

## CAN THE BIOMECHANICAL MODEL EXPLAIN IDIOPATHIC SCOLIOSIS?

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### Abstract

Physiotherapists often use a postural biomechanical model of explanation to integrate in their clinical rationale the causes of various musculoskeletal conditions such as scoliosis. Scoliosis represents the most common spinal disorder in children, adolescent and adult population. It is believed that postural deviations, body asymmetries and pathomechanics are the predisposing and maintaining factors for many musculoskeletal conditions in general, scoliosis in particular. This model also plays an important role in clinical assessment and physiotherapeutic management, including the choice of manual techniques and the exercise prescribed. Existing literature presents various ways of classification of scoliosis; in neither we find a type of weak or bad postural scoliosis. There is a widespread opinion that scoliosis is caused by poor posture, wearing a backpack on one shoulder, incorrect sitting posture or asymmetrical ergonomics. In reality, the majority of scoliosis patients have an idiopathic condition and biomechanics can be considered aggravating factors not causes. Yet understanding the asymmetrical loading of the scoliotic patient is one of the keys of a successful rehabilitation. Various theories about the reason of the majority of scoliosis were stated from heredity to gene modification, from level of melatonin to systemic disorders. None of these found the explanation to rule out the idiopathic from the diagnostic.

**Keywords:** *idiopathic scoliosis, biomechanics, posture, etiopathogenesis.*

### Introduction

Postural asymmetries and anatomical imperfections were considered to be only pathologic in the past. Today we have to take into consideration that this can be normal variations and not necessarily a pathology. Better understanding of the patient is needed to not consider him more or less sick than his clinical reality. Neuromuscular and motor control variations are also normal. The body has surplus capacity to tolerate such variation without loss to normal function or development of symptomatic conditions. Pathomechanics do not determine symptomatology if they develop gradually and slowly (Van Nieuwenhuyse et al., 2009). Scoliosis is a three-dimensional deformity of the spine and torso that can deteriorate rapidly during periods of accelerated growth (Goldberg et al., 2002). Idiopathic scoliosis is a fixed lateral curvature of the spine greater than or equal to 10°, affecting approximately

2-3% of the entire population of children. In about 20% of cases, scoliosis is secondary to another pathological process. The remaining 80% are classed as idiopathic scoliosis, as the cause is unclear. Adolescent idiopathic scoliosis with a Cobb angle greater than 10° has an incidence ranging from 0.93% to 12% in the population, with values of 2% and 3% being the most common in the literature (Grivas et al., 2006). Of all diagnosed cases, about 10% require conservative treatment and about 0.1-0.3% require surgery. These percentages make it the most common abnormality of the spine during the period of accelerated human growth and development, clinically, being defined as a bone deformity with subtle, painless onset in an apparently healthy subject (Marosy et al., 2010). Although the female-to-male ratio is 1:1 for minor curves, this percentage increases dramatically towards the female sex as the severity of the curves increases. Most patients

with scoliosis (80-90%) have an insufficiently elucidated cause and are diagnosed with idiopathic scoliosis. In the remaining cases, scoliosis is secondary to other pathologies such as: neurofibromatosis; cerebral palsy; congenital developmental anomalies of the vertebrae; neoplastic formations or various syndromes (e.g. Marfan's). Treatment of symptomatic scoliosis will be influenced by its cause. As scoliosis develops during growth, but also in adulthood, the main aim of (therapeutic) intervention is to halt the development of curvature (Goldberg et al., 2002).

According to the Scoliosis Research Society, a region of the spine must have a Cobb angle greater than  $10^\circ$  to be considered curvature. In children, the rotational aspect should be considered even if the curvature is less than  $10^\circ$  but shows a clinical trunk rotation greater than 4 indices measured with a Scoliometer. Idiopathic scoliosis is the combination of torsional regions joined by the junctional area (Doubouset, 2001). A lateral curvature greater than  $10^\circ$  measured by the Cobb angle is considered to be a deformation. Lateral curvature of the spine has been called scoliosis, based on the Greek word '*skolios*' which means bented (Hawes, 2003).

