Effectiveness of Physiotherapeutic Interventions for Early Adolescent Idiopathic Scoliosis: Emphasis on the Schroth Method

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Abstract

Adolescent Idiopathic Scoliosis (AIS) is a complex and prevalent three-dimensional spinal deformity characterized by a lateral curvature of the spine and vertebral rotation, most commonly manifesting during periods of rapid growth in early teenage years, typically between the ages of 10 and 18. This comprehensive review critically examines current conservative, non-surgical treatment strategies for AIS, with a particular emphasis on the growing body of evidence supporting Physiotherapeutic Scoliosis-Specific Exercises (PSSE). Among these, the Schroth Method stands out as a highly specialized and widely recognized approach. Specifically targeted at adolescents aged 13 to 15, the Schroth Method is an individualized exercise program that combines unique principles of customized postural corrections, muscle strengthening, and specialized rotational angular breathing techniques. These components work synergistically to address the specific patterns of spinal misalignments, improve trunk stability, restore muscular symmetry around the torso, and enhance spinal flexibility. The core objective is to de-rotate, deflex, and elongate the spine. By systematically evaluating current literature, this paper highlights the significant effectiveness of early intervention with PSSE in managing the progression of scoliosis, particularly in reducing Cobb angle progression, improving postural alignment, and enhancing overall functional outcomes. Furthermore, the review explores how these targeted exercises contribute to a better quality of life for adolescents with AIS by alleviating pain, improving body image, and increasing physical activity levels. The study ultimately emphasizes the crucial importance of integrating structured, evidence-based physiotherapy, such as the Schroth Method, into the routine care pathway for

AIS patients. Such proactive and holistic conservative management aims to delay or, in many cases, entirely prevent the need for more invasive surgical correction, offering a vital alternative for affected adolescents.

Keywords: Adolescent Idiopathic Scoliosis, Physiotherapeutic Scoliosis-Specific Exercises, Schroth Method, Non-Surgical Treatment, Spinal Deformity, Early Intervention, Cobb Angle.

Introduction

Posture, or the manner in which the body is held, is a growing concern that has drawn our attention for further study and analysis—driven not only by the increasing prevalence of postural issues among children today, but more importantly, by the long-term negative consequences these deviations may cause if not corrected in a timely manner. Since 1850, "correct posture education" has been an integral part of educational policies for the younger generations in wealthier societies—especially in the United States—although the primary aim at the time was to promote "an aesthetically pleasing appearance" (Quka et al., 2015).

Posture has been approached from various perspectives depending on the scientific field studying it. Nevertheless, the most commonly accepted definition of "correct posture" is the relative alignment of body segments in relation to the sagittal axis. Conversely, "incorrect posture" refers to a misalignment in which the body segments are not in line with the sagittal axis, appearing displaced or unbalanced. Correcting postural deviations in children is especially important (Cordeiro et al., 2014), and current research emphasizes that **early intervention is more effective and achievable before the skeletal system completes its growth process**.

Therefore, **early diagnosis of postural deviations in children is critical**, as it offers both the time and opportunity for effective correction (Cosma et al., 2015; Quka & Kacurri, 2016).

Scoliosis—has become an increasing concern among adolescents worldwide, particularly affecting individuals aged 13 to 15. Our study, **"Rehabilitation of Scoliosis in Adolescents Aged 13–15,"** addresses this pressing health issue by focusing on the potential of targeted rehabilitation strategies to improve the quality of life and physical functioning in adolescents diagnosed with scoliosis. Globally, there is growing recognition of the need for evidence-based rehabilitation programs. In Albania and neighboring regions, the demand for such research is considerable, yet **local resources dedicated to scoliosis rehabilitation in youth populations remain limited**. Through our study, we aim to contribute to the growing body of knowledge in scoliosis management, aligning our objectives with both national and international standards. **Our research responds directly to the needs of local healthcare institutions, educational bodies, and sports federations**. This work is

especially relevant within the context of Albania's national academic and public health priorities.

There is increasing emphasis on the advancement of rehabilitation sciences and healthcare methodologies that meet global standards. Universities and research institutions in Albania recognize the need for evidence-based practices to support early intervention and holistic management of adolescent scoliosis. Globally, scoliosis research has gained considerable momentum, with studies across North America, Europe, and Asia focusing on early detection, effective treatment methods, and long-term management strategies. These studies underscore the importance of reducing the physical impact of scoliosis, improving posture, and enhancing overall quality of life. However, despite notable international progress, research into scoliosis rehabilitation for adolescents remains underdeveloped in some regions, including our own.

