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Workouts tailored for idiopathic scoliosis- a review

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ABSTRACT

Introduction and purpose

Idiopathic scoliosis is a three-dimensional, structural deformity (curvature) of the spine and torso, occurring in 1-3% of children, most commonly between the ages of 10 and 16 (often noted during adolescence and rapid growth). It is significantly more prevalent in girls, and its cause remains unknown. Untreated scoliosis typically progresses, leading to postural abnormalities, abnormal breathing patterns, pain syndromes, and a reduced quality of life for the patient. The aim of our study was to present scoliosis-specific exercises that can halt and potentially reverse the spinal curvature angle.

Materials and methods

The literature included in the PubMed databases is searched through the words such as scoliosis, idiopathic scoliosis, physiotherapy and exercises.

Description of the state of knowledge:

The literature review shows the breadth of the issue. Physiotherapeutic exercises specific to scoliosis is conducted for therapeutic objectives, with the aim of reducing deformity and slowing its advancement. Moreover, it seeks to maintain the achieved enhancement, ultimately striving to minimize reliance on corrective devices or surgical procedures. In each case, the treatment of idiopathic scoliosis involves the application of exercises based on specific physiotherapy methods for scoliosis, such as the Schroth Method, Lyon Method, and others. Exercises are individually tailored to the size and shape of the curvature as well as the patient's

capabilities. Their aim is three-dimensional correction of the deformity, stabilization of the corrected posture, and maintaining it during daily activities.

Conclusions

The objectives of physiotherapy include halting the progression of curvature during adolescence, preventing respiratory dysfunction, preventing and treating spinal pain syndromes, and importantly, improving aesthetics through postural correction.

Keywords:

scoliosis, idiopathic scoliosis, exercises, physical activity, physiotherapy

1. Introduction

Idiopathic scoliosis is the most frequent form of spinal curvature, predominantly affecting children and adolescents during their growth phases. Early detection is crucial in preventing its progression. This necessitates parents having basic knowledge of its symptoms and regular preventive check-ups during childhood and adolescence [1].

Monitoring, physiotherapy exercises tailored to scoliosis (PSSE), and idiopathic scoliosis bracing during growth are therapeutic interventions endorsed by the International Society on Scoliosis Orthopaedic and Rehabilitation Treatment in 2011 (SOSORT). Currently, surgical treatment is the only method that effectively resolves scoliosis, although it is reserved for advanced cases. Early detection of the disease is crucial as it allows for timely implementation of specific physiotherapeutic methods [2].

2. Objective of the work

The aim of this study is to present physiotherapeutic exercises used in the treatment of scoliosis in children and adolescents. We described several selected methods, with particular emphasis on clinical studies that have demonstrated their effectiveness.

3. Materials and Methods

To compile this review paper, extensive searches were conducted across databases such as PubMed and Google Scholar. The search terms encompassed "scoliosis", "idiopathic scoliosis", "exercises", "physical activity" and "physiotherapy". Articles considered were those published between 1999 and 2024, with the greatest focus on the last 5 years. This screening process aided in identifying articles pertinent to the paper's theme. Subsequently, a comprehensive analysis of the complete texts of possibly relevant articles was conducted, facilitating the extraction of the most relevant information. Original research and review articles were selected, drawing from the authors' research and clinical expertise. Ultimately, 38 research articles were cited.

4. Description of the state of knowledge

Epidemiology and the definition of scoliosis

Idiopathic scoliosis is the most prevalent form, making up 80% of all scoliosis cases. It is estimated that idiopathic scoliosis (with a Cobb angle $>10^\circ$) affects about 2-3% of the child and adolescent population. Scoliosis from other causes is much less common [3].

Scoliosis is a postural defect characterized by a three-dimensional curvature of the spine. The spine undergoes lateral curvature and rotation, most commonly accompanied by flattening of the physiological thoracic kyphosis and alterations in the size of the lumbar and cervical lordosis [4]. The spinal curvature in scoliosis becomes most apparent when the child bends forward. This reveals a protrusion in the thoracic spine and/or in the lumbar spine, depending on the curvature [5,6]. Moreover, the positioning of the shoulders, shoulder blades, and pelvis is uneven, presenting asymmetry. Typically, one shoulder shifts upward and forward, while one shoulder blade protrudes further. The waist indentation of the child appears uneven, and the arms and hips are at differing heights. These manifestations stem from the spinal curvature, typically occurring in the thoracic region. Consequently, this disrupts torso balance, leading to a shift in the body's center of gravity [3,5,7].