Scoliosis is a term used to describe the lateral curvature of the spine. Most cases involve the thoracic vertebrae, whose axial rotation favours three-dimensional deformations of the torso. In addition to the degree of spinal deviation that defines scoliosis as functional or structural, over time, the condition will produce structural rib deformities that create an asymmetry of the trunk. The functional aspects are related to the reversibility of the deviation and often during physiotherapy the altered posture is corrected. To maintain the corrections achieved and create a new posture corrective reflex, however, sustained therapy and control of posture in leisure time activity is needed. On the other hand, structural aspects of scoliosis, mechanical adaptations of discs, vertebrae and ribs are not reversible during the therapy session or in the short term. However, growth and development and intensive therapy can influence these changes, but if bone maturation is achieved, they

become irreversible. Being a condition that produces three-dimensional deformities, it is worth mentioning that in the frontal plane we find a lateral deviation of the spine on a sagittal axis, which will lead to the formation of a convexity and a concavity; in the sagittal plane the curvatures are most often reduced, resulting in a thoracic hypokyphosis (which in severe cases may be reversed into a lordosis) and a lumbar hypolordosis, and in the transverse plane a vertebral rotation on a frontal axis, especially at the apex of the curvature, occurs on the same side as the convexity. To avoid any confusion observed in the literature search, we note the rotation of the vertebral body on the same side as the convexity, with the spinous apophysis rotating on the opposite side.

### Topic Addressed

The clinical variation of idiopathic scoliosis limited therapeutic options, and inability to detect individuals at significant risk of progression have led to the creation of high-cost screening programs in the United States (Marosy et al., 2010). The annual budget allocated in this country is estimated at \$4 billion and does not include potential morbidities in adulthood caused by spinal fusion performed in childhood. In Romania there is no clear strategy for screening or treatment of idiopathic scoliosis. Through the literature search we could not find a statistic on the number of patients with idiopathic scoliosis in Romania. It should be mentioned, however, that in 2010 there was a Ministry of Health screening project, which consisted, in the first phase, in providing skills to specialists (doctors, physiotherapists) in scoliosis screening and, in the second phase, in conducting a population screening (Program național de screening al scoliozei la copil/ National Childhood Scoliosis Screening Program, 2011, see <https://www.viata-medicala.ro/ars-medici/program-national-de-screening-al-scoliozei-la-copil-3827>). This was carried out mainly in the Mures and Bucharest counties.

The female to male ratio is dependent on the Cobb angle of the subject. Thus, in subjects with a Cobb angle between  $10^\circ$  and  $20^\circ$  the

ratio is 1.3 to 1 in favour of the female sex. It increases to 5.4 to 1 at angles between 20° and 30° and 7 to 1 at angles above 30° (Lonstein, 2006). The progression of deformity observed in adolescence is more common among female subjects. Idiopathic scoliosis can develop at any time during childhood or adolescence. It is more common in the accelerated growth phases: between 6 and 25 months; 5 and 8 years and 11 and 14 years. If poor posture would have been the cause we would have not seen such an unbalanced ratio between the sexes because nowadays boys and girls go to the same schools, have the same desks, play and do sports together.

The critical threshold of scoliosis is considered to be between 30° and 50°, with no fixed value. If growth and development are completed above this threshold, many authors consider that there is an increased risk of developing health problems in adult life, of having a low quality of life, of cosmetic deformity and visible disability, of developing musculoskeletal pain and progressive functional limitations (Lonstein, 2006). At the onset of puberty, the percentage of spinal curvature development accelerates the most (Grivas et al., 2006). During puberty, stage T2 and P2 in girls and boys, according to the Tanner scale, there is an initial phase of accelerated growth of the lower limbs, followed by longitudinal growth of the axial skeleton. This is also the period when the scoliotic deformity evolves the most. After about two-thirds of the pubertal period, when menarche begins in girls, there is a slowing of growth and thus of the progression of scoliosis. After the completion of spinal growth, the risk of progression is very low, and this is particularly observed in scoliosis whose curvatures exceed 50° and have weak and untrained muscles.

#### *Classification of scoliosis*

The objectives of any classification system for any disease process must be to distinguish between clinically meaningful groups of individuals with that disease, be easy to apply in the clinical setting, be reproducible over time and by observers, guide treatment and predict outcome. There are several classifications of scoliosis, depending on the reference criteria chosen to define them: angulation, correctability, aetiology, topography or age of diagnosis. The ideal classification system for adolescent idiopathic scoliosis continues to elude researchers (Sangole et al., 2010).

