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Scoliosis-Specific Exercises and the S4D Approach

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SUMMARY

Adolescent idiopathic scoliosis (AIS) is a complex condition requiring a multidisciplinary approach to optimize outcomes and limit the progression of spinal deformities. This thesis aims to evaluate the effects of specific physiotherapeutic exercises on AIS, with a particular focus on the Cobb angle reduction and patient-reported outcomes.

- The first section provides an overview of AIS, detailing its definition, pathological anatomy, classification, epidemiology, etiology, and progression-predicting factors. These elements are critical for understanding the disease's complexity and tailoring effective interventions.
- The second section emphasizes the clinical assessment of AIS, highlighting the importance of evaluating quality of life alongside biomechanical and structural parameters. The efficacy of Physiotherapeutic Scoliosis-Specific Exercises (PSSE) is critically analyzed, alongside other kinesiotherapy approaches. Treatment outcomes are discussed, and common misconceptions surrounding AIS management are addressed to clarify evidence-based practices.
- The third section presents the S4D Brasil method, a novel approach integrating classification, assessment, and treatment strategies, including the use of the S4D brace. This method also explores the role of physical activity in scoliosis management, providing a framework for incorporating corrective postures and functional exercises into daily activities.

Finally, a clinical case series conducted at UNEB University in Brazil is presented. The study examines the clinical profiles of patients treated in a university setting, the therapeutic interventions applied, and the observed outcomes. Critical issues, limitations, and follow-up strategies are also discussed to enhance the validity and applicability of the findings.

This work underscores the importance of personalized, evidence-based physiotherapeutic interventions in the management of AIS, aiming to contribute to the optimization of treatment strategies and patient outcomes.

CHAPTER 1: Idiopathic Scoliosis

1.1 DEFINITION

The International Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT)[1] defines scoliosis as a "three-dimensional torsional deformity of the spine and trunk." On the frontal plane, scoliosis manifests as a lateral bending movement; on the sagittal plane, it involves an alteration of the spinal curves, with the inversion of these curves being the most common presentation; on the axial plane, it is characterised by vertebral rotation[2].

The Scoliosis Research Society[3] offers a definition of scoliosis commonly used in both clinical practice and the literature. It describes scoliosis as a "curve of more than 10° of Cobb's angle in the frontal plane" without considering lateral plane modifications, which significantly influence the progression of scoliosis and its response to orthotic treatment. This definition implies that scoliosis is diagnosed when a Cobb angle of 10° or greater is observed, accompanied by identifiable axial rotation. The severity of scoliosis is then classified based on the degrees of the Cobb angle found in the patient.

It is crucial to distinguish between structural scoliosis and functional scoliosis. Functional scoliosis, also known as scoliotic posture, is a secondary curve that arises from extra-spinal causes, such as limb length discrepancy. In this type of scoliosis, vertebral rotation is absent, and the curvature disappears upon anterior flexion[1].

1.2 PATHOLOGICAL ANATOMY

Scoliosis is a condition that results in a complex deformity of the spine, affecting not only the vertebrae, which become deformed and lose functionality due to rotational forces, but also all the surrounding tissues that are connected to the spine. In idiopathic scoliosis, several key elements characterize the condition[4]:

1. Major or Primary Curve: This is the curve with the most significant vertebral rotation and usually has the largest angle. It can occur in various parts of the spine, including the thoracic, cervical, or lumbar regions, or it can involve multiple regions. This primary curve tends to be the most rigid and structured, making it particularly challenging to correct.

2. Secondary (or Compensatory) Curves: These curves develop above or below the primary curve and serve to realign the trunk by compensating for the primary curve. Typically, these secondary curves have a smaller magnitude than the primary curve and are generally easier to treat.

3. Rotations: In all parts of the spine affected by the curvature, individual vertebrae exhibit rotation. The vertebral bodies typically rotate toward the convex side of the curve, while the spinous processes are directed toward the concave side.

Understanding these elements is crucial for comprehending the nature and management of idiopathic scoliosis.

Within each scoliotic curve, specific key vertebrae provide vital information about the nature of the curve. The apical vertebra is the vertebra furthest from the midline, showing the greatest degree of torsion in the transverse plane compared to other vertebrae within the same curve. This vertebra generally exhibits the most pronounced angle of rotation relative to all other vertebrae in the spine. The limiting vertebrae are the vertebrae that border the curve, with one located above and one below; these vertebrae are distinguishable by their inclination relative to the vertebral axis[1].

As demonstrated in the studies by Asher & Burton[5], the apical vertebra is also the most vulnerable to the degenerative processes associated with scoliosis. During the progression of scoliosis, this vertebra tends to undergo degeneration, often transforming into a trapezoidal shape. This degeneration is attributed to increased pressure on the growth plate cartilage within the concavity of the curve, which impairs ossification on the concave side compared to the convex side, thereby exacerbating the asymmetry and deformity in accordance with Wolff's law. In contrast, the limiting vertebrae experience much less severe degenerative changes compared to the apical vertebra, due to the reduced pressure generated by the curvature.

The degenerative process affects not only the vertebral bodies but also the intervertebral discs located between them. These discs, subjected to abnormal pressures, tend to thin and degenerate toward the concave side of the curve, contributing to the development of arthritis, which is a major cause of pain and functional limitation in individuals with scoliosis.

Deformities of the ribs and chest are another characteristic feature of idiopathic scoliosis, particularly evident in the formation of the posterior rib hump. The ribs on the convex side of the curve are pushed posteriorly and tend to straighten vertically, creating a posterior prominence known as a rib hump. Meanwhile, the vertebrae on the concave side are displaced anteriorly, forming an anterior rib hump. The rib hump is one of the most distinctive signs of scoliosis.

Moreover, anatomical changes occur in the soft tissues surrounding the scoliotic curve. These tissues typically stretch toward the convex side of the curve while retracting toward the concave side. Both sides of the curve exhibit a loss of elasticity, further complicating the overall condition.

1.3 CLASSIFICATION

The International Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT)[1], proposes the following classification for Idiopathic Adolescent Scoliosis:

Chronological (SoE: V)		Angular (SoE: VI)		Topographic (SoE: V)		
Age at diagnosis (years.months)		Cobb degrees			Apex	
					from	to
Infantile	0–2.	Low	Up to 20	Cervical	–	Disc C6–7
Juvenile	3–9.	Moderate	21–35	Cervico-thoracic	C7	T1
Adolescent	10–17.	Moderate to severe	36–40	Thoracic	Disc T1–2	Disc T11–12
Adult	18+	Severe	41–50	Thoraco-lumbar	T12	L1
		Severe to very severe	51–55	Lumbar		Disc L1–2
		Very severe	56 or more			

Figure 1. Classification for idiopathic adolescent scoliosis. Negrini, S. et al. 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth.

Chronological Classification

In the chronological mode, scoliosis is classified according to the age of the scoliosis patient at the time of diagnosis and onset of the condition. This method, proposed by James JI[6], places great emphasis on the fact that the earlier the diagnosis is made, the better the prognosis is and the more effective conservative treatment is also increased. Four types of scoliosis are distinguished according to the chronological method:

- Infantile, from 0 to 2.11 years: approximately 1% of idiopathic scoliosis;

- Juvenile, from 3 to 9.11 years: 10 to 15% of idiopathic scoliosis and can very easily lead to severe cardiopulmonary complications, the risk for surgery is great;

- Adolescent, 10 to 17.11 years: >80%; they represent the majority of idiopathic scoliosis;

- Adult, over 18 years or beyond bone maturity.

Angular classification

Angular classification is based on the measurement of Cobb's angle by radiographic imaging in the frontal plane. This is obtained by calculating the intersection of two tangent lines generated by the upper margin of the upper limiting vertebra and the lower margin of the lower limiting vertebra, respectively. The congruent angle formed by the intersection of the perpendiculars from the tangents described is called Cobb's angle. The procedure for calculating the Cobb angle is subject to error as it has been shown that even when selecting the same vertebrae, a difference of 3-5° will be obtained depending on the operator.

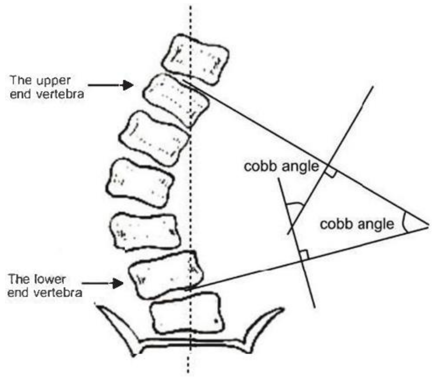


Figure 2. Cobb angle calculation methodology

- Low: Up to 20°;

- Moderate: 21° to 35°;

- Moderate to severe: 36° to 40°;

- Severe: 41° to 50°;

- Severe to very severe: 51° to 55°

- Very severe: over 56° amplitude.

Given the growing interest and recent studies on the impact of this pathology on QoL (quality of life), cut-offs have been proposed that are considered significant for prognosis:

- Scoliosis less than 10°: the diagnosis should not be made;

- Scoliosis greater than 30°: risk of progression to adulthood and possible health problems and reduced quality of life;

- Scoliosis greater than 50°: will almost certainly progress to adulthood and lead to health problems and reduced quality of life.

