schroth advised against the use of sole lift. Addition of the sole lift on the side of the low pelvis would cause spinal imbalance, as evidenced by the tilted gluteal cleft [39]. Instead, patients should be advised to contract the hip abductor on the side of the higher pelvis to level the pelvis [39]. The patients can also flex the knee on the side of the high iliac crest [71] or raise the heel on the side of the low iliac crest when standing at ease [72]. This would reduce the lumbar curve and the associated stress on the facet joints and the adjoining soft tissue structures.

6.3 Spinal bracing

The effects of bracing in the treatment of adult scoliosis patients have been controversial [17, 68]. Some authors were of the opinion that brace does not halt curve progression and any pain relief provided is offset by associated deconditioning [7, 17]. Yet, recent studies have shown that spinal bracing stabilized the curves [68, 73, 74]. In a study which followed 158 adults with spinal deformities (ASD) treated by lordosing bivalve polyethylene overlapping brace for over 5 years showed that 24% of the curves reduced by more than 5°, 56% of the curves stabilized (±5°), and 20% worsened (>5°) [68]. Similarly, Palazzo et al. in a long-term follow-up study of 22 years showed that the progression of curves in ADIS and DLS patients reduced [74]. The yearly progression for curves in patients with DLS reduced from 1.47 to 0.24° per year and that for patients with ADIS from 0.7 to 0.24° per year [74]. de Mauroy suggested that the brace treatment is not only palliative; it treats lumbar instability by reducing the pressure in disc and stabilizing the lumbar area in lordosis [73].

7. Clinical management

Adult patients with low back pain and thoracolumbar and lumbar curves which have a high risk of progression or which are accompanied by sagittal imbalance

are suggested to be treated by scoliosis-specific exercises, together with standard physiotherapy care. Exercises should target at improving the sagittal profile as well as the coronal curves. The exercises should preferably be supervised, as studies have shown that the physiotherapist-supervised Schroth Best Practice® (SBP®) exercises were associated with better outcome than home-based SBP® exercises [75]. In case of curve progression or pain, the patient should be prescribed a spinal brace. He or she should wear it 6–8 hours a day or as needed and perform the corrective scoliosis-specific exercises 3–4 times weekly to avoid deconditioning of the truncal muscles.

Recent studies showed that 46.6% of patients with DLS had sarcopenia involving the appendix and the trunk [76]. The trunk skeletal muscle mass index (SMI) was found to be significantly negatively correlated with SVA, PT, lumbar scoliosis, and apical vertebral rotation, suggesting that the reduction in trunk musculature was related to the stooped posture, pelvic retroversion, and lumbar scoliosis [76]. In view of the propensity of the DLS to progress, PSSE may also be taught to DLS patients who are asymptomatic as preventive measures.

If all these interventions fail and the patient has signs and symptoms suggestive of clinically significant spinal stenosis, he or she should be referred for surgical management [77].

Author details

Shu-Yan Ng[1], Tsz-Ki Ho[2]* and Yin-Ling Ng[2]

1 Wanchai Chiropractic Clinic, Wanchai, Hong Kong

2 Spine Technology Ltd, Wanchai, Hong Kong

*Address all correspondence to: angelh@ezped.com

IntechOpen

References

[1] Kobayashi T, Atsuta Y, Takemitsu M, Matsuno T, Takeda N. A prospective study of de novo scoliosis in a community based cohort. Spine (Phila Pa 1976). 2006;**31**:178-182

[2] Urrutia J, Diaz-Ledezma C, Espinosa J, Berven SH. Lumbar scoliosis in postmenopausal women: Prevalence and relationship with bone density, age, and body mass index. Spine (Phila Pa 1976). 2011;**36**(9):737-740

[3] Kebaish KM, Neubauer PR, Voros GD, Khoshnevisan MA, Skolasky RL. Scoliosis in adults aged 40 years and older: Prevalence and relationship to age, race, and gender. Spine (Phila Pa 1976). 2011;**1976**:731-736