The significance of our study lies in its dual response—addressing both local healthcare needs and broader policy goals. In Albania and surrounding areas, scoliosis is a growing concern, increasingly detected through school screenings and routine physical examinations. Our study aims to fill these gaps by responding directly to the demands outlined by national healthcare systems, educational institutions, and sports organizations.Current evidence highlights the effectiveness of early, personalized treatment approaches in managing adolescent idiopathic scoliosis. Conservative methods involving postural control, improved body balance, and muscle strengthening have proven successful in preventing spinal curvature progression and improving patient quality of life.

The Schroth method and other functional rehabilitation techniques help maintain muscular balance and trunk stability, mitigating the physical and emotional impact of scoliosis. The rehabilitation of idiopathic scoliosis requires a **multidisciplinary approach**, involving orthopedic specialists, physiotherapists, and psychologists to develop tailored treatment plans. These programs focus on posture correction, muscle strengthening, and psychological support. Conservative treatment methods such as Schroth and strengthening exercises are effective in avoiding or delaying surgical interventions.

In summary, our study aims to provide new insights and practical applications that contribute to ongoing efforts to improve scoliosis care at the local level and bring Albanian rehabilitation practices in line with international standards. Through its findings, our research seeks to benefit the immediate needs of adolescents affected by scoliosis while establishing a foundation for advancing rehabilitation practices across the national healthcare and educational systems.

Methodology

The study uses a comparative and observational design, focusing on adolescents aged 13–15. Methods include radiographic Cobb angle analysis, surface EMG, and 4D

posture analysis. Participants undergo targeted PSSE rehabilitation protocols versus general exercise controls.

The literature search was conducted using databases containing peer-reviewed journal articles and conference proceedings. Throughout the search process, carefully selected keywords of studies directly related to the research topic: *Idiopathic Scoliosis*, *Spinal Curvature*, *Postural Control*, *Muscle Imbalance*, *Schroth Method*, *Muscle Strength*, *Postural Asymmetry*, *Functional Rehabilitation*, *Scoliosis Progression*, *Body Balance*, *Cobb Angle*, *Trunk Stability*, and *Quality of Life*.The literature search was carried out using the following databases and sources: PubMed, SportDiscus, ResearchGate, Scopus, Google Scholar, Spine Journal, Journal of Orthopaedic Research, Journal of Orthopaedic Surgery-Research, Clinical Orthopaedics -Related Research, European Spine Journal, Journal of Pediatric Orthopaedics, MedlinePlus.

Selection of Key Studies. To ensure that only the most relevant and high-quality studies were included in the review, well-defined inclusion and exclusion criteria were applied during the selection process. This step was crucial to maintain consistency with the research objectives.

Inclusion criteria:

Studies published between 2014 and 2024

Sources from credible and accessible websites focused on diagnosis, treatment, and advances in scoliosis research

Studies exploring advanced orthopedic research, including scoliosis treatment and management

Exclusion criteria:

Articles published before 2014

Studies not directly focused on scoliosis or spinal pathologies

Articles not available in English or Albanian

Literature Review

Over the course of 4.5 million years, the human spine has evolved to support upright posture, resulting in sagittal spinal curvatures that are unique to our species. Unlike in primates, adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that causes trunk imbalance and primarily appears during adolescence (Kubat & Ovadia, 2020). Globally, scoliosis affects about 2–3% of the population, with 6 to 9 million cases reported. Many individuals remain undiagnosed until adulthood (Fleming, 2018).

Scoliosis is typically identified by asymmetries such as uneven shoulders, rib cage imbalance, or lateral trunk deviation, and in severe cases, may affect respiratory function.

There are three main types of scoliosis:

Idiopathic (unknown cause; ~80% of cases)

Congenital (present from birth)

Neuromuscular (caused by conditions like muscular dystrophy, spinal muscular atrophy, or spina bifida) (Fleming, 2018).