Etiology and diagnosis

Idiopathic Scoliosis (80% of all scolioses)	Neuromuscular	Muscular	Congenital
<ul style="list-style-type: none">- infantile (0-3 years)- juvenile (4-10 years)- adolescent (>10 years)	<ul style="list-style-type: none">- myelomeningocele- spinal muscular atrophy- cerebral palsy	<ul style="list-style-type: none">- arthrogryposis- muscular dystrophies	<ul style="list-style-type: none">- vertebral formation disorders- rib fusions

Table 1. Etiological Classification of Scoliosis [3]

The causes of scoliosis are presented in Table 1. Idiopathic scoliosis can manifest at different ages during growth, and based on the timing of its appearance, it is categorized into early childhood scoliosis observed until the age of 3, childhood scoliosis from the age of 4, and adolescent scoliosis. Congenital scoliosis is rare and tends to worsen as the child develops. Unfortunately, the earlier the symptoms of scoliosis appear, the worse the prognosis for the further development of the deformity [3,5,8].

The severity of scoliosis is measured from X-ray images, where the degree of lateral spinal curvature is assessed using the Cobb angle, and the rotation angle of the trunk is measured with a scoliometer. If the Cobb angle on the X-ray is less than 10 degrees, it's termed as postural scoliosis. When the angle exceeds 10 degrees on the Cobb scale, it's diagnosed as scoliosis [7,9].

Scoliosis correction is typically pursued during a child's growth phase. For girls, this usually ends around 15-16 years of age (2-3 years after the onset of menstruation), while for boys, it's around 17-18 years old. However, it's important to note that these values vary individually and may differ significantly in specific cases [4,10].

The child's skeletal age and spinal growth stage are assessed through X-ray imaging, which shows the development of the iliac crests. A specialist determines spinal bone maturity using the six-level (0-5) Risser scale, with 5 indicating the end of spinal bone growth. After this stage, treatment options such as physiotherapy or bracing are very limited [6,7,9].

Treatment Methods

Experts concur that, with our current understanding, only surgical intervention can effectively correct scoliosis. These surgeries are highly demanding for the patient, which is why

the criteria for surgery are very strict. As the worsening of the curvature can lead to respiratory dysfunction (restrictive lung changes, particularly in patients with a curvature $>60^\circ$ according to Cobb) and chronic back pain syndromes, early detection of scoliosis is crucial [9,11]. Early-stage conservative treatments (physiotherapy, kinesiotherapy, and bracing) can effectively prevent the progression of the deformity [7,12]. Idiopathic scoliosis most frequently appears in adolescents, for whom physical appearance is critically important. It is essential to consider the aesthetic implications of both the condition and its treatments (such as bracing) and their effects on the mental well-being of young individuals. Effective communication and cooperation with the patient lead to better treatment outcomes [8,10].

Physiotherapy

Exercises are not seen as a substitute for bracing or surgery, but rather as a therapeutic measure that can be applied either independently or in combination with bracing or surgical intervention, depending on individual indications [2,12,13].

Exercises are commonly employed in numerous Central and Southern European nations, whereas most facilities in other regions worldwide do not advocate their usage. One rationale is that many healthcare professionals are typically unfamiliar with the distinctions between general physiotherapeutic exercises and PSSE: while the former encompass general exercises, typically comprising low-impact stretching and strengthening exercises like yoga, pilates, and the Alexander technique, PSSE comprises a regimen of exercise protocols tailored to the curvature, individually adjusted to the location, size, and clinical characteristics of the patient's curvature. PSSE is undertaken for therapeutic purposes, aiming to diminish deformity and impede its progression. Furthermore, it aims to stabilize the attained improvement, with the ultimate objective of reducing the necessity for corrective appliances or surgical intervention [1,8,14].