[4] Schwab F, Dubey A, Pagala M, Gamez L, Farcy JP. Adult scoliosis: A health assessment analysis by SF-36. Spine (Phila Pa 1976). 2003;**28**:602-606

[5] Xu L, Sun X, Huang S, Zhu Z, Qiao J, Zhu F, et al. Degenerative lumbar scoliosis in Chinese Han population: Prevalence and relationship to age, gender, bone mineral density, and body mass index. European Spine Journal. 2013;**22**(6):1326-1331

[6] Silva FE, Lenke LG. Adult degenerative scoliosis: Evaluation and management. Neurosurgical Focus. 2010;**28**(3):E1

[7] Pizones J, Martin-Buitrago MP, Perez-Grueso JS, et al. Function and clinical symptoms are main factors that motivate thoracolumbar adult scoliosis patients to pursue surgery. Spine (Phila Pa 1976). 1 Jan 2017;**42**(1):E31-E36

[8] Marty-Poumarat C, Scattin L, Marpeau M, Garreau de Loubresse C, Aegerter P. Natural history of progressive adult scoliosis. Spine. 2007;**32**(11):1227-1234

[9] Weinstein SL, Ponseti IV. Curve progression in idiopathic scoliosis. The Journal of Bone and Joint Surgery. American Volume. 1983;**65**(4):447-455

[10] Ascani E, Bartolozzi P, Logroscino CA, et al. Natural history of untreated idiopathic scoliosis after skeletal maturity. Spine (Phila Pa 1976). 1986;**11**(8):784-789

[11] Iida T, Ohyama Y, Katayanagi J, Ato A, Mine K, Matsumoto K, et al. Differences between pre-existing type and de novo type left convex thoracolumbar/lumbar scoliosis. Scoliosis. 2015;**10**(Suppl 2):S6

[12] Li Z, Li G, Chen C, Li Y, Yang C, Li M, et al. The radiographic parameter risk factors of rapid curve progression in Lenke 5 and 6 adolescent idiopathic scoliosis: A retrospective study. Medicine (Baltimore). 2017;**96**(52):e9425

[13] Pritchett JW, Bortel DT. Degenerative symptomatic lumbar scoliosis. Spine (Phila Pa 1976). 1993;**18**(6):700-703

[14] Faraj SS, Holewijn RM, van Hooff ML, de Kleuver M, Pellisé F, Haanstra TM. De novo degenerative lumbar scoliosis: A systematic review of prognostic factors for curve progression. European Spine Journal. 2016;**25**(8):2347-2358

[15] Jimbo S, Kobayashi T, Aono K, Atsuta Y, Matsuno T. Epidemiology of degenerative lumbar scoliosis: A community-based cohort study. Spine (Phila Pa 1976). 2012;**37**(20):1763-1770

[16] Yang C, Yang MY, Chen YY, Wei XZ, Ni HJ, Chen ZQ, et al. Radiographic parameters in adult degenerative scoliosis and different parameters between sagittal balanced and

imbalanced ads patients. Medicine (Baltimore). Jul 2015;**94**(29):e1198

[17] Youssef JA, Orndorff DO, Patty CA, et al. Current status of adult spinal deformity. Global Spine Journal. 2013;**3**(1):51-62

[18] Kotwal S, Pumberger M, Hughes A, et al. Degenerative scoliosis: A review. HSS Journal. 2011;**7**:257-264

[19] Tempel ZJ, Gandhoke GS, Bonfield CM, et al. Radiographic and clinical outcomes following combined lateral lumbar interbody fusion and posterior segmental stabilization in patients with adult degenerative scoliosis. Neurosurgical Focus. 2014;**36**:E11

[20] Korovessis P, Piperos G, Sidiropoulos P, Diures A. Adult idiopathic lumbar scoliosis. A formula for prediction of progression and review of the literature. Spine. 1994;**19**(17):1926-1932

[21] Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA. Adolescent idiopathic scoliosis. Lancet. 2008;**371**(9623):1527-1537

[22] Simmons EH, Jackson RP. The management of nerve root entrapment syndromes associated with the collapsing scoliosis of idiopathic lumbar and thoracolumbar curves. Spine (Phila Pa 1976). 1979;**4**(6):533-541