One of the most visible signs of idiopathic scoliosis is shoulder asymmetry, which, when exceeding 2 cm, can indicate a high risk of curve progression (Farshad et al., 2022). Since scoliosis is a three-dimensional structural deformity involving the sagittal, coronal, and transverse planes, accurate assessment is crucial for effective rehabilitation (Xinyu et al., 2022; Kuan-Wen et al., 2020).

Adolescent Idiopathic Scoliosis typically affects 1–3% of the population aged 10– 16 years and may lead to spinal deformity, back pain, psychological distress, and rarely cardiopulmonary complications (Villareal & Ingrid 2023; Anderzej et al.,2024). Early use of auto-corrective exercises and continuous monitoring using surface electromyography (EMG) can help assess neuromuscular activation and treatment effectiveness (Mantana et al., 2024).

From a biomechanical standpoint, gravitational force and spinal imbalance are major contributors to scoliosis development. The presence of a primary spinal curve often leads to compensatory secondary curves, worsening the deformity if left untreated (Jacek, 2021). Muscle imbalance, especially due to impaired central nervous system regulation, has been proposed as a key etiological factor in AIS (Bahar et al., 2021).

Genetics also play a significant role, particularly mutations in genes such as **GPR126** and **COL1A1**.Early genetic screening could help identify at-risk children and improve prevention strategies (Zhenguo et al.,2024; Shang et al., 2024).

Scoliosis may also impair thoracic structure and lung function. In adolescents with moderate scoliosis, VO_2max and ventilatory capacity are significantly lower than in healthy peers, underscoring the need for cardio-respiratory rehabilitation (Andrzej et al., 2024; Siwiec et al., 2024).

Body Mass Index (BMI) is another influencing factor. Both underweight and overweight adolescents are at greater risk for rotational spinal deformities. A BMI outside the normal range disrupts postural balance, affecting growth and increasing scoliosis risk (Parmitha et al., 2024; Ida et al., 2024). Sedentary behavior, poor posture, and unbalanced backpack carrying during adolescence further contribute to musculoskeletal imbalances (Bal et al., 2023; Naseer et al., 2023).

Ultimately, early screening, balanced nutrition, and regular physical activity are crucial to reducing scoliosis progression and improving long-term spinal health.

Category	Factor	Description	Source
Clinical Sign	Shoulder Asymmetry	≥2 cm asymmetry indicates high progression risk	Farshad et al., 2022
Structure	3D Deformity	Affects sagittal, coronal, and transverse planes	Xinyu et al.,2022
Prevalence	Adolescents (10–16)	1–3% affected globally	Villareal & Ingrid, 2023
Symptoms	Pain, Imbalance	Postural deviation, back pain, respiratory issues	Anderzej et al., 2024
Diagnosis Tool	Surface EMG	Tracks muscle activation during therapy	Mantana et al., 2024
Biomechanics	Gravitational Load	Causes spinal curves due to vertical pressure	Jacek, 2021
Etiology	CNS Dysfunction	Disrupts muscle tone and spinal control	Bahar et al., 2021
Genetics	GPR126, COL1A1	Affect vertebral development and structure	Zhenguo et al., 2024
Lung Function	VO_2max Decrease	Lower capacity in adolescents with scoliosis	Siwiec et al., 2024
BMI	High/Low BMI	Both linked to greater scoliosis risk	Ida et al., 2024
Lifestyle	Sedentary/Posture	Poor habits increase muscle imbalance	Bal et al., 2023; Naseer et al., 2023

Table 1: *Key Literature Insights on Adolescent Idiopathic Scoliosis*

In adolescent idiopathic scoliosis (AIS), muscle fiber changes occur, particularly in the paraspinal muscles on the concave and convex sides of the spine. Studies (Mantana et al., 2023; Shahidi et al., 2021) show that although muscle fibers on the convex side are larger, overall muscle tissue is atrophic compared to healthy individuals, with collagen levels similar to those in degenerative spinal pathology.The three-dimensional deformity in AIS involves muscular imbalances, including abdominal muscles (external/internal obliques and transverse abdominis), which contribute to trunk asymmetry and imbalance (Carole et al., 2016; Sung-Young & Sang- Yeol, 2023).

Early correction of this muscular asymmetry is key to gradual spinal realignment. The International Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) and the Scoliosis Research Society (SRS) endorse the PSSE Schroth method as an effective rehabilitation protocol. A study of 163 patients (Nikos et al., 2024) showed that PSSE significantly improved trunk rotation, self-perception, and quality of life compared to generalized exercises.