An early classification system for idiopathic scoliosis was developed in 1950 by Dr. Ponseti and Dr. Friedman (Berdishevsky et al., 2016). This classification system was based on the number of curves and their location. Thus, they described idiopathic scoliosis with one curvature, double curvature or triple curvature. Each form of curvature was further described according to its apex: cervicothoracic or thoracic with cranial apex of the T12 or L1 vertebrae; thoraco-lumbar with apex of the T12 or L1 vertebrae; lumbar with caudal apex of the T12 or L1 vertebrae. The two considered double-curvature scoliosis have a higher risk of progression than single-curvature scoliosis, and thoracolumbar and lumbar curvatures have a higher risk of progression than thoracolumbar curvatures. Although this was a starting point in the classification of scoliosis, more complex methods have been developed given the complexity of idiopathic scoliosis and its dynamic nature of progression and evolution. Thus, the size (Cobb angle value), vertebral rotation and the number of vertebrae involved which modify during the evolution of the condition make classification a dynamic process and require from the assessing specialist a lack of rigidity given by a first classification.

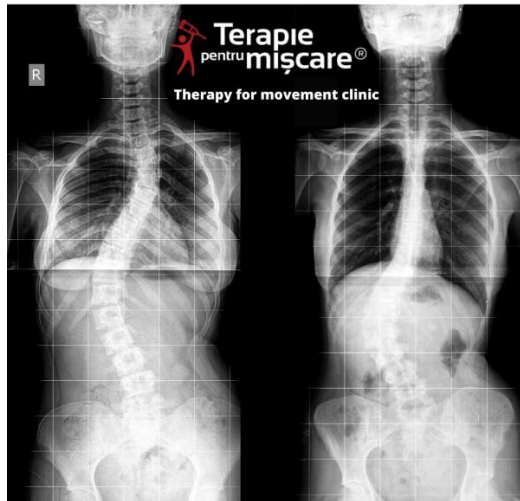


Figure 1. Types of scoliosis regarding the localisation of the curvature  
(image created by one of the co-authors, the founder of the Therapy for movement clinic)

The most common direction of scoliotic deformity is thoracic curvature with convexity on the right side (Marosy et al., 2010) independent of the dominant hemisphere. This is also confirmed in clinical practice - the authors mention that in their clinical careers have had rarely observed idiopathic scoliosis with a left thoracic convexity.

The classification with angulation as the evaluation criterion is based on the Cobb angle measurement (Weiss & Goodall, 2008):

- curves below  $10^{\circ}$  cannot be classified as scoliosis;
- scoliosis has been classified as mild, with Cobb angle below  $30^{\circ}$ ;
- medium, with Cobb angle between  $30^{\circ}$  and  $50^{\circ}$ ;
- severe, with a Cobb angle above  $50^{\circ}$ .

The decision on the type of treatment is based on the Cobb angle and will take into account the Stagnara criteria and the age of the patient. Classification in terms of curvature reducibility divides scoliosis into functional scoliosis and structural scoliosis (Jianu, 2010). The curve can be fully corrected by a translational movement in the opposite direction to convexity, whereas the latter cannot be fully corrected by either passive or active mobilisation.

From the point of view of etiology, there are described in the literature scoliosis with known cause and scoliosis whose cause is not sufficiently elucidated, called idiopathic

scoliosis (Burwell et al., 2009). The most common causes of secondary scoliosis are lower limb inequality, congenital spinal defects, congenital torticollis, cerebral palsy or spinal tumours. There are many theories of the cause of idiopathic scoliosis, none of which has yet been proven to be the primary cause.

Chronologically, scoliosis can be assessed according to the age of onset or the age at which the patient was diagnosed. The following categories are distinguished (Weiss & Goodall, 2008):

- infantile scoliosis,
- early onset scoliosis,
- adolescent idiopathic scoliosis,
- adult scoliosis.