Topographic classification

This type of classification is based on the anatomical site of the primary curve in the frontal plane. Curves in different positions can be distinguished: Cervical (up to C6/7);

Cervico-thoracic (C7 to T1); Thoracic (T1 to T11/12); Thoraco-lumbar (T12 to L1) and Lumbar (under L2).

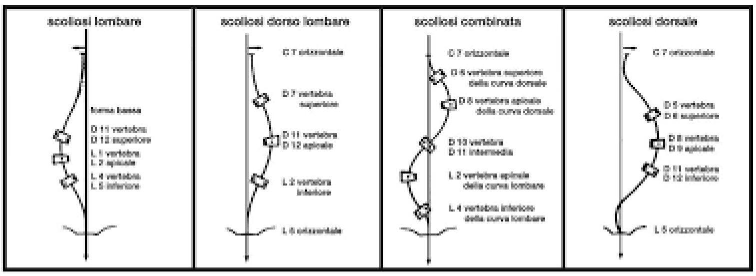


Figure 3. AIS topographic classification

Lenke Classification of Adolescent Idiopathic Scoliosis

The Lenke classification system is widely used for the evaluation and surgical planning of adolescent idiopathic scoliosis (AIS). It provides a comprehensive approach based on three primary components:

1. Curve Type: Determines the six types of scoliosis curves (1-6), classified based on the location and structural characteristics of the curve patterns (thoracic, thoracolumbar, or lumbar).
2. Lumbar Modifier: Assesses the relationship between the lumbar spine and the central sacral vertical line (CSL), categorized as A, B, or C.
3. Sagittal Thoracic Modifier: Evaluates the thoracic kyphosis from T5 to T12, described as hypo-kyphotic (-), normal (N), or hyper-kyphotic (+).

This system enhances surgical decision-making by considering the structural and non-structural curves, the involvement of the lumbar spine, and sagittal balance.

For more details, refer to Chapter 3 of the thesis, where the Lenke classification is explained in depth with visual examples and its implications on therapeutic strategies.

Risser Scale

Many of the studies that we are going to analyse take this scale into account in the criteria for inclusion in their studies. This method of identifying skeletal development is based on radiographic measurement of the ossification of the iliac apophysis. The radiograph starts from the most lateral portion of the iliac crest and proceeds in a medial direction dividing the apophysis into 4 symmetrical quadrants. The Risser scale (or Risser sign) ranges from a value of 0 (no ossification) to a value of 5 (ossification of all quadrants and fusion of the apophysis to the iliac bone). As we discuss later on in this chapter, the risk of progression is inversely proportional to the Risser sign.

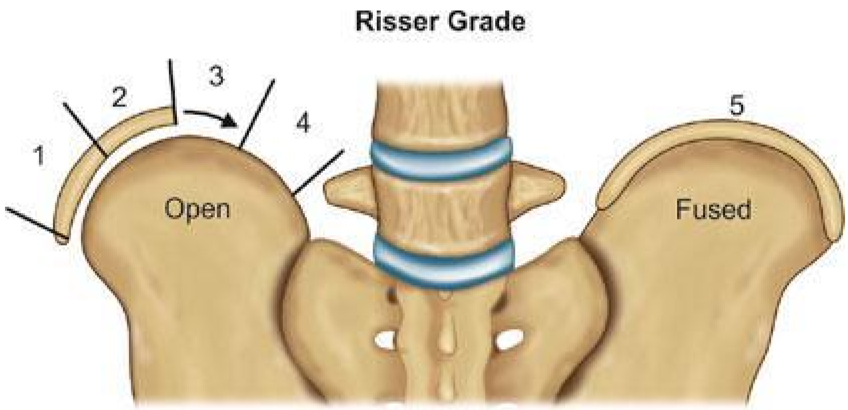


Figure 5. Risser scale

1.4 EPIDEMIOLOGY

Scoliosis is the most prevalent spinal deformity encountered during childhood and adolescence. Approximately 20% of cases are associated with other medical conditions, while the remaining 80% are classified as idiopathic scoliosis[7]. The prevalence of idiopathic scoliosis within the general population varies widely, ranging from 0.93% to 12% for Cobb angles greater than 10°, depending on the screening techniques and definitions employed[8;9].

According to the literature, the standard prevalence of scoliosis is estimated to be between 2% and 3% among individuals aged 10 to 18 years. The severity of scoliosis curves observed in patients can vary greatly: approximately 95% of cases at the time of the first specialist consultation present with curves measuring less than 20° Cobb, around 4% exhibit curves between 20° and 40° Cobb, and only 1% display curves of 40° Cobb or more, classifying them as cases of major scoliosis[1].

The magnitude of the scoliosis curve at the conclusion of skeletal development is a critical factor in determining the patient's long-term prognosis. Curves that stabilize between 30° and 50° pose a significantly increased risk of leading to life-threatening complications, in addition to causing a marked reduction in the quality of life due to aesthetically noticeable deformities and associated functional limitations[1].

Approximately 10% of scoliosis cases will require some form of therapeutic intervention, while only 0.2% will necessitate surgical correction of the spinal curvature. Idiopathic scoliosis exhibits a higher prevalence in females, particularly for Cobb angles exceeding 30°, where the prevalence ratio is 7.2:1 for curves greater than 40°. However, this gender disparity is less pronounced in cases with lower Cobb angles, with a distribution ratio of 1.4:1 for angles between 10° and 20°[1].

1.5 AETIOLOGY

Scoliosis can be classified according to its aetiology. There are scoliosis with well-defined causes. Neuromuscular scoliosis[10] occurs in the presence of diseases that impair muscle or nerve control, such as spinal muscular atrophy (SMA), cerebral palsy, or muscular dystrophy, and often progress rapidly. Congenital scoliosis[11], on the other hand, results from vertebral malformations present from birth, such as hemispondylar, vertebral synostosis, or nonsegmented bars, which interfere with symmetrical spinal growth. Syndromic or secondary scoliosis[12] occurs in association with genetic or multisystem disorders, such as neurofibromatosis, Marfan syndrome, or Ehlers-Danlos syndrome.

Idiopathic scoliosis, on the other hand, is the most common, especially in adolescence, and its genesis is considered multifactorial, involving genetic predispositions, biomechanical and environmental factors. Numerous scientifically credible theories have been proposed to identify the underlying causes of this condition. Among the most prominent hypotheses, several focus on the biomechanics of the body, neuromuscular abnormalities, genetic predispositions, hormonal influences, and environmental factors. However, despite extensive research, the precise primary cause of scoliosis remains elusive, with no single theory offering a definitive explanation.

The notably higher prevalence of scoliosis in females, particularly in cases involving more severe spinal curves, has led researchers to speculate about a potential X-linked genetic transmission. This hypothesis suggests that the genetic factors responsible for scoliosis may be linked to the X chromosome, which could explain the gender disparity observed in the incidence of the condition. However, a significant study conducted by Ward et al.[13] challenged this theory, providing evidence that the expression of scoliosis is polygenic rather than X-linked. This means that multiple genes, rather than a single gene or chromosome, contribute to the development of the disease, further complicating the understanding of its genetic basis.

In patients with idiopathic scoliosis, the deformity is frequently accompanied by disturbances in balance, altered sensory perception, and various central nervous system disorders. These clinical observations have led to the hypothesis that idiopathic scoliosis may involve neurological dysfunction, particularly affecting the deep paravertebral muscles. It is postulated that abnormal maturation of cortical and subcortical centers within the brain may result in impaired neural control over these muscles, leading to an imbalance in the forces acting on the spine. This imbalance could then contribute to the structural deformities observed in scoliosis, especially the characteristic rotational aspect of the spinal curvature[14].

The observation that scoliosis tends to manifest in certain families, while being absent in others, has further fuelled speculation about the role of genetic factors in the development of the condition. Family studies have sought to identify patterns of inheritance that might explain the familial clustering of scoliosis cases. However, despite these efforts, research has not yet yielded conclusive results regarding specific genetic susceptibility patterns within families. This ongoing uncertainty highlights the complexity of the genetic components involved in scoliosis[15].

1.6 PROGRESSION PREDICTING FACTORS

A systematic review from 2015[16] revealed that multiple studies have demonstrated significant or borderline associations between the severity or progression of AIS and various clinical and demographic factors. These include an increase in the Cobb angle or axial rotation during brace treatment, and a reduction in the rib-vertebral angle at the apical level of the convex side while undergoing brace treatment. Additionally, a more severe initial Cobb angle, specifically above 25 degrees, as well as the presence of osteopenia, have been linked to worsening scoliosis outcomes. Other critical factors include a patient's age at diagnosis being less than 13 years, premenarchal status, skeletal immaturity, and thoracic deformity. Studies also suggest that brain stem vestibular dysfunction plays a role, and several indices combining radiographic, demographic, and physiological characteristics have been shown to predict scoliosis progression. These findings highlight the importance of early and comprehensive evaluation to anticipate the progression of AIS and inform more targeted intervention strategies.