The Schroth Method- Germany

During normal inhalation, there is a symmetrical increase in the pressure of the rib heads against the vertebral bodies, primarily due to heightened tension in the external intercostal muscles. However, during asymmetrical movement, as seen in lateral spinal curvatures, the force acting to increase rib pressure operates unilaterally, exacerbating vertebral rotation. Subsequent abnormal inhalations further worsen the condition as air is directed into already

expanded areas of the chest. Taking into consideration the aforementioned details, therapeutic breathing is focused on targeting the so-called weak areas – the posterior and anterior rib concavities, along with vulnerable regions of the lumbar spine. The author of this method suggests that this directed airflow horizontally displaces the ribs on the concave side, leading to derotation of the thoracic curvature. In the Schroth method, it's crucial to discern the direction of the curvature and distinguish between its concave and convex sides. The curvature's direction invariably correlates with the thoracic section's curvature [4,15].

The assessment relies on a three-dimensional evaluation of posture. This involves comparing three areas of the patient's body: the pelvic region, the thoracic region, and the shoulder region, to geometric shapes, and assessing their alignment relative to each other [14]. In the frontal plane, the patient's body can be compared to three rectangles. The first rectangle encompasses the pelvis, lower abdomen, and lumbar spine. The second rectangle lies between the lines passing through the Th12 and Th3 vertebrae, while the third rectangle encompasses the shoulder girdle and extends to the external occipital protuberance. Under normal conditions, these rectangles are proportionally aligned with each other. In the sagittal plane, body segments assume a trapezoid shape [15,16]. In the horizontal plane, when viewing the patient from above, four concentric ovals can be distinguished. The first represents the head, while the subsequent ones depict the shoulder girdle, pelvic girdle, and outline of the chest [16,17].

The primary goals of therapy include:

- stabilizing correction;
- halting the progression of the deformity;
- correcting body posture and cosmetic silhouette;
- reducing pain symptoms;
- fostering a positive psychological attitude towards the condition;
- improving cardiovascular and respiratory endurance [4,17].

The exercises used in the Schroth method therapy can be divided into ventilatory (correcting angular-rotational breathing), mobilization, hanging, shaping, and strength exercises.

Studies confirm the efficacy of the Schroth method. Schreiber et al. examined the effect of Schroth PSSE intervention alongside standard treatment (experimental group) compared to standard treatment alone (control group) in adolescent idiopathic scoliosis patients. After six months, the Schroth group exhibited a significantly smaller maximum curve than the control

group (-3.5° to -5.9°, $p = 0.006$). The research validated that integrating this method into standard treatment reduced the intensity of the Cobb angle in adolescents [16,18].

In a randomized controlled trial, Kocaman et al. proved that Schroth exercises are more effective than trunk stabilization exercises in correcting scoliosis and related issues in mild adolescent idiopathic scoliosis, while trunk stabilization exercises are more effective than Schroth exercises in enhancing peripheral muscle strength [5].

In another study of 51 patients with adolescent idiopathic scoliosis, it was demonstrated that a Schroth exercise regimen conducted in a clinic under the guidance of a physiotherapist yielded better results compared to home exercises and control groups. Furthermore, progression of scoliosis was noted in the untreated control group [19].

The Lyon method- France

The Lyon Method is the first method in the world that combines mechanical correction of scoliosis with individually tailored and specific exercises.

The Lyon Method stands out with several original concepts: chaotic and linear scoliosis, opening of the ilio-lumbar angle, tensegrity and plastic deformation of soft tissues, focus on the automatic extrapyramidal system, 3D correction via regional coupled movements, isostatic balance in the sagittal plane, incorporating sports activities, and the integration of a hypercorrective device with physiotherapy [20].

The core idea is to stimulate the extrapyramidal system. Activation of the deep paraspinal muscles is based on the physiology of activating four pathways: the reticulospinal, vestibulospinal, rubrospinal, and tectospinal tracts. Sensory-motor organization includes a collection of sensory receptors, cortical integration centers, sensory-motor coupling, motor integration centers, and postural muscles [20,21].

A key feature of the Lyon Method is symmetry, which ensures the head is always aligned with the lower limbs. Correction happens in the sagittal and frontal planes, with derotation resulting from coupled movements. 3D correction using coupled movements is performed in the sagittal and frontal planes. 3D postural correction is based on the law of coupled spinal movements and overall distortion through translation along the vertical axis in active axial self-elongation. A notable aspect of the method is the asymmetric structural change of the lumbo-iliac junction, involving a disruption of the ilio-lumbar angle [20,22].