This classification is relevant for the clinician, since the longer the chronological period between diagnosis and completion of growth, the greater the risk of developing a severe and complicated form. Idiopathic scoliosis is classically divided according to the age at which it is first observed into infantile (0 - 3 years), juvenile (3 - 10 years) and adolescent (over 10 years) idiopathic scoliosis (Weinstein et al., 2008). Infantile scoliosis refers to postural defects observed at birth, which are included in various syndromes, most often based on intrauterine compressive forces caused by fetal malposition during pregnancy. This type of scoliosis has a different prognosis, being a uniplanar, not

three-dimensional disorder and very often shows spontaneous remission. There is a preference for head rest on one side and asymmetrical range of motion at the hip joints. With specific physiotherapy, a gradual remission is observed, this type being defined as regressive. A totally opposite prognosis is given to scoliosis with a vertebral defect at birth - of the hemivertebra or vertebral block type. In these cases of structural changes, surgery is the only truly effective solution.

Given the ambiguity surrounding the prepubertal stages of growth, this classification has been modified (Marosy et al., 2010). Thus the term "early onset" is used extensively and defines idiopathic early onset scoliosis chronologically located before the age of 5 years. Most early-onset scoliosis is associated with neurological disorders or genetic causes. The second type is "later onset" scoliosis, associated with the classic form of adolescent idiopathic scoliosis. The onset is often in a child who was previously healthy and had no other condition that could guide the clinician to this pathology. It is precisely this aspect that has frustrated clinicians around the world for many decades. We note that there is no classification about the postural scoliosis or biomechanical induced scoliosis in the current available literature.

#### *The etiopathogenesis of idiopathic scoliosis*

The causes of this disease have been investigated in the direction of congenital or acquired disorders of the spine. The role of genetic factors in the development of these spinal disorders has been a direction of research, as the familial nature can be

observed, with researchers suggesting a hereditary disorder in the tightness and functioning of the estrogen receptor (Grivas et al., 2006). Another area of investigation that many researchers are pursuing is the impact of melatonin levels on scoliosis. Although it has been thought that a disorder in melatonin synthesis may be the cause of the development of scoliosis, melatonin is currently attributed a limited role (Burwell et al., 2013), which can be analysed in connection with age and menarche in different latitudes (Grivas et al., 2006). Another hypothesis put forward by a number of authors is the possible involvement of IL-6 and MMP genes with the development of idiopathic scoliosis by creating a predisposition in the development of vertebral developmental asymmetry (Aulisa et al., 2007). However, there is no clarity in the aetiology of this disease, and determining a cause-effect relationship is still open to research.

The hypothesised vicious circle of scoliosis can explain its progression (Burwell et al., 2013); yet, this idea cannot explain the cause of the onset of scoliosis, but it may provide a model for understanding its aggravation. It starts with the point at which wedged vertebrae begin to form. The trapezoidal shape in the frontal plane of the vertebrae will cause the creation of scoliosis curvature, resulting in asymmetrical weight bearing in the spine. At this point, the growth and development of the vertebrae will be asymmetrical as there is a different loading on them, a process which will further accentuate the wedge shape of the vertebral bodies.

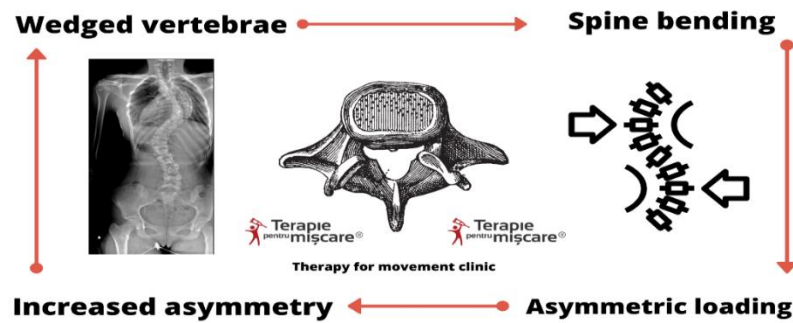


Figure 2. The vicious circle of scoliosis  
(image created by one of the co-authors, the founder of the Therapy for movement clinic)

We consider this hypothesis is relevant to thoracic curvatures, in which the scoliotic curvature is created due to structural changes in the thoracic vertebrae. In the lumbar spine, the curvature is due to changes in the shape of the intervertebral disc and not the vertebral body. Further research is needed on whether this hypothesis also applies to the lumbar vertebral disc. In clinical practice, this hypothesis supports the importance of educating the patient considering posture, during daily activities.