Risk of Scoliosis Progression			
Degree of Curve (Cobb Angle)	Age 10-12	Age 13-15	Age over 16
<20°	25%	10%	0%
20°-30°	60%	40%	10%
30° -60°	90%	70%	30%
>60°	100%	90%	70%

The above data has been obtained from the Scoliosis Research Society.

Table 1: Risk of progression in patient with idiopatic scoliosis

Risser Sign

As explained earlier, Risser's sign is also important in assessing the likelihood of worsening of a curve: the more immature the bones, and thus the lower the Risser's sign, the more they are subject to further deformation.

CHAPTER 2: ASSESSMENT AND TREATMENT

2.1 CLINICAL EXAMINATION

The clinical examination is conducted with the objective of diagnosing scoliosis, it consists of three primary components: anamnesis, physical examination, and radiographic evaluation[1]. The accuracy and completeness of the clinical examination are essential, and, in Italy, the diagnosis of scoliosis is exclusively made by a physician, typically a physiatrist.

Anamnesis

The initial data collection, or anamnesis, is a critical step in both diagnosing the condition and planning its treatment. It establishes a baseline for monitoring the progression of the disease and the effectiveness of the therapeutic interventions. The following key data points are collected during anamnesis:

- **Patient Age:** The risk of scoliosis curve progression is higher when the Risser grade, and therefore bone maturity, is lower. However, it is well-established that the earlier the treatment is initiated, the better are the outcomes.

- **Family History:** The presence and progression of scoliosis in family members.

- **Psychomotor Development:** Assessment of developmental achievement and any related issues.

- **Medical History:** Detailed history of the patient’s past and current illnesses.

- **General Health:** Overview of the patient’s overall health and lifestyle.

- **Sports Activity:** Information on the patient's involvement in sports.

- **Aetiology of Scoliosis:** Investigation of potential causes for acquired scoliosis.

- **Previous Interventions:** Review of prior pharmacological treatments, surgeries, or trauma.

Anamnesis also plays a crucial role in building rapport with the patient, who is likely to face a long-term and sometimes challenging journey. Focusing on both physical and psychological health helps create a supportive environment, encouraging patient engagement in their long-term care.

Physical Examination

The physical examination aims to detect scoliosis through systematic evaluation of the undressed and barefoot patient in various positions, as described by Kotwicki[17].

Examination of the Standing Patient

The patient is examined standing with tense lower limbs and relaxed upper limbs. Feet are positioned parallel, slightly apart to prevent knee contact, ensuring a stable support base and minimizing compensatory postures. If the patient uses a foot elevation, the examination should be conducted both with and without it. Pelvic imbalances are corrected using a raised platform under the shorter limb. The examination focuses on several key aspects:

- **Spinal Profile:** Evaluation of the physiological curves of the spine.
- **Pelvic Position:** Observation of the iliac spines for signs of anterior or posterior tilt.
- **Abdominal Protrusion:** Noting any abnormal prominence of the abdomen.
- **Trunk Balance:** Assessment of trunk positioning, including antepulsion or retropulsion.
- **Head Positioning:** Relative position of the head to the trunk and the entire body.
- **Shoulder and Scapular Asymmetry:** Observation of asymmetry in relation to spinal curvature.
- **Waistline Asymmetry:** Evaluation of the space between the lateral trunk and arms, typically reduced on the convex side of the curve.

Examination of the Patient in Forward Flexion (Adam's Test)

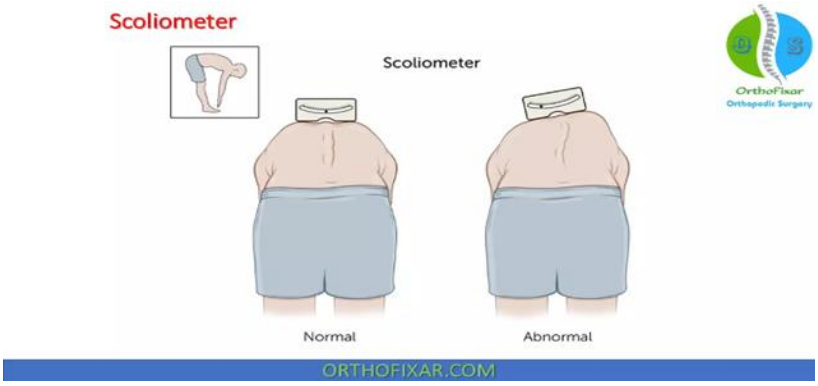
Scoliosis is further assessed by the Adam's test, where the patient bends forward. The degree of spinal deviation is observed by noting the spinous process's distance from the midline. Height differences between the concave and convex sides are measured, and the use of a plumb line helps evaluate physiological spinal curves.

Various scales, tests, and instruments enhance the objectivity of the physical examination, surpassing simple visual observation. For instance, the Adam's test identifies the spinal hump at different trunk flexion angles, highlighting lumbar and thoracic abnormalities. The severity of this hump is quantified using scoliometric devices.

Bunnel Gibbometer (Scoliometer)

The Bunnel gibbometer measures the angle of trunk rotation (ATR) with reliable inter-examiner repeatability[18]. It is used alongside the Adam's test to assess scoliosis severity, noting the maximum inclination during trunk flexion. Measurements are recorded at specific points (e.g., C7, D7-9, L3, S1) and can be used for subsequent patient assessments. The ATR's sensitivity and specificity guide decisions on the need for radiographic imaging in particular if it detects more than 7° a radiography is needed. Additional tests evaluate muscle tension, abdominal and trunk muscle strength, joint mobility, and ligamentous hyperlaxity, which may influence scoliosis development due to altered collagen properties. Curve stiffness is also a significant factor in determining scoliosis progression.

To obtain a more comprehensive functional assessment, the patient should be evaluated in different positions, including kyphosis, lateral flexion, passive extension, and trunk rotation. These positions help identify potential compensatory mechanisms and structural limitations. The presence or absence of ligamentous hyperlaxity is a critical aspect to assess, as literature suggests that this condition could increase the risk of scoliosis development due to altered collagen properties. Furthermore, evaluating curve stiffness provides essential information about the biomechanical behaviour of the spine and its potential for progression, aiding in treatment planning and prognostic considerations.



https://orthofixar.com/specialest/adams-forward-bend-test/

Radiographic Evaluation

Radiographic evaluation is the gold standard for scoliosis diagnosis and essential for assessing curve progression until skeletal maturity. It involves antero-posterior and lateral projections, with the Cobb angle serving as the primary metric for curve assessment. Radiography provides critical insights, including:

- **Differentiation between Functional and Structural Scoliosis:** Identification of scoliosis type.
- **Curve Localization and Count:** Determination of the location and number of scoliotic curves.
- **Risser Sign:** Assessment of skeletal maturity.
- **Vertebral Rotation** with Nash-Moe method: it assesses the position of the pedicles on anteroposterior radiographs classifying vertebral rotation into five grades, based on how much the pedicles shift towards the midline; despite its limitations, it remains a commonly used tool due to its ease of use and non-invasive nature[19].

- **Presence of altered kyphosis or lordosis:** normal thoracic kyphosis goes from 20° to 45°, normal lumbar lordosis goes from 20° to 50°.

However, radiographic evaluation has limitations, notably the patient's exposure to ionizing radiation. This is particularly concerning for individuals with structural scoliosis, who may require frequent imaging throughout their lives[20].

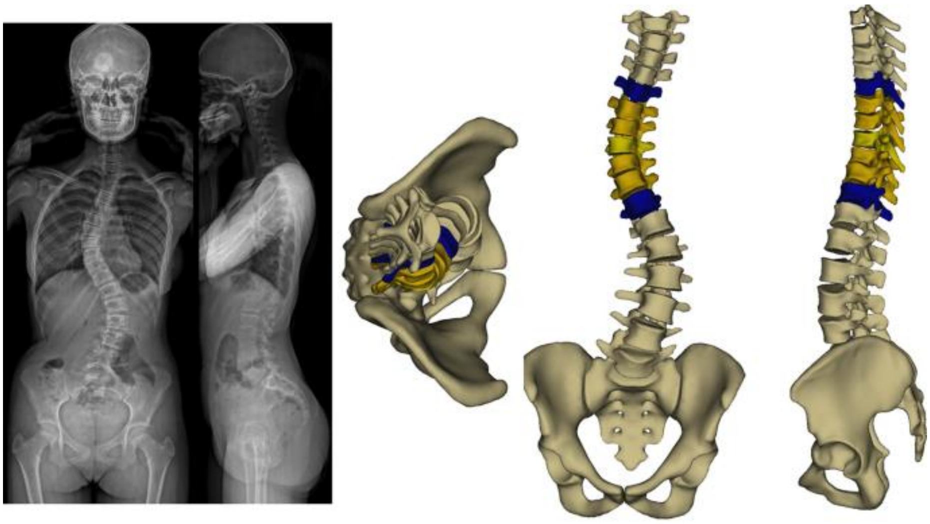


Figure 2: Karam M, Vergari C, Skalli W, Bizdikian AJ, Mehanna J, Kawkabani G, Kharrat K, Ghanem I, Assi A. Assessment of the axial plane deformity in subjects with adolescent idiopathic scoliosis and its relationship to the frontal and sagittal planes.