[23] Grubb SA, Lipscomb HJ, Coonrad RW. Degenerative adult onset scoliosis. Spine (Phila Pa 1976). 1988;**13**(3):241-245

[24] San Martino A, D'Andria FM, San Martino C. The surgical treatment of nerve root compression caused by scoliosis of the lumbar spine. Spine (Phila Pa 1976). 1983;**8**(3):261-265

[25] Briard JL, Jegou D, Cauchoix J. Adult lumbar scoliosis. Spine (Phila Pa 1976). 1979;**4**(6):526-532

[26] Kostuik JP, Bentivoglio J. The incidence of low-back pain in adult scoliosis. Spine (Phila Pa 1976). 1981;**6**(3):268-273

[27] Jackson RP, Simmons EH, Stripinis D. Incidence and severity of back pain in adult idiopathic scoliosis. Spine (Phila Pa 1976). 1983;**8**(7):749-756

[28] Glassman SD, Berven S, Bridwell K, Horton W, Dimar JR. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. Spine. 2005;**30**:682-688

[29] Ploumis A, Liu H, Mehbod AA, et al. A correlation of radiographic and functional measurements in adult degenerative scoliosis. Spine. 2009;**34**:1581-1584

[30] Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP. Pelvic tilt and truncal inclination: Two key radiographic parameters in the setting of adults with spinal deformity. Spine (Phila Pa 1976). 2009;**34**(17):E599-E606

[31] Mac-Thiong JM, Labelle H, Charlebois M, et al. Sagittal plane analysis of the spine and pelvis in adolescent idiopathic scoliosis according to the coronal curve type. Spine. 2003;**28**:1404-1409

[32] Li WS, Li G, Chen ZQ, et al. Sagittal plane analysis of the spine and pelvis in adult idiopathic scoliosis. Chinese Medical Journal. 2010;**123**:2978-2982

[33] Savage JW, Patel AA. Fixed sagittal plane imbalance. Global Spine Journal. 2014;**4**:287-296

[34] Lazennec JY, Ramare S, Arafati N, et al. Sagittal alignment in lumbosacral fusion: Relations between radiological parameters and pain. European Spine Journal. 2000;**9**:47-55

[35] Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity

classification: A validation study. Spine. 2012;**37**:1077-1082

[36] Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. Spine. 2005;**30**(18):2024-2029

[37] Stagnara P. Scoliosis in adults. Consequences of idiopathic scoliosis in adulthood. Chirurgie. 1982;**108**(4):356-363

[38] Ames CP, Smith JS, Scheer JK, et al. Impact of spinopelvic alignment on decision making in deformity surgery in adults: A review. Journal of Neurosurgery: Spine. 2012;**16**(6):547-564

[39] Lehnert Schroth C. Three-dimensional treatment for scoliosis. A physiotherapeutic method for deformities of the spine. Calif: Martindale Press; 2007

[40] Radcliff KE, Orozco F, Molby N, Chen E, Sidhu GS, Vaccaro AR, et al. Is pelvic obliquity related to degenerative scoliosis? Orthopaedic Surgery. 2013;**5**(3):171-176

[41] Smith JS, Shaffrey CI, Fu KM, et al. Clinical and radiographic evaluation of the adult spinal deformity patient. Neurosurgery Clinics of North America. 2013;**24**(2):143-156

[42] Giles LG, Taylor JR. Low-back pain associated with leg length inequality. Spine (Phila Pa 1976). 1981;**6**(5):510-521

[43] Weiss HR. Measurement of vertebral rotation: Perdriolle versus Raimondi. European Spine Journal. 1995;**4**(1):34-38

[44] Barsanti CM, DeBari A, Covino BM. The torsion meter: A critical review. Journal of Pediatric Orthopaedics. 1990;**10**:527-531

[45] Omeroglu H, Ozekin O, Bicimoglu A. Measurement of vertebral rotation in idiopathic scoliosis using the Perdriolle torsionmeter: A clinical study on intraobserver and interobserver error. European Spine Journal. 1996;**5**:167-171