The Lyon Method for treating scoliosis consists of five stages [21]:

1. The Lyon approach to assessment.

2. Awareness of torso deformity.
3. What to do: sample exercises.
4. What not to do and why.
5. Sports or just physiotherapy?

The Scientific Exercise Approach to Scoliosis (SEAS) method- Italy

The SEAS Method is an integral part of the comprehensive treatment plan for patients with idiopathic scoliosis. As one of the specific scoliosis treatment methods, it focuses on educating both the patient and their parents, 3D self-correction of spinal curvature, maintaining stabilization and correction during daily activities, enhancing body aesthetics, and preventing cardiovascular and respiratory restrictions [23,24].

This method is based on three-dimensional self-correction of posture (with individualized, specific trunk movements performed in a specific sequence) without the use of external aids, followed by maintaining the correction during activities with or without tools and in daily tasks. The aim is to achieve postural control, enable the patient to maintain stability during 3D self-correction, and develop the habit of adopting correct posture (by teaching and integrating the reflex into the nervous system). SEAS exercises can also be performed while wearing a corrective brace [23,25,26].

During exercises, particularly at the start of therapy, biofeedback is employed, for instance, through the use of mirrors. The patient learns to respond to the therapist's questions, thus observing and sensing their body position [27]:

1. Do I feel that my spine is not relaxed?
2. Is my body more symmetrical during self-correction than when relaxed?
3. Can I maintain self-correction during the exercise?
4. Can I recognize when my body returns to the relaxed (uncorrected) position it was in before self-correction?

The skill of using 3D self-correction in daily activities and body awareness is honed by setting progressive "challenges" for the patient (increasing the difficulty of exercises). This can include closing the eyes, changing the starting position, adding an unstable surface, or introducing other external stimuli [25,27].

In Gao's et al. study, it was shown that after 6 months of intervention, patients utilizing orthoses alongside the SEAS exercise group exhibited improved Cobb angle correction

compared to patients in the group using only orthoses. After 6 months of observation, there was a statistically significant difference between the groups regarding back muscle endurance time and lung function parameters [28].

The Funkcjonalna Indywidualna Terapia Skolioz (FITS) method- Poland

The method follows a consistent concept, taking into consideration the principles of addressing muscular and fascial imbalances. Therapy begins with enhancing proprioception/deep sensation, releasing hypertonic muscles, then strengthening weakened muscles, until optimal conditions are achieved for performing corrective patterns and self-correcting body posture [1,2].

The FITS Method encompasses three stages [29]:

1. Assessment and patient awareness.
2. Preparation for correction: sensorimotor control training, addressing musculo-fascial barriers restricting corrective movement.
3. Three-dimensional correction: developing and stabilizing corrective movement patterns in both open and closed biokinematic chains, in functional positions.

Key, innovative aspects of the FITS method [22,30]:

1. Patient awareness - psychological component - treating the patient as a collaborator rather than a subject,
2. Evaluation of active and passive corrective movement capacities,
3. Elimination of musculo-fascial obstacles restricting corrective movement,
4. Establishment and stabilization of new corrective movement patterns,
5. Correction of the primary curve through functional compensatory adjustments.

Trzcińska et al., in their three-week observation, demonstrated the effectiveness of the FITS method among girls aged 11-13 suffering from adolescent idiopathic scoliosis [31].

Białek demonstrated that the best results of the FITS method were achieved in cases of scoliosis with a curvature of 10-25 degrees, which is a good indication for starting therapy before further structural changes in the spine occur [32].

The FITS physiotherapy was effective in preventing curvature progression in children with early-onset idiopathic scoliosis [30].

The Barcelona Scoliosis Physical Therapy School (BSPTS) method- Spain

BSPTS is a specialized method for treating idiopathic scoliosis. A fundamental aspect of the approach involves thorough and accurate patient diagnosis, as well as therapeutic recommendations based on clinical expertise, scientific evidence, and patient and parental preferences [1,2,33].

The BSPTS method aims to achieve comprehensive three-dimensional correction of spinal alignment and body posture, employing techniques such as asymmetric chest expansion, muscle activation, and integration of the newly acquired body position. Recognized for its holistic patient-centered approach, the method also encompasses extensive knowledge of deformity, patient and parental education, stabilization and maintenance of correction during daily activities, and prevention of pain and restrictions in the cardiovascular and respiratory systems [2,16,33].