Burwell et al. (2013) consider that there is no full understanding of the primary asymmetry, the point of onset of scoliosis, although many authors believe that scoliosis begins around the primary curvature as an attempt to posturally adapt the body (in an attempt) to maintain uprightness despite postural disorganization. Secondary curvature describes a vertebral deviation that has developed compensatory to primary curvature. In the primary curvature, structural deformations are pronounced and flexibility is more restricted compared to the other curvatures. This is the curvature that will influence posture and body statics. The secondary curvature has no or minor structural deformities and is characterised by functional reversibility.

The causes of scoliosis are being sought in congenital or acquired disorders of vertebral structure. Patients with this type of deformity are usually noted to suffer from such co-existent abnormalities as asymmetrical structure of the brain stem, sensory and

balance impairment, disorders of blood platelet and collagen function (Vasiliadis et al., 2009). The role of genetic factors in the development of spinal axial disorders is also emphasised and is confirmed by the tendency of scoliosis to run in families, with researchers suggesting a hereditary disorder of oestrogen receptor structure and function (Grivas et al., 2006.). Existing data suggest that the causes of scoliosis are systemic disorders of, among others, mucopolysaccharide and lipoprotein synthesis.

Observing the development of spinal curvatures in chickens due to an pinealectomy and later ameliorating it by correcting the melatonin deficiency was a starting point in research about the melatonin role in idiopathic scoliosis. Dubousset and his research group proposed that scoliosis develops as a result of melatonin synthesis disorder, with reduced serum melatonin levels found in girls with rapidly progressive idiopathic scoliosis (Grivas et al., 2008). Other authors suggest that melatonin is attributed only a limited role in scoliosis pathogenesis (Burwell et al., 1992). The possible role of melatonin in scoliosis etiology is also discussed in connection to age at menarche in different geographic latitudes (Grivas et al., 2006). According to other studies, calmodulin can be the cause of the abnormal melatonin levels and some authors suggested to be the cause of curve progression (Kindsfater et al., 1994). Thus, melatonin plays a secondary role in the spontaneous

induction of scoliosis. It is a consequence of interaction with calmodulin, a protein that has receptors for calcium ions and is thus able to influence the contractility of skeletal muscles and that can be also found in blood platelets. In patients with scoliotic progression rates of more than 10° over 12 months, the level of calmodulin in platelets was higher (Grivas et al., 1991).

Other authors have evaluated the possibility that gene variants of IL-6 and MMPs might be associated with scoliosis and suggests that MMP-3 and IL-6 promoter polymorphisms constitute important factors for the genetic predisposition to scoliosis (Aulisa et al., 2007).

Although considered a musculoskeletal pathology by many specialists, the etiology of idiopathic scoliosis includes both biomechanical and somatosensory disorders that have an increased impact on body awareness (Yagci et al., 2020).

It is up to this date that the etiology of scoliosis has not been fully elucidated. Based on the variety of opinions on idiopathic

scoliosis development, we can assume a multifactorial origin. The opinions presented above can be considered supplementary rather than mutually exclusive. At the same time, they explain the complex determinants of and relationships between development of spinal deformities in children and adolescents.

*Biomechanics and posture matter in treatment*

Whatever the cause of scoliosis, when postural balance fails, deformity often occurs (Neumann, 2017). All the concepts of physiotherapy specific to scoliosis mention and promote this aspect under different names. In Schroth's concept of posture awareness therapy, this is exactly what it is about - weight barring should be as symmetrical as possible during daily activities. Whether the patient is in orthostatic (symmetrical weight barring on both lower limbs) or sitting (weight barring on both ischial bones), the patient must correct and maintain posture in a position where weight is symmetrically distributed.



Figure 3. Assymmetric loading in lumbar right convexity scoliosis

**Conclusion**

Postural imbalance can result in severe structural scoliosis, for which surgical treatment is the only therapeutic solution. Regardless of the triggering cause of a scoliotic curve, eliminating asymmetric antigravity loading by restoring postural balance can set the stage for an improvement

in signs and symptoms due to scoliosis, even if it has become structural. If asymmetric loading is removed before growth is complete and before too much time has elapsed, spinal deformity can be completely eliminated (Hawes & O'Brien, 2003). Creating a correct posture reflex, therefore, becomes a priority in the treatment of idiopathic scoliosis.

However, in order to achieve this therapeutic goal, it is necessary to know the types of posture and to educate patients about them.

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