[46] Schwab FJ, Blondel B, Bess S, Hostin R, Shaffrey CI, et al. Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity: A prospective multicenter analysis. Spine (Phila Pa 1976). 2013;**38**(13):E803-E812

[47] Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine (Phila Pa 1976). 1994;**19**(14):1611-1618

[48] Protopsaltis TS, Lafage R, Smith JS, Passias PG, Shaffrey CI, Kim HJ, et al. International spine study group. The lumbar pelvic angle, the lumbar component of the T1 pelvic angle, correlates with HRQOL, PI-LL mismatch, and it predicts global alignment. Spine (Phila Pa 1976). 2018;**43**(10):681-687

[49] Casciaro S, Conversano F, Pisani F, Muratore M. New perspectives in echographic diagnosis of osteoporosis on hip and spine. Clinical Cases in Mineral and Bone Metabolism. 2015;**12**(2):142-150

[50] Ding WY, Yang DL, Cao LZ, Sun YP, Zhang W, Xu JX, et al. Intervertebral disc degeneration and bone density in degenerative lumbar scoliosis: A comparative study between patients with degenerative lumbar scoliosis and patients with lumbar stenosis. Chinese Medical Journal. 2011;**124**(23):3875-3878

[51] Birknes JK, Harrop JS, White AP, Albert TJ. Adult degenerative scoliosis: A review. Neurosurgery. 2008;**63**(3 suppl):94-103

[52] Everett CR, Patel RK. A systematic literature review of nonsurgical treatment in adult scoliosis. Spine (Phila Pa 1976). 2007;**32**(19 suppl):S130-S134

[53] Kluba T, Dikmenli G, Dietz K, Giehl JP, Niemeyer T. Comparison of surgical and conservative treatment for degenerative lumbar scoliosis. Archives of Orthopaedic and Traumatic Surgery. 2009;**129**:1-5

[54] Ryan DJ, Protopsaltis TS, Ames CP, Hostin R, Klineberg E, Mundis GM, et al. International spine study group. T1 pelvic angle (TPA) effectively evaluates sagittal deformity and assesses radiographical surgical outcomes longitudinally. Spine (Phila Pa 1976). 2014;**39**(15):1203-1210

[55] Negrini A, Negrini MG, Donzelli S, Romano M, Zaina F, Negrini S. Scoliosis-Specific exercises can reduce the progression of severe curves in adult idiopathic scoliosis: A long-term cohort study. Scoliosis. 2015;**10**:20

[56] Monticone M, Ambrosini E, Cazzaniga D, Rocca B, Motta L, Cerri C, et al. Adults with idiopathic scoliosis improve disability after motor and cognitive rehabilitation: Results of a randomised controlled trial. European Spine Journal. 2016;**25**(10):3120-3129

[57] Barrios C, Lapuente JP, Sastre S. Treatment of chronic pain in adult scoliosis. Studies in Health Technology and Informatics. 2002;**88**:290-303

[58] Morningstar MW. Outcomes for adult scoliosis patients receiving chiropractic rehabilitation: A 24-month retrospective analysis. Journal of Chiropractic Medicine. 2011;**10**:179-178

[59] Maruyama T, Kitagawal T, Takeshita K, Nakainura K. Side shift exercise for idiopathic scoliosis after skeletal maturity. Studies in Health Technology and Informatics. 2002;**91**:361-364

[60] Harrison DE, Oakley PA. Scoliosis deformity reduction in adults: A CBP® Mirror Image case series incorporating the 'non-commutative property of finite rotation angles under addition' in five patients with lumbar and thoraco-lumbar scoliosis. Journal of Physical Therapy Science. 2017;**29**(11):2044-2050

[61] Ng SY, Chan WY, Ho TK, Ng YL. A pilot study on the effect of outpatient Schroth exercises on thoracolumbar and lumbar curves in adult scoliosis patients. In: Bettany-Saltikov J, Schreiber S, editors. Innovations in Spinal Deformities and Postural Disorders. Rijeka: Intech; 2017. pp. 93-112