BSPTS has proven efficacy in both younger patients (preventing curvature progression, correcting curvature, improving body aesthetics, among others) and adults (enhancing body aesthetics, reducing pain, and cardiovascular-respiratory restrictions). Its principles can be applied to patients post-scoliosis surgery, as well as to those with scoliosis other than idiopathic, Scheuermann's disease, and certain postural and chest wall abnormalities [33].

Zapata et al. conducted a one-year study involving 49 patients with mild adolescent idiopathic scoliosis. After one year of observation, the group exercising with the BSPTS method had smaller curvatures than the control group (16.3° compared to 21.6° , $p = 0.04$) and less curvature progression (0° compared to 5.6° , $p = 0.02$) [22].

The Dobomed method- Poland

The method's creator asserted that the primary cause of the deformity's progression (and perhaps its onset) is the reduction of thoracic kyphosis and spinal rotation within the thoracic cage. This leads to muscle tension asymmetry and altered thoracic cage mobility due to the uneven positioning of ribs (vertical on the convex side and horizontal on the concave side) [34,35].

The main objectives of the Dobosiewicz method include [34,36]:

- restoring the spine's natural curves in the sagittal plane (with a primary focus on deepening thoracic kyphosis);

- introducing an asymmetrical breathing pattern to activate the rib-vertebral and rib-transverse joints on the concave side of the curve;
- equalizing muscle tension on both sides of the curve;
- solidifying the achieved corrections.

The therapy is primarily based on asymmetrical breathing exercises conducted in symmetrical unloaded starting positions. The choice of the appropriate position depends on the location of the apex vertebra of the curve. During the exercises, while inhaling, the participant is instructed to increase the flexion of the entire spine. Air is directed towards the concave side of the curve, thereby causing its elongation. Conversely, during exhalation, the convex side of the curve is lowered to reduce the rotation of the thoracic cage and spine. In this corrected position, the patient must isometrically engage the trunk muscles [36,37].

The next phase of improvement involves performing the same exercises under axial load conditions, such as standing or sitting [37]. The entire therapy lasts from 10 to 14 days and is conducted in specialized clinics. Physiotherapists are responsible for educating the child's parents or guardians on performing similar exercises at home. Consistent exercise is crucial for achieving the intended goals [35].

In a retrospective analysis of radiological results of 152 patients with progressive idiopathic scoliosis, a predominant stabilization of scoliotic curvatures was demonstrated in children treated with the Dobomed Method from October 1999 to December 2004 [38].

5. Conclusion

Adolescents with idiopathic scoliosis are typically detected through school screening programs or when the patient, caregivers, or doctors notice spinal curvature or asymmetry. A younger age at diagnosis (especially below 12 years old), female gender, a family history of clinically significant scoliosis, and relative skeletal immaturity are risk factors for progression. Referral for surgery and/or bracing is advised when the initial Cobb angle measures 40 degrees or more. Generally, observation is recommended for patients with an initial Cobb angle of less than 20 degrees, although referral for physiotherapy may be considered. Several specialized therapeutic methods, referred to as PSSE, are recommended for idiopathic scoliosis patients. Scientific evidence confirms their effectiveness in halting or limiting further spinal curvature progression.

Disclosures

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References:

1. Bettany-Saltikov J, Parent E, Romano M, Villagrassa M, Negrini S. Physiotherapeutic scoliosis-specific exercises for adolescents with idiopathic scoliosis. *Eur J Phys Rehabil Med.* 2014 Feb;50(1):111-21. Epub 2014 Feb 13. PMID: 24525556.
2. Berdishevsky H, Lebel VA, Bettany-Saltikov J, Rigo M, Lebel A, Hennes A, et al. Physiotherapy scoliosis-specific exercises - a comprehensive review of seven major schools. *Scoliosis Spinal Disord.* 2016 Aug 4;11:20. doi: 10.1186/s13013-016-0076-9. PMID: 27525315; PMCID: PMC4973373.
3. Comité Nacional de Adolescencia SAP; Comité de Diagnóstico por Imágenes SAP; Sociedad Argentina de Ortopedia y Traumatología Infantil; Sociedad Argentina de Patología de la Columna Vertebral (SAPCV); Comité de Diagnóstico por Imágenes; Colaboradores. Consenso de escoliosis idiopática del adolescente [Adolescent idiopathic scoliosis]. *Arch Argent Pediatr.* 2016 Dec 1;114(6):585-594. Spanish. doi: 10.5546/aap.2016.585. PMID: 27869435.
4. Ceballos Laita L, Tejedor Cubillo C, Mingo Gómez T, Jiménez Del Barrio S. Effects of corrective, therapeutic exercise techniques on adolescent idiopathic scoliosis. A systematic review. *Arch Argent Pediatr.* 2018 Aug 1;116(4):e582-e589. English, Spanish. doi: 10.5546/aap.2018.eng.e582. PMID: 30016036.
5. Kocaman H, Bek N, Kaya MH, Büyükturan B, Yetiş M, Büyükturan Ö. The effectiveness of two different exercise approaches in adolescent idiopathic scoliosis: A single-blind, randomized-controlled trial. *PLoS One.* 2021 Apr 15;16(4):e0249492. doi: 10.1371/journal.pone.0249492. PMID: 33857180; PMCID: PMC8049223.
6. Chen Y, Zhang Z, Zhu Q. The effect of an exercise intervention on adolescent idiopathic scoliosis: a network meta-analysis. *J Orthop Surg Res.* 2023 Sep 4;18(1):655. doi: 10.1186/s13018-023-04137-1. PMID: 37667353; PMCID: PMC10476432.
7. Kuznia AL, Hernandez AK, Lee LU. Adolescent Idiopathic Scoliosis: Common Questions and Answers. *Am Fam Physician.* 2020 Jan 1;101(1):19-23. PMID: 31894928.
8. Peng Y, Wang SR, Qiu GX, Zhang JG, Zhuang QY. Research progress on the etiology and pathogenesis of adolescent idiopathic scoliosis. *Chin Med J (Engl).* 2020 Feb 20;133(4):483-493. doi: 10.1097/CM9.0000000000000652. PMID: 31972723; PMCID: PMC7046244.

9. Romano M, Minozzi S, Bettany-Saltikov J, Zaina F, Chockalingam N, Kotwicki T, et al. Exercises for adolescent idiopathic scoliosis. *Cochrane Database Syst Rev*. 2012 Aug 15;2012(8):CD007837. doi: 10.1002/14651858.CD007837.pub2. Update in: *Cochrane Database Syst Rev*. 2024 Feb 28;2:CD007837. doi: 10.1002/14651858.CD007837.pub3. PMID: 22895967; PMCID: PMC7386883.
10. Qi X, Peng C, Fu P, Zhu A, Jiao W. Correlation between physical activity and adolescent idiopathic scoliosis: a systematic review. *BMC Musculoskelet Disord*. 2023 Dec 19;24(1):978. doi: 10.1186/s12891-023-07114-1. PMID: 38115016; PMCID: PMC10729348.
11. Essex R, Bruce G, Dibley M, Newton P, Thompson T, Swaine I, et al. A systematic scoping review and textual narrative synthesis of the qualitative evidence related to adolescent idiopathic scoliosis. *Int J Orthop Trauma Nurs*. 2022 May;45:100921. doi: 10.1016/j.ijotn.2022.100921. Epub 2022 Jan 14. PMID: 35217471.
12. Zhou Z, Liu F, Li R, Chen X. The effects of exercise therapy on adolescent idiopathic scoliosis: An overview of systematic reviews and meta-analyses. *Complement Ther Med*. 2021 May;58:102697. doi: 10.1016/j.ctim.2021.102697. Epub 2021 Feb 23. PMID: 33636298.
13. Negrini S, Donzelli S, Aulisa AG, Czaprowski D, Schreiber S, de Mauroy JC, et al. 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord*. 2018 Jan 10;13:3. doi: 10.1186/s13013-017-0145-8. PMID: 29435499; PMCID: PMC5795289.
14. Ma RT, Wu Q, Xu ZD, Zhang L, Wei YX, Gao Q. Exercise therapy for adolescent idiopathic scoliosis rehabilitation: a bibliometric analysis (1999-2023). *Front Pediatr*. 2024 Jan 4;11:1342327. doi: 10.3389/fped.2023.1342327. PMID: 38239594; PMCID: PMC10794515.
15. Ceballos-Laita L, Carrasco-Uribarren A, Cabanillas-Barea S, Pérez-Guillén S, Pardos-Aguilella P, Jiménez Del Barrio S. The effectiveness of Schroth method in Cobb angle, quality of life and trunk rotation angle in adolescent idiopathic scoliosis: a systematic review and meta-analysis. *Eur J Phys Rehabil Med*. 2023 Apr;59(2):228-236. doi: 10.23736/S1973-9087.23.07654-2. Epub 2023 Jan 24. PMID: 36692412; PMCID: PMC10170402.
16. Park JH, Jeon HS, Park HW. Effects of the Schroth exercise on idiopathic scoliosis: a meta-analysis. *Eur J Phys Rehabil Med*. 2018 Jun;54(3):440-449. doi: 10.23736/S1973-9087.17.04461-6. Epub 2017 Oct 2. PMID: 28976171.