2.2 IMPORTANCE OF QUALITY OF LIFE ASSESSMENT

It is widely recognized that self-perception and self-image are critical factors in the effective treatment of spinal disorders, particularly in Adolescent Idiopathic Scoliosis (AIS). These psychological elements significantly influence treatment adherence and overall psychological well-being. The bio-psycho-social model acknowledges this connection, integrating psychological and social factors into therapeutic planning. To assess these dimensions, various instruments have been developed, with the Scoliosis Research Society-22 (SRS-22) questionnaire[21] specifically designed for AIS patients.

The SRS-22 has become the primary tool for assessing quality of life in adult scoliosis patients as well. This multidimensional instrument encompasses four core domains: pain (including sensations, medication usage, and illness days due to back pain), function (spinal motor performance in daily activities), self-image (appearance and self-perception), and mental health (covering anxiety, depression, and overall emotional well-being). Each domain consists of five items, with two additional items evaluating patient satisfaction with care. These domains were carefully selected to provide a comprehensive assessment of scoliosis-related quality of life.

The validity of the SRS-22 questionnaire has been consistently demonstrated across numerous studies, including translations and validations in 17 languages. Adolescent scoliosis affects not only physical health but also aesthetics. The visible spinal curvature can cause asymmetry in the shoulders, hips, and rib cage, which may worsen over time. These deformities can significantly impact self-esteem and body image, especially during adolescence. Psychological distress from these changes often leads to social anxiety, low confidence, and appearance concerns. Treatments, such as bracing or specific scoliosis exercises, aim not only to stabilize the curve but also to improve aesthetics, posture, and symmetry, enhancing overall quality of life.

2.3 TREATMENT

The treatment of Adolescent Idiopathic Scoliosis (AIS) involves various approaches that all converge towards the primary objective of preventing the progression of the spinal curve. Severe deformities resulting from AIS can lead to significant functional limitations, including respiratory complications due to thoracic deformities, impaired physical activity, and severe body imbalance affecting load and weight distribution at the foot level.

The treatment strategies outlined in the guidelines of various countries can be categorized into four main approaches[22]:

- **Observation**: This initial approach involves careful and frequent monitoring, including both radiographic imaging and clinical assessments. Observation is not a passive "wait-and-see" strategy but an active process of surveillance. Typically, the interval between assessments does not exceed three months. This method is generally recommended for small curves (not exceeding 15-20°), as premature intervention with bracing or other treatments during the early stages of scoliosis could potentially exacerbate the condition.
- **Physiotherapy**: Specific Scoliosis Physiotherapeutic Specific Exercises (PSSE) are diverse, with various schools of thought proposing different corrective exercises. Physiotherapy is usually prescribed for curves ranging from 10° to 25°, with the frequency of sessions varying from twice weekly to daily, depending on the severity and specific needs of the patient. It is generally agreed that for curves exceeding 25°, physiotherapy alone is insufficient.
- **Bracing**: Bracing is a contentious intervention in the management of scoliosis. While it may be effective in stabilizing the curve and preventing further progression, there is limited evidence linking bracing to significant curve improvement. Bracing is typically prescribed for curves greater than 25° and increasing. For curves between 20° and 30°, a combined approach using both bracing and PSSE exercises may be considered. In cases where the curve ranges

between 30° and 45°, a plaster cast followed by a removable brace is often recommended. Some studies suggest that bracing can effectively stabilize curves even up to 50°, although evidence of curve improvement remains limited. It’s important that the brace is used for 20 to 23 hours during the growth phase.

- **Surgical Treatment**: Surgery is generally indicated for scoliosis with Cobb angles greater than 45° to 50°.

The 2016 SOSORT (International Society on Scoliosis Orthopaedic and Rehabilitation Treatment) guidelines delineate specific goals for conservative treatment during growth, with a consensus of at least 70% among participating experts. These goals are divided into three categories[1]:

- **Absolute Treatment Goals**: These are the foundational principles of any conservative treatment for AIS and include:
  1. **Avoidance of Surgery**: Given its invasive nature, surgery is often avoided unless absolutely necessary.
  2. **Improvement of Aesthetics**: Enhancing the patient's physical appearance.
  3. **Enhancement of Quality of Life**: Improving the overall well-being of the patient.
- **Primary Goals**: These goals represent the best possible outcomes tailored to the specific degree of curvature:
  1. **Low Curvature**: Maintain curvature below 20°.
  2. **Moderate Curvature**: Maintain curvature below 30°.
  3. **Severe Curvature**: Maintain curvature below 40°.
- **Secondary Goals**: These compromise goals are considered when the primary goals are unattainable. They include maintaining the curve below 45° and delaying surgery as long as possible.

2.4 PHYSIOTERAPEUTIC SCOLIOSIS-SPECIFIC EXERCISES (PSSE)

Physiotherapy Scoliosis Specific Exercises (PSSE) represent a targeted, individualized approach specifically designed to manage scoliosis through 3D self-correction of spinal curvature[23]. These exercises aim to empower the patient to actively realign their posture in three dimensions—laterally, rotationally, and vertically—counteracting the curve. A crucial aspect of PSSE is the stabilization of the corrected posture, which is maintained not only during exercises but also integrated into daily activities (ADLs), helping the patient to reinforce proper alignment throughout their daily routines.

Each PSSE program is customized based on a thorough clinical assessment to address the unique characteristics of the patient's spinal curvature. The main objectives of PSSE are to prevent or slow the progression of scoliosis, especially during growth periods. The exercises are typically performed daily, supported by a home exercise program that complements the supervised sessions, ensuring continuous progress and consistency.

To be truly effective and specific, PSSE must adhere to four essential pillars[1]:

1. Active self-correction in three dimensions: This involves teaching the patient how to adjust their posture in all planes of movement, ensuring that corrections are both precise and sustained.

2. Postural training during daily activities (ADLs): The patient learns how to incorporate the corrected posture into everyday movements, making these exercises functional and practical.

3. Stabilization of the corrected posture: Through repeated practice, the patient develops the strength and endurance to maintain the corrected alignment throughout different activities, preventing the return of the scoliotic curve.

4. Patient education: Providing the patient with knowledge about their condition and teaching them how to take an active role in managing their scoliosis is key to long-term success. This education fosters independence, encouraging the patient to integrate postural awareness into all aspects of their life.

By focusing on these foundational elements, PSSE offers a comprehensive, evidence-based approach to scoliosis management, giving patients the tools to take control of their condition and improve their overall spinal health. This structured and personalized method reinforces the importance of consistent practice and professional guidance for optimal outcomes.

This approach ensures that PSSE is not only corrective but also sustainable, offering a comprehensive framework to stabilize the spinal curve and improve both function and quality of life for individuals with scoliosis.

The seven most accredited and successful schools in scoliosis treatment include:

- **The Schroth Methodology**: The Schroth method is one of the most widely researched and utilized approaches for scoliosis treatment. Its effectiveness is often attributed to Rotational Angular Breathing (RAB) techniques, which are central to its three-dimensional scoliosis treatment. The method focuses on postural correction according to specific patterns identified by the Schroth classification, with mirror monitoring providing immediate feedback on body position. The five foundational principles of the Schroth method are: de-torsion (self-elongation), deflection, de-rotation, rotational angular breathing, and stabilization. Over time, several sub-types of treatment have emerged based on these principles[24].

- **The Lyon School**: The Lyon approach emphasizes three-dimensional spinal mobilization, lumbar scoliosis mobilization, patient education, and the correction of daily activities, including sitting posture. The method aims to avoid spinal extension during exercises and increase thoracic kyphosis while promoting lumbar lordosis. This is combined with frontal plane correction, segmental mobilization, core stabilization, proprioception, and balance training.

- **SEAS (Scientific Exercise Approach to Scoliosis)**: SEAS exercises focus on self-correction and stabilization. The primary goals are to enhance spinal function and stability while addressing impediments such as muscle weakness, retractions, and motor coordination issues identified during the initial assessment.

- **BSPTS (Barcelona Scoliosis Physical Therapy School):** The BSPTS approach is based on the fundamentals of the Schroth method, with correction principles rooted in global postural alignment. High-intensity forces generated within the body, involving isometric tensions and specific breathing techniques, are applied. The four basic concepts of BSPTS are: three-dimensional postural correction, expansion/contraction techniques, muscle tension stabilization, and integration.

- **Side Shift**: The Side Shift method focuses on intensive training for trunk flexion. It involves active self-correction, where the patient is taught to move the trunk laterally over the pelvis in the opposite direction of the primary curve's convexity.

- **DoboMed**: The DoboMed method emphasizes strengthening and increasing thoracic kyphosis through closed kinetic chain exercises. It involves symmetrical pelvic positioning followed by active stabilization of the optimal posture, which is then maintained and developed as a habitual posture. The method also includes angular rotation and Schroth breathing exercises.