[62] Morningstar MW, Woggon D, Lawrence G. Scoliosis treatment using a combination of manipulative and rehabilitative therapy: A retrospective case series. BMC Musculoskeletal Disorders. 2004;**5**:32

[63] Negrini A, Parzini S, Negrini MG, Romano M, Atanasio S, Zaina F, et al. Adult scoliosis can be reduced through specific SEAS exercises: A case report. Scoliosis. 2008;**3**:20

[64] Yang JM, Lee JH, Lee DH. Effects of consecutive application of stretching, Schroth, and strengthening exercises on Cobb's angle and the rib hump in an adult with idiopathic scoliosis. Journal of Physical Therapy Science. 2015;**27**(8):2667-2669

[65] Fishman LM, Groessl EJ, Sherman KJ. Serial case reporting yoga for idiopathic and degenerative scoliosis. Global Advances in Health and Medicine. 2014;**3**(5):16-21

[66] Lebel A, Lebel VA. Severe progressive scoliosis in an adult female possibly secondary thoracic surgery in childhood treated with scoliosis specific Schroth physiotherapy: Case presentation. Scoliosis and Spinal Disorders. 2016;**11**(Suppl 2):41

[67] Haggard JS, Haggard JB, Oakley PA, Harrison DE. Reduction of progressive thoracolumbar adolescent idiopathic scoliosis by chiropractic biophysics® (CBP®) mirror image® methods following failed traditional chiropractic treatment: A case report. Journal of Physical Therapy Science. 2017;**29**(11):2062-2067

[68] de Mauroy JC, Lecante C, Barral F, Pourret S. Prospective study of 158 adult scoliosis treated by a bivalve polyethylene overlapping brace and reviewed at least 5 years after brace fitting. Scoliosis and Spinal Disorders. 2016;**11**(Suppl 2):28

[69] Morningstar MW, Joy T. Scoliosis treatment using spinal manipulation and the Pettibon Weighting System TM: A summary of 3 typical presentations. Chiropractic and Osteopathy. 2006;**14**:1

[70] Hales J, Larson P, Iaizzo PA. Treatment of adult lumbar scoliosis with axial spinal unloading using the LTX3000 lumbar rehabilitation system. Spine. 2002;**27**(3):E71-E79

[71] Weiss HR, Lehnert-Schroth C, Moramarco M. Schroth Therapy: Advances in Conservative Scoliosis Treatment. Germany: Lap Lambert Acad Pub; 2015

[72] Maruyama T, Takeshita K, Kitagawa T. Side-shift exercise and hitch exercise. Studies in Health Technology and Informatics. 2008;**135**:246-249

[73] de Mauroy JC, Lecante C, Barral F, Pourret S. Bracing in adult with scoliosis: Experience in diagnosis and classification from a 15 year prospective study of 739 patients. Scoliosis and Spinal Disorders. 2016;**11**(Suppl 2):29

[74] Palazzo C, Montigny JP, Barbot F, Bussel B, Vaugier I, Fort D, et al. Effects of bracing in adult with Scoliosis: A retrospective study. Archives of Physical Medicine and Rehabilitation. 2017;**98**:187-190

[75] Kuru T, Yeldan İ, Dereli EE, Özdinçler AR, Dikici F, Çolak İ. The efficacy of three-dimensional Schroth exercises in adolescent idiopathic scoliosis: A randomised controlled clinical trial. Clinical Rehabilitation. 2016;**30**(2):181-190

[76] Eguchi Y, Suzuki M, Yamanaka H, Tamai H, Kobayashi T, Orita S, et al. Associations between sarcopenia and degenerative lumbar scoliosis in older women. Scoliosis and Spinal Disorders. 2017;**12**:9

[77] Neuman BJ, Baldus C, Zebala LP, Kelly MP, Shaffrey C, et al. Patient factors that influence decision making: Randomization versus observational nonoperative versus observational operative treatment for adult symptomatic lumbar scoliosis (ASLS). Spine (Phila Pa 1976). 2016;**41**(6):E349-E358