17. Schreiber S, Whibley D, Somers EC. Schroth Physiotherapeutic Scoliosis-Specific Exercise (PSSE) Trials-Systematic Review of Methods and Recommendations for Future Research. *Children* (Basel). 2023 May 27;10(6):954. doi: 10.3390/children10060954. PMID: 37371186; PMCID: PMC10297476.
18. Schreiber S, Parent EC, Khodayari Moez E, Hedden DM, Hill DL, Moreau M, et al. Schroth Physiotherapeutic Scoliosis-Specific Exercises Added to the Standard of Care Lead to Better Cobb Angle Outcomes in Adolescents with Idiopathic Scoliosis - an Assessor and Statistician Blinded Randomized Controlled Trial. *PLoS One*. 2016 Dec 29;11(12):e0168746. doi: 10.1371/journal.pone.0168746. PMID: 28033399; PMCID: PMC5198985.
19. Kuru T, Yeldan İ, Dereli EE, Özdiçler AR, Dikici F, Çolak İ. The efficacy of three-dimensional Schroth exercises in adolescent idiopathic scoliosis: a randomised controlled clinical trial. *Clin Rehabil*. 2016 Feb;30(2):181-90. doi: 10.1177/0269215515575745. Epub 2015 Mar 16. PMID: 25780260.
20. Negrini S, Fusco C, Minozzi S, Atanasio S, Zaina F, Romano M. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Disabil Rehabil*. 2008;30(10):772-85. doi: 10.1080/09638280801889568. PMID: 18432435.
21. Marti CL, Glassman SD, Knott PT, Carreon LY, Hresko MT. Scoliosis Research Society members attitudes towards physical therapy and physiotherapeutic scoliosis specific exercises for adolescent idiopathic scoliosis. *Scoliosis*. 2015 May 27;10:16. doi: 10.1186/s13013-015-0041-z. PMID: 26056527; PMCID: PMC4459052.
22. Zapata KA, Sucato DJ, Jo CH. Physical Therapy Scoliosis-Specific Exercises May Reduce Curve Progression in Mild Adolescent Idiopathic Scoliosis Curves. *Pediatr Phys Ther*. 2019 Jul;31(3):280-285. doi: 10.1097/PEP.0000000000000621. PMID: 31220013.
23. den Boer WA, Anderson PG, v Limbeek J, Kooijman MA. Treatment of idiopathic scoliosis with side-shift therapy: an initial comparison with a brace treatment historical cohort. *Eur Spine J*. 1999;8(5):406-10. doi: 10.1007/s005860050195. PMID: 10552325; PMCID: PMC3611202.
24. Day JM, Fletcher J, Coghlan M, Ravine T. Review of scoliosis-specific exercise methods used to correct adolescent idiopathic scoliosis. *Arch Physiother*. 2019 Aug 23;9:8. doi: 10.1186/s40945-019-0060-9. PMID: 31463082; PMCID: PMC6708126.