- **FITS (Functional Individual Therapy of Scoliosis):** FITS is a two-stage approach that involves the release and elimination of myofascial restrictions, followed by the development of new postures during daily activities.

2.5 KINESIOTHERAPY AND PSSE

Kinesiotherapy, particularly Physiotherapeutic Scoliosis-Specific Exercises (PSSEs), serves distinct roles in the treatment of Adolescent Idiopathic Scoliosis (AIS). For cases of minor scoliosis, the primary objective of physiotherapy is to correct and maintain spinal alignment, often as the only therapeutic intervention. However, when used as an adjunct to other treatments such as bracing or surgery, physiotherapy aims to facilitate the reduction of spinal deformities, eliminate compensatory mechanisms within the spine and the rest of the body, maintain and enhance pulmonary function, minimize the side effects of orthotic devices, and accelerate postoperative recovery.

It's recommend that rehabilitation programs be designed and implemented by physiotherapists who are specifically trained in scoliosis treatment methodologies. In the domain of scoliosis physiotherapy, several recognized schools of thought have developed[1;23].

The frequency of kinesiotherapy sessions varies depending on the chosen methodology, the complexity of techniques, patient motivation, and the ability to adhere to the treatment regimen. Typically, sessions occur three to four times per week, but intensive home-based programs may require daily practice. Each approach must be carefully explained to patients, as the techniques and underlying principles may be challenging for some individuals to grasp.

Although there remains some global skepticism regarding the efficacy of these kinesiotherapy techniques in scoliosis patients, numerous studies, particularly recent ones, affirm the effectiveness of these methods[24]. They have been shown to slow or reduce scoliotic curvature and provide additional benefits, such as improved neuromotor control, enhanced respiratory function, increased muscle strength, and improved body aesthetics and posture.

2.6 TREATMENT OUTCOMES

In their 2023 scoping review, Joarder et al. explored the varying definitions of "successful" treatment outcomes in Adolescent Idiopathic Scoliosis (AIS), revealing a lack of consensus in the literature. The authors reviewed clinical and radiographic measures traditionally used to define success, such as the reduction or stabilization of the Cobb angle, along with broader criteria including patient-reported outcomes and quality of life measures. They highlighted that while most studies emphasize the importance of halting curve progression, there is growing recognition of the need to integrate functional outcomes, psychosocial factors, and patient satisfaction into success metrics. The review underscores the complexity of defining treatment success in AIS and advocates for a more holistic approach, combining radiographic criteria with individual patient experiences and long-term functional health. This more comprehensive perspective can better guide clinicians in tailoring interventions that address both the physical and psychosocial dimensions of scoliosis[25].

One of the most commonly used tools to assess the quality of life in adolescents with idiopathic scoliosis is the Scoliosis Research Society-22 questionnaire (SRS-22). This questionnaire is specifically designed to evaluate patients' perceptions regarding their function, pain, self-image, mental health, and satisfaction with treatment. The SRS-22 is widely adopted because it is validated, easy to administer, and sensitive to changes over time, making it particularly suitable for both clinical and research settings. Its use allows clinicians and researchers to capture the patient’s subjective experience, complementing objective measures such as the Cobb angle. Moreover, considering that adolescents with scoliosis may experience psychological and social challenges related to body image and treatment adherence, the SRS-22 offers a comprehensive view of the impact of scoliosis and its treatment on daily life, thus supporting a more patient-centered approach in evaluating treatment outcomes.[3]

2.7 MYTHS TO DISPEL

Various false beliefs exist around scoliosis, mainly due to the complexity of the condition and the predisposition to seek the quickest and easiest solution.

Until a few decades ago, treatment options for scoliosis were limited, and approaches such as exercise were seen as one of the few tools available. Even today, even some health professionals rely on outdated or incomplete information about scoliosis, perpetuating beliefs that are not supported by recent studies.

- Swimming as a recommended sport during scoliosis treatment.

It is not true that any muscle strengthening can help correct the curve; in fact, as was already explained at the beginning of Chapter Three, the problem is not only muscle strength, but also bone structure and growth, so correction often requires a more specialized and targeted approach.

A body immersed in water is subjected to less gravitational force, and for this reason the antigravity muscles do not need to work as much as they would under normal conditions, but it is these muscles that act most on the spine and posture.

Studies show that swimming, especially competitive swimming, can increase the risk of muscular asymmetries and spinal deformities such as hyperlordosis and hypercyphosis, worsening posture in some cases of scoliosis[26].

For this reason swimming is no longer recommended by specialists in the field, in its place other sports stand out that help more with muscle control and postural alignment; one above all is ballet, this in fact emphasizes all those characteristics that can be useful in maintaining correct posture. Care must be taken here, too, as it has been observed that some adolescent dancers, especially those with intense training and delayed menarcheal development, may have a higher incidence of scoliosis. Therefore, dance can be beneficial if practiced in moderation and with attention to physical growth and development[27].

Other recommendable sports are yoga and pilates mainly because they improve body awareness as well as being useful for strengthening trunk muscles and stabilizing the spine[28], walking and cycling because they are low impact and can be safely practiced by those with scoliosis, promoting physical endurance without causing excessive stress on the spine[29].

Finally, it is interesting to note the finding that is made by this last mentioned study: as the prevalence of health problems associated with a sedentary lifestyle increases, there is a worldwide promotion of sports activities to stimulate physical activity. As a result, the number of children and adolescents participating in recreational and competitive sports is growing. As a result, more and more children will require a medical examination before starting such activities. During this evaluation, scoliosis is often first detected. To provide adequate information, a physician caring for children and adolescents must have knowledge about scoliosis, its progression, and potential complications.

- Poor posture causes scoliosis.

A recent study of a large sample of adolescent girls found that there is no significant association between lifestyle factors (such as posture or environment) and the onset of adolescent idiopathic scoliosis. However, the study identified some other risk factors, such as ballet practice, a low body mass index, and a family history of scoliosis, while finding no correlation between posture or general activities and scoliosis[30].

- Scoliosis is always painful

In fact, scoliosis, especially adolescent idiopathic scoliosis, often does not cause pain. Although pain may appear in adulthood or in severe cases, many adolescents with mild or moderate scoliosis do not experience any painful symptoms. Studies show that scoliosis does not always cause significant discomfort, especially in the early stages[31].

- All curvatures progressively worsen over time

Not all scoliosis worsens with time; progression depends on various factors such as age and the extent of the initial curve. For example, mild curves (<20°) in adults often remain stable and do not require special treatment[32].

CHAPTER 3: THE S4D METHOD

3.1 THE THEORY BEHIND THE METHOD

It is important to establish that scoliosis is not merely a postural defect but a true alteration of the growth plate, which means that without positive stimuli, the likelihood of progression is high[33].A study on patients with idiopathic scoliosis, using transcranial magnetic resonance imaging, demonstrated that these individuals have altered mental representations of posture and motor patterns[34].

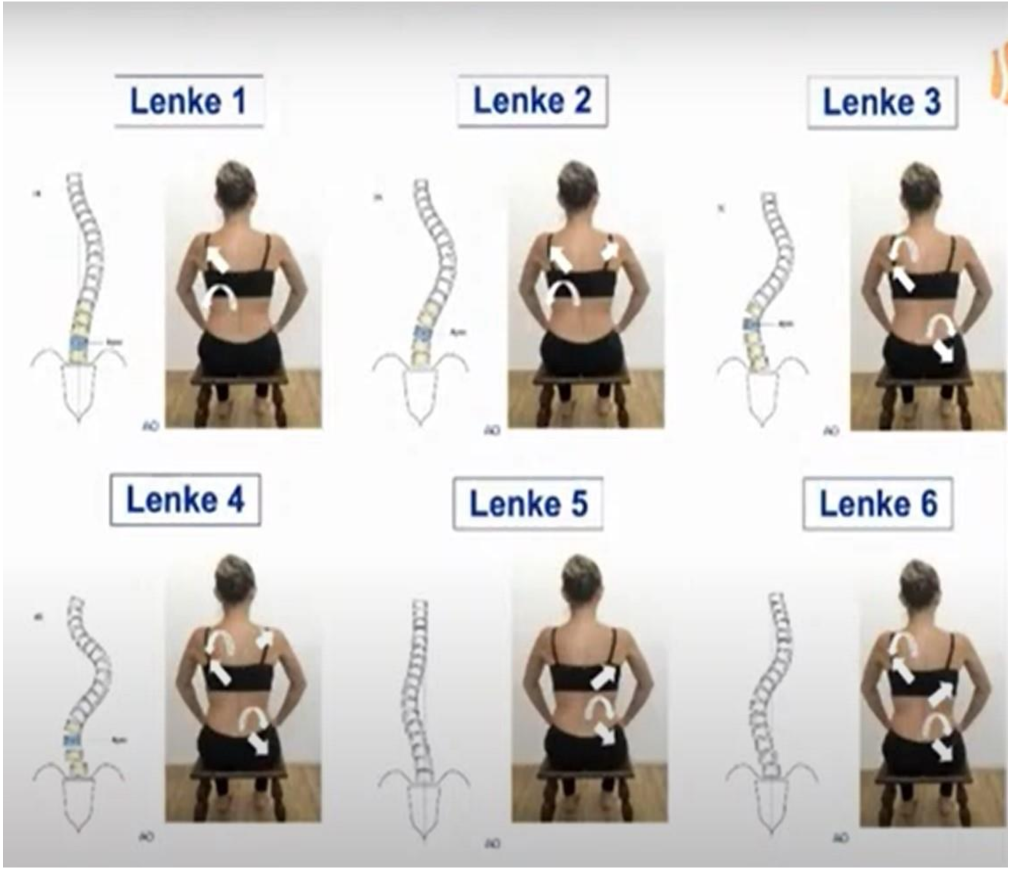
For this reason, the core concept behind S4D exercises is that they should not be only focused on the musculature, but aimed at a true cortical modification. For these exercises to be effective, it is crucial that the patient understands both the ratio and the correct execution, allowing them to actively participate in their treatment. For this reason, having a trained professional present to provide verbal feedback is essential in helping the patient both physically and cognitively. The use of a mirror is also important as it enables the patient to self-correct in real-time. In the clinic it would be perfect if there was also the possibility of showing the patient his back, for example via a television connected to a camera placed behind. Moreover, the exercises should be performed with minimal pain, as pain can reduce adherence to the treatment plan.

3.2 LENKE CLASSIFICATION SYSTEM

The Lenke classification system[35] is a widely used method for categorizing the curve patterns in adolescent idiopathic scoliosis (AIS). It was developed to provide a comprehensive and reliable means to guide treatment, particularly surgical intervention. The use of this classification to propose specific exercises for each possible type of scoliosis is one of the major advantages that the s4d method brings as it not only allows for greater customization but also greater understanding on the part of the patient and his family but also of any other professional figures who can assist him. The classification system is based on three main components: curve type, lumbar spine modifier, and sagittal thoracic modifier.

Curve Type: The Lenke system identifies six primary curve types based on the location and number of structural curves:

- 1. Thoracic scoliosis
- 2. Thoracic and proximal scoliosis
- 3. Primary thoracic and secondary lumbar scoliosis
- 4. Thoracic, proximal, and lumbar scoliosis
- 5. Lumbar scoliosis
- 6. Primary lumbar and secondary thoracic scoliosis



Primary lumbar and secondary thoracic scoliosis

Primary lumbar and secondary thoracic scoliosis Lumbar Spine Modifier: This modifier is based on the position of the lumbar curve relative to the central sacral vertical line (CSVL). It isn't used in conservative treatment but it's important in case of surgery. It is categorized into three types:

- A: The lumbar curve apex is between the CSVL and the lateral border of the vertebral body.
- B: The lumbar curve apex is on the CSVL.
- C: The lumbar curve apex is lateral to the CSVL.

Sagittal Thoracic Modifier: This modifier assesses the thoracic kyphosis (the curvature of the upper spine) and is categorized into three types:

- -: Hypokyphosis (less than 10 degrees)
- N: Normal kyphosis (10 to 40 degrees)
- +: Hyperkyphosis (greater than 40 degrees)

- ## 3.3 ASSESSMENT

In cases where scoliosis is suspected through clinical evaluation, it is essential to confirm the diagnosis with an X-ray, which should be taken both in the frontal and sagittal planes. This radiograph will be used to:

- Assess the **Risser sign** for skeletal maturity,

- Determine whether the curve is compensated by checking the vertical alignment of the occipit with the sacrum,

- Measure the degree of curvature using the **Cobb angle**,

- Evaluate vertebral rotation using the **Nash-Moe** method,

- Check for the presence of **hyperlordosis** or **hypolordosis**, as well as **hyperkyphosis** or **hypokyphosis**.

Based on this objective data, a personalized therapeutic plan is developed.

Before initiating the treatment, other tests are made, and photos are taken to serve as a reference point for tracking the patient's physical changes over time.

1. A photographic evaluation should be performed every 30 days. These photos are taken with a grid and laser as background tools to help assess postural.

Photos are captured with the patient in various positions: front view, back view, side views, seated, balancing on one foot, forming an arc with the torso and arm, and in forward bending.

2. Bilateral third finger-to-floor test. Assess the patient in a lateral view.

3. Seated rotation test: mark the center of the bench with the laser and ask the patient to rotate with arms crossed in front of the chest, while seated, bilaterally.

4. Third finger-to-floor test: the patient stands against the symmetrogaph, the therapist stabilizes the pelvis and asks for lateral flexion with the arm sliding down the side of the body. Once the maximum range of motion is achieved, use a tape measure to assess the distance between the third finger and the floor.

5. **SCOLIOMETER (Adams Forward Bend Test)**: observe the trunk rotation angle. Using a scoliometer, the patient places hands together (palm to palm) and slowly bends forward, performing an anterior trunk flexion while the scoliometer is passed from the nape of the neck to the base of the spine. Record findings with a photo or video.

6. **INCLINOMETER**: assess the patient in the sagittal plane for physiological curvatures. Position the inclinometer on C7, then assess T12 and sum the results. Afterwards, measure S1 and sum it with the T12 measurement.

- Lumbar ≈ 50º
- Thoracic ≈ 45º

7. **SCHOBER'S TEST**: assess lumbar spine mobility. Identify the posterior superior iliac spines (PSIS), locate the midpoint between them, and using a tape measure, measure from this point to 10 cm above, with the patient standing.

Subsequently, the patient performs anterior trunk flexion and re-measures the 10 cm mark (previously measured) with the newly found data. **RESULT**: If the patient exceeds 5 cm (e.g., 15 cm total or more = good lumbar mobility), below this value = poor mobility.

8. **STIBOR TEST**: assess the mobility of the thoracic spine. Initially, measure the midpoint of the posterior superior iliac spines (PSIS) with C7, then the patient performs anterior trunk flexion and a new measurement between these points is obtained. **RESULT**: ideal measurement should exceed 10 cm (e.g., 47 cm initial measurement, 55 cm second measurement, with 8 cm total indicating thoracic hypomobility).

9. 3rd finger test: during an anterior bending take the measure from the 3rd finger of the patient to the floor

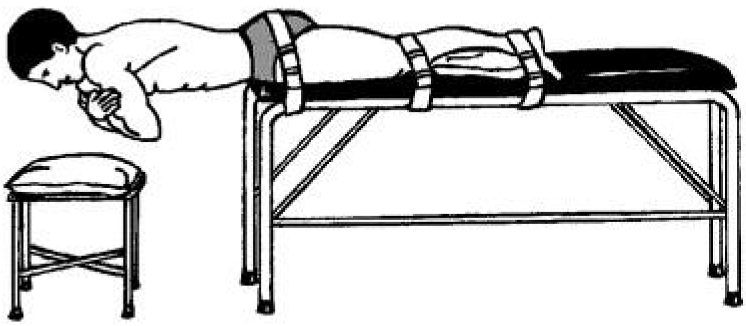
LYING DOWN:

10. Difference between the lower limbs: the patient lies down and relaxes, perform apparent and real measurements.

- Apparent measurement: highest point of the umbilical scar to the medial malleolus.
- Real measurement: from the anterior superior iliac spine (ASIS) to the lateral malleolus.

11**. Extension Mobility of the Spine**: patient in the prone position on the table with head supported, measure with a tape measure from the table to the sternal manubrium (initial measurement), then ask for extension of the trunk and measure again (final measurement). **RESULT**: initial measurement – final measurement = “x” assess the active range of motion (ADM). The acceptable range of motion is between 10 cm and 20 cm. < 10 cm indicates hypomobility, > 10 cm indicates hypermobility.

12**. SORENSEN TEST**: Patient positioned in the prone position with the trunk off the table, the



therapist stabilizes the pelvis and requests trunk extension for 1 minute. Assess the presence of pain or oscillations; if unable to maintain for 1 minute, note how many seconds the patient was able to hold the position.

ABDOMINAL STRENGTH TEST: patient lying supine, evaluate statically and dynamically, with knees flexed at 60º, request trunk flexion. **RESULTS**:

- **GRADE 3** (performed with arms extended in front of the body)
- **GRADE 4** (arms crossed over the chest)
- **GRADE 5** (hands behind the head and elbows open)

13. According to the assessed grade for fast-twitch fibers, instruct the patient to perform a 30º abdominal contraction and maintain this position for 1 minute to assess slow-twitch fibers. Assess for pain or oscillations; if unable to maintain for 1 minute, note how many seconds were achieved as the test result.

3.4 TREATMENT

After identifying the scoliotic pattern, the personalised three-dimensional correction begins starting with the patient seated, It proceeds from the bottom upwards.

The underlying principle of curve correction is that, on the concave side, there is an ipsilateral vertebral rotation and approximation of the transverse processes. If there is a lumbar curve, it will be corrected by moving the hip on the concave side backwards, to compensate for the rotation, and downwards, to distance the transverse processes from each other. A good proprioceptive feedback method involves placing a pen under the ipsilateral gluteus so that the patient can feel themselves pressing on it.