25. Romano M, Carabalona R, Petrilli S, Sibilla P, Negrini S. Forces exerted during exercises by patients with adolescent idiopathic scoliosis wearing fiberglass braces. *Scoliosis*. 2006 Jul 21;1:12. doi: 10.1186/1748-7161-1-12. PMID: 16859544; PMCID: PMC1578587.
26. Negrini S, Zaina F, Romano M, Negrini A, Parzini S. Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. *J Rehabil Med*. 2008 Jun;40(6):451-5. doi: 10.2340/16501977-0195. PMID: 18509560.
27. Fahim T, Virsanikar S, Mangharamani D, Khan SN, Mhase S, Umate L. Physiotherapy Interventions for Preventing Spinal Curve Progression in Adolescent Idiopathic Scoliosis: A Systematic Review. *Cureus*. 2022 Oct 14;14(10):e30314. doi: 10.7759/cureus.30314. PMID: 36381707; PMCID: PMC9650952.
28. Gao C, Zheng Y, Fan C, Yang Y, He C, Wong M. Could the Clinical Effectiveness Be Improved Under the Integration of Orthotic Intervention and Scoliosis-Specific Exercise in Managing Adolescent Idiopathic Scoliosis?: A Randomized Controlled Trial Study. *Am J Phys Med Rehabil*. 2019 Aug;98(8):642-648. doi: 10.1097/PHM.0000000000001160. PMID: 31318743.
29. Nisser J, Smolenski U, Sliwinski GE, Schumann P, Heinke A, Malberg H, et al. The FED-Method (Fixation, Elongation, Derotation) - a Machine-supported Treatment Approach to Patients with Idiopathic Scoliosis - Systematic Review. *Z Orthop Unfall*. 2020 Jun;158(3):318-332. English, German. doi: 10.1055/a-0881-3430. Epub 2019 Aug 12. PMID: 31404938.
30. Bialek M. Mild angle early onset idiopathic scoliosis children avoid progression under FITS method (Functional Individual Therapy of Scoliosis). *Medicine (Baltimore)*. 2015 May;94(20):e863. doi: 10.1097/MD.0000000000000863. PMID: 25997065; PMCID: PMC4602882.
31. Trzcińska S, Nowak Z. Analysis of scoliosis deformation in the Zebris computer study as an assessment of the effectiveness of the FED method in the treatment of idiopathic scolioses. *Pol Merkur Lekarski*. 2020 Jun 17;48(285):174-178. PMID: 32564042.
32. Bialek M. Conservative treatment of idiopathic scoliosis according to FITS concept: presentation of the method and preliminary, short term radiological and clinical results based on SOSORT and SRS criteria. *Scoliosis*. 2011 Nov 28;6:25. doi: 10.1186/1748-7161-6-25. PMID: 22122964; PMCID: PMC3286410.

33. Seleviciene V, Cesnaviciute A, Strukcinskiene B, Marcinowicz L, Strazdiene N, Genowska A. Physiotherapeutic Scoliosis-Specific Exercise Methodologies Used for Conservative Treatment of Adolescent Idiopathic Scoliosis, and Their Effectiveness: An Extended Literature Review of Current Research and Practice. *Int J Environ Res Public Health.* 2022 Jul 28;19(15):9240. doi: 10.3390/ijerph19159240. PMID: 35954620; PMCID: PMC9368145.
34. Dobosiewicz K, Durmala J, Kotwicki T. Dobosiewicz method physiotherapy for idiopathic scoliosis. *Stud Health Technol Inform.* 2008;135:228-36. PMID: 18401093.
35. Kalichman L, Kendelker L, Bezalel T. Bracing and exercise-based treatment for idiopathic scoliosis. *J Bodyw Mov Ther.* 2016 Jan;20(1):56-64. doi: 10.1016/j.jbmt.2015.04.007. Epub 2015 Apr 23. PMID: 26891638.
36. Dobosiewicz K, Durmała J, Kotwicki T. Biodynamic method for 3-D correction of idiopathic scoliosis: a description of the method. *Ortop Traumatol Rehabil.* 2005 Feb 28;7(1):49-54. PMID: 17675956.
37. Dobosiewicz K, Durmala J, Jendrzejek H, Czernicki K. Influence of method of asymmetric trunk mobilization on shaping of a physiological thoracic kyphosis in children and youth suffering from progressive idiopathic scoliosis. *Stud Health Technol Inform.* 2002;91:348-51. PMID: 15457753.
38. Dobosiewicz K, Durmala J, Czernicki K, Piotrowski J. Radiological results of Dobosiewicz method of three-dimensional treatment of progressive idiopathic scoliosis. *Stud Health Technol Inform.* 2006;123:267-72. PMID: 17108438.