Similarly, if there is a thoracic curve, it will be corrected by moving the shoulder on the concave side upwards and backwards.

On the sagittal plane, the upper limbs assist in the correction: the hands are placed on the hips, and the elbows are brought forward to increase kyphosis or moved backwards to decrease it. Typically, scoliotic patients present with a straightened spine, so the elbows should be brought a little forward. Lumbar lordosis can be increased by anterior pelvic tilt or decreased by posterior pelvic tilt that should also be performed with a lower range in cases of normal lordosis, as it helps activate the abdominal muscles.

	Limits	Physiological degrees
Thoracic Kyphosis	T5-T12	20-45°
Lumbar Lordosis	L1-S1	20-50°

In practice, verbal feedback will include:

"Sit with knees shoulder-width apart, hands on hips, elbows forward/backward, pelvis on the concave side back and down, opposite shoulder up and back, grow tall, take three deep breaths on the side of the thoracic concavity (same side as the moved shoulder), relax. Repeat 10 times."

Once the correction is understood and internalized, the difficulty will progressively increase. First, by going from 3 breaths for 10 repetitions to 10 breaths for 3 repetitions, then by adding a second exercise and a third. When 3 exercises are mastered, the first will be replaced each time a new one is introduced.

Examples of additional exercises:

- Starting seated with the correction described above, the patient stands up. An additional correction is made before sitting back down, and before relaxing, the breaths are performed with a possible third correction if needed.

- Standing with forearms against a doorframe, the foot of the convex side of the lordosis is brought forward, and the arm on the concave side of the thoracic curve is slightly raised. These adjustments help compensate for the vertebral rotation and transverse process approximation.

- With the patient seated, a pole is positioned on the side of the thoracic concavity. The arm on the same side holds the pole higher to open the concavity, while the opposite arm, that is farther, reaching the pole allows compensation of the rotation. This exercise is particularly beneficial when the thoracic curve is predominant.

- with hands placed on a backrest at eye level, the patient will bend forward so that the torso and arms are in line and the legs are straight. All adjustments will be performed in the same way but in this case there is greater intervertebral traction due to the position.

- same as before but on one foot

There are many other exercises; here, I have only mentioned some of the most commonly used ones. More generally, each patient will perform exercises focusing on function, balance, mobility, and dual-tasking while maintaining active self-correction. However, there are no supine exercises included.

The protocol for exercise dosage recommends daily sessions of 30 minutes, with a change in the exercise routine every month.

3.5 S4D BRACE

The Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT)[1] and the Scoliosis Research Society (SRS)[36] recommend to use braces in patients with a Cobb angle between 20° and 40° who are still growing, typically identified by a Risser sign between 0 and 2 or in girls before menarche.

The main indication for bracing is a documented curve progression of more than 5 degrees. The primary goal of brace treatment is to prevent further progression of the spinal deformity, thus avoiding the need for surgical intervention[37]. Additionally, bracing aims to maintain proper spinal alignment during growth, enhancing the patient's cosmetic appearance and postural balance.

The recommended duration of brace wear depends on the severity of the curve and the type of brace, but typically ranges from 16 to 23 hours per day. Treatment continues until skeletal maturity is reached, which corresponds to a Risser sign of 4 or 5, or two years post-menarche in girls. During the treatment period, regular follow-up visits are essential every 4 to 6 months, including clinical and radiographic evaluations to monitor curve progression and the effectiveness of the brace correction. X-rays are usually performed while wearing the brace to assess the postural correction achieved, and adjustments are made according to growth and curve evolution.

It is also crucial to consider the psychological and social aspects associated with bracing, as the treatment can affect the adolescent's body image and social life. Therefore, proper education and psychological counselling can improve adherence to the treatment. Furthermore, combining bracing with Physiotherapy Scoliosis Specific Exercises (PSSE) has proven beneficial in enhancing postural control and increasing compliance[38].

Brace treatment is generally stopped once skeletal maturity is reached and the curve is stabilized. In this case, gradual weaning from the brace is recommended to prevent possible curve rebound.

The Sforzesco 4D (S4D) brace is an advanced version of the Sforzesco brace developed in Italy, incorporating a "fourth dimension": active muscle stimulation along with passive control of spinal curvature. This feature sets it apart from traditional scoliosis braces, like the Boston or Chêneau braces, which focus mainly on 3D containment of the spine. Here are the main features that distinguish the S4D from other braces:

1. Integration of the "fourth dimension" (active movement and stimulation):

- The S4D brace is designed not only to provide passive support and correction but also to stimulate the postural muscles. This stimulation is achieved through specific openings and pressure zones that encourage muscle activation and ongoing self-correction while the patient wears it.

- The goal is to activate spinal muscles to improve stability and actively support spinal alignment, even when the brace is not being worn.

2. Custom decompression and pressure zones:

- Like the classic Sforzesco brace, the S4D is custom-made and includes pressure zones targeting the prominent parts of the scoliotic curves, combined with decompression openings that allow some freedom of movement. In the S4D, these zones are further refined to enhance muscle response and alignment without rigid compression, enabling the patient to move more naturally.

3. Modular and adaptable structure:

- The S4D design allows for precise adjustments as the patient grows or as spinal morphology changes. It is built to accommodate modifications without compromising effectiveness, so the brace can be precisely adjusted over time.

4. Improved comfort and compliance:

- The S4D is designed to be less bulky than classic rigid braces, offering a balance between control and comfort. This improvement increases patient compliance, which is essential for successful conservative scoliosis treatment.

These characteristics make the S4D brace a recommended option for growing patients and for scoliotic curves at risk of progression.

To build this kind of brace a 3D scan of the patient in active self-correction is performed and uploaded into specialized software, through which a 3D printer will create the brace.
To verify its effectiveness, an X-ray will be taken with the brace on and compared to a previous one taken without correction[39].

3.6 S4D AND PHYSICAL ACTIVITY

As described earlier in section 2.5, the long-term goal of treatment is to automate the correct posture, which initially involves consciously applying corrections even during daily activities. To achieve this, Andrade provides examples of exercises to perform and avoid in the gym[40].

In cases where hypokyphosis of the thoracic spine is present, which is common, exercises that bring the shoulder blades together should be avoided. This is because contraction of the rhomboid muscles can straighten the spine, worsening the Cobb angle and complicating breathing, which is also a crucial part of rehabilitation. However, if hyperkyphosis is present, these exercises can be beneficial. This underlines the importance of an initial evaluation, as a correct assessment is key to successful therapy.

So, should exercises like rows and pull-ups be completely ruled out for all hypokyphotic patients? Not necessarily. Patients should be taught to stop before their shoulder blades excessively come together. Therefore, it is essential that physical activities and daily routines align with the corrective posture learned in clinical settings.

Andrade further explains that exercises involving axial loading on the spine may worsen the curve in individuals with existing imbalances in antigravity muscles and lacking postural control[41]. Although no conclusive evidence exists, this might be a question of ethics; however, there is proof supporting that traction can correct spinal deformities[42]. Similarly, exercises involving trunk bending or twisting require caution: they should be prescribed in a way that emphasizes the side where the curve opens, allowing the vertebrae to rotate toward the convexity.

Therefore, it is crucial for healthcare professionals working with scoliosis patients to have specialized knowledge of the condition and coordinate with one another to properly guide patients.

CHAPTER 4: CLINICAL CASES IN UNEB UNIVERSITY ENVIRONMENT

4.1 INTRODUCTION TO THE PROJECT

This chapter is a relato of my experience at the University of Bahia (UNEB) in Salvador (Br). I arrived at this university through the "*Ulisse overseas*" program and the cooperation of Professor Angelini from the University of Padua and Professor Lessa from UNEB.

During my stay in Salvador, I followed the activities proposed by Professor Paulo Lessa, who will be the co-rapporteur of this thesis, both in terms of the theoretical part in the classroom and the practical part, actively participating in the clinic-school of orthopedics and extensão regarding scoliosis and lumbar problems.

By "extensão" we mean an additional, non-compulsory, more topic-specific practical part; during which I learned most of the notions I am reporting in this thesis.

At the University of Bahia there is a curricular internship for sixth-semester students called "clinica-escola," it involves students following a patient on his or her therapeutic journey with the assistance of a professor.

Patients, in this way, get free physical therapy sessions, which, in a country like Brazil, for many people is the only way to get such treatment. Students, on the other hand, can take their first steps into the world of physiotherapy by putting into practice the theory they have already studied and with less responsibility, as the professor is always ready to correct and advise how to carry out the session.

4.2 LOCAL ORGANIZATION

Each subject has its own part of the clinica-escola and therefore almost every patient can be expected and almost every area is practiced by the student. In addition to the better known areas of orthopedics, neurology and developmental age there are those kind of stage in sports, respiratory, occupational and geriatric physiotherapy, women's health, worker's health and a specific one for temporomandibular joint rehabilitation that is very advanced in Brazil.

From my point of view, this model of stage is extremely effective because the tutor is the same professor who delivers the theory in the classroom and therefore there is the right continuity with the practical part, avoiding that, on the contrary, the knowledge required is different from the knowledge possessed.

As far as I am concerned, I participated in the 8-hour weekly “clinica-escola” in the orthopedic field, in which I was assigned 6 patients, and the 4-hour weekly extension, which is the main character of the thesis. Both practical parts were held in such a way that there was always at the beginning and/or at the end a time for teaching and discussion of the practices to be used while in between patients would arrive in turn for an initial assessment visit or to continue the course already started with the assigned student.

The main differences are that in the orthopedics practice, I had fixed patients who only changed when their treatment was completed, and in my group, there were 5 other students, each with their own patients. In the scoliosis extension program instead, there were 15 students, and patients were often monitored by a pair of students who were not always the same. This experience was also valuable for observing different types of curves and figuring out, case by case, how to proceed with the treatment

An interesting peculiarity regarding the organization of the extension is that since it is optional, students from different years of the course can participate in it, so those who have more experience act as monitors for the others, without necessarily having to go through the professor each time, who therefore does not have to follow all the students with their patients at the same time.

One of the most commonly used tools to assess the quality of life in adolescents with idiopathic scoliosis is the Scoliosis Research Society-22 questionnaire (SRS-22). This questionnaire is specifically designed to evaluate patients' perceptions regarding their function, pain, self-image, mental health, and satisfaction with treatment. The SRS-22 is widely adopted because it is validated, easy to administer, and sensitive to changes over time, making it particularly suitable for both clinical and research settings. Its use allows clinicians and researchers to capture the patient's subjective experience, complementing objective measures such as the Cobb angle. Moreover, considering that adolescents with scoliosis may experience psychological and social challenges related to body image and treatment adherence, the SRS-22 offers a comprehensive view of the impact of scoliosis and its treatment on daily life, thus supporting a more patient-centered approach in evaluating treatment outcomes.[3]

4.3 CLINICAL PROFILE OF PATIENTS WITH SPINAL DEFORMITIES AND POSTURAL ALTERATION IN A SCHOOL-CLINIC IN A BRAZILIAN PUBLIC UNIVERSITY

During these 6 months, 20 children were evaluated, 17 females (85%) and 4 males (15%), aged 8-18 years (mean 23). The first evaluation visit was in March 2023 while the last one was in November 2024 which makes it impossible to compare the effectiveness of treatments with each other.

In their first visit 15 patients presented after the diagnosis of scoliosis, while of the remaining 5, 2 arrived after arthrodesis surgery, 1 had hypercifosis, and 2 had functional scoliosis.

Here is the summary table of the 20 observed patients sorted by Lenke's classification and degrees of the major curve.

Patient	Sex	Age	Lenke	Cobb of the proximal curve	Cobb of the thoracic curve	Cobb of the lumbar curve	Risser	Brace	Scoliometer thorax	Scoliometer lumbar
001	F	14	1	#	28L	#	3	NO	13D	4E
002	F	15	1	#	35R	#	3	NO	12D	8E
003	F	8	1	#	39R	#	0	NO	15D	5E
004	F	11	1	#	43R	25L	2	YES	11D	5E
005	F	22	1	#	49R	#	5	NO	8D	10E
006	F	12	3	#	32R	32L	1	YES	5D	7E
007	F	12	3	#	39R	21L	2	NO	5D	6E
008	F	12	3	#	41R	20L	4	NO	12D	4E
009	F	15	3	#	42R	16L	4	NO	9D (6E prox)	4E
010	M	14	3	#	43R	30L	5	NO	10D	5E
011	F	13	4	28L	27R	33L	2	YES	8D (8E prox)	3E
011	F	13	5	#	#	30R	2	NO	#	9D
013	M	14	5	#	#	33R	3	NO	7E	9D
014	F	17	6	#	29R	33L	5	NO	6D	8E

015	F	12	6	#	39R	42L	2	NO	11D	6E
016	M	11	Non-structural scoliosis		#	#	N.E.	NO	#	#
017	F	14	Non-structural scoliosis		9L	#	N.E.	NO	3E	2D
018	F	11	Hipercifosis		#	#	N.E.	NO	5D	5E
019	F	18	Arthrodesis		#	#	2	NO	16D	8E
020	F	16	Arthrodesis		#	#	5	NO	5D	10E

Using the SOSORT classification explained in chapter 1.3, there were 7 moderate, 2 moderate to severe and 6 severe scoliosis.

low (0-20)	moderate (21-35)	moderate to severe (36-40)	severe (41-50)	severe to very severe (51-55)	arthrodesis	not scoliosis
0	7	2	6	0	2	3

As you can see at the time of the first evaluation 5 patients present a type 2 Lenke, none type 2, 5 type 3, 1 type 4, 2 type 5 and 2 type 6.

At that time the Risser classification was 0 for 1 patient, 1 for another, 2 for 6 of them, 3 for 3, 4 for 2 and 5 for 4; only 3 patients were wearing a brace.

LENKE	TOT	RISSER	TOT	BRACE	TOT
1	5	0	1	YES	3
2	0	1	1	NO	17
3	5	2	6		
4	1	3	3		
5	3	4	2		
6	3	5	4		

Table: patient characteristics at intake

4.3.1 THERAPEUTIC INTERVENTIONS

As already explained, sessions are held once a week, the time devoted to each patient varies depending on the time of treatment but as there are several mirrors in the room up to 8 patients can be attended simultaneously with the supervision of at least one student.

Typically, the first evaluation can last up to an hour, while a classic session lasts no more than 40 minutes.

As foreseen by the s4d method, the exercises during the session were decided based on each patient's specific curve type and then strongly recommended to be repeated at home. Family members, always present as minor caregivers, had the secondary task of helping in understanding the exercise and stimulating independent repetition, although the focus was more on the patient's own motivation.

4.4 CRITICAL ISSUES AND LIMITATION

The decision to conduct a simple descriptive study was influenced by several limiting factors. Firstly, the absence of a control group prevented us from determining the specific impact of the S4D method on the observed changes in the population. Secondly, the sample size was too small to be representative, which limits the generalizability of the findings. Additionally, the observation period was insufficient to assess the long-term effectiveness of the treatment: many participants had started rehabilitation less than six months prior, making it premature to evaluate the outcomes meaningfully within such a short timeframe.

Conducting a randomized clinical trial in this context would pose significant challenges, particularly due to the individualized and non-standardized nature of the protocol, which would require rigorous monitoring of adherence. Furthermore, the variability introduced by measurements taken by different operators complicates the reliability of the data collected. Another significant limitation is the influence of external factors: patients engaged in activities outside the prescribed treatment plan, making it impossible to isolate the effects of the S4D method on the scoliotic curve.

On a personal level, I encountered initial challenges related to the language barrier. During the early phase of my experience, I struggled to give precise instructions for small, specific movements of particular body areas, despite having a clear theoretical understanding of the technique. However, by closely observing my colleagues and continuing to study the language, I was able to standardize my communication, ensuring that the information provided was clear and consistent for all patients.

Lastly, the study design does not account for potential biases, such as the placebo effect or patient motivation, which may have influenced the results. Future studies could address these issues by implementing more controlled designs, increasing the sample size, and extending the observation period to better evaluate long-term outcomes. Moreover, standardizing the training of operators and creating guidelines for activity restrictions could help reduce variability and improve data reliability.

4.5 CONCLUSIONS

The results of this project provide an important basis for understanding the role of specific exercises in the management of adolescent idiopathic scoliosis. However, the collection of initial data without comprehensive follow-up limits the ability to definitively evaluate the effectiveness of long-term interventions.

To consolidate and extend the knowledge gained, it would be desirable to design follow-up at 6 and 12 months, with the following main objectives:

1. Assess changes in Cobb's degree over time.

Repeated radiographic measurements would make it possible to determine the true effectiveness of specific exercises in slowing the progression of scoliosis or improving spinal alignment.

2. Monitor treatment adherence

Collecting data on exercise adherence and difficulties encountered by patients would allow identification of possible barriers to treatment success.

3. Analyze effects on functional and qualitative aspects.

Assessing the impact of exercises on quality of life, pain perception, and posture during daily activities would provide a more complete view of the benefits of treatment.

4. Identify predictive factors for success

Analysis of longitudinal data could help identify which patient characteristics (age, initial Cobb grade, motivation, etc.) are associated with better outcomes, thus optimizing individualization of treatment.

Follow-up proposal

Follow-up could be structured with:

- Periodic evaluation sessions: every 6 months for a total of 1-2 years.

- Monitoring tools: use of standardized questionnaires (e.g., SRS-22), training cards to record exercise performance, and monitored radiographic measurements.

- Multidisciplinary involvement: input from physical therapists, physicians, and psychologists would improve monitoring and treatment adherence.

In this way, follow-up would not only fill the gaps in the current project but would provide a solid basis for promoting the use of specific exercises as an integral part of conservative treatment of adolescent idiopathic scoliosis.

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