At diagnosis, careful monitoring of erector spinae muscle differences between the convex and concave sides is essential. Research (Ozren, 2020; Wilczynski, 2021) found that erector spinae muscles are shortened on the concave side and elongated

on the convex side, with muscle tone asymmetries varying by spinal region, influencing curve progression. Diagnostic tools like Diers 4D imaging and electromyography provide detailed assessments of spinal alignment and muscle function (Jonathan et al., 2020; Mantana et al., 2024).

Muscle imbalances contribute to postural and gait deficits that worsen scoliosis progression if untreated (Naseer et al., 2023). Clinical and instrumental assessments beyond radiography, including MRI and computerized analysis, are critical for comprehensive evaluation and tailored rehabilitation (Alessandro et al., 2022). Trunk imbalance strongly correlates with scoliosis severity, low back pain, mental health, and self-image (Carole et al., 2016; Ingrid, 2023). In a study of 55 AIS patients, 85% had trunk imbalance and 73% reported low back pain, emphasizing the need for early detection and intervention. A study on children aged 10-13 (Quka et al., 2023) highlights the growing postural problems linked to modern lifestyles, with only 7.8% having normal posture. Scoliosis prevalence was 11.3%, with high rates of other postural deformities. This calls for early screening and multidisciplinary intervention involving healthcare and education professionals.

Aspect	Findings / Data	Reference
Muscle fiber changes	Convex side fibers wider but overall atrophic compared to healthy controls; collagen levels similar to degenerative spinal pathology	Mantana et al., 2023; Shahidi et al., 2021
Paraspinal muscle tone asymmetry	Higher tone in erector spinae on convex side (thoracic), concave side (lumbar); causes imbalance and asymmetry	Jacek Wilczynski, 2021; Luca et al., 2021
Abdominal muscles role	Imbalance in oblique and transverse abdominal muscles contributes to 3D trunk deformity and imbalance	Carole et al., 2016; Sung- Young & Sang-Yeol, 2023
PSSE Schroth method effectiveness	Study on 163 patients (age 10-15): improved trunk rotation, self-perception, QoL; better than general exercises	Nikos et al., 2024; Karavidhas et al., 2024
Postural imbalance prevalence	85% of patients showed trunk imbalance; 73% reported low back pain	Carole et al., 2016
Prevalence in general childrens (10-13 years)	7.8% normal posture; 11.3% scoliosis (frontal plane); 90.25% postural deviations (posterior); kyphosis 3.57%; lordosis 6.49%	Quka et al., 2023

Diagnostic tools used	Diers 4photogrammetry, electromyography, MRI, radiographs for objective assessment	Jonathan et al., 2020; Alessandro et al., 2022

Table 2. Specific Field of Study

Diagnostic and Treatment Methods. AIS diagnosis combines clinical assessment and imaging. Standard tools include full- spine standing X-rays (AP/lateral), scoliometer, and postural inspection. Advanced tools like Zebris and Diers 4D analyze posture and movement, while dynamometers measure trunk muscle strength.

Treatment Methods: Treatment depends on curve severity and progression risk. It includes:

Observation for mild, non-progressive curves.

PSSE-Schroth exercises for 3D correction, postural training, and rotational breathing.

Core stabilization exercises to strengthen trunk muscles.

Bracing (e.g., Boston brace) for curves >25° with progression.

Surgery for severe curves (>45–50°).

Scoliosis diagnosis commonly uses digital radiography with anteroposterior and lateral spine views, measuring the Cobb angle. To reduce radiation exposure in children (aged 13–15), low-dose techniques and limited radiographs (no more than once a year) are recommended (Xinyu et al., 2022). Non-invasive methods like the Zebris system use ultrasound to assess spinal curvature and muscular imbalances, allowing repeated evaluations without radiation (Maria et al., 2018). The Diers 4D system offers dynamic, radiation-free analysis of spinal deformities, muscle imbalances, and plantar foot positioning in static and moving states, useful for early detection and rehabilitation monitoring (Jonathan et al., 2020). Muscle tone assessment with a dynamometer is crucial for tracking scoliosis progression and guiding rehabilitation, especially to restore trunk symmetry by strengthening weakened muscles (Jonathan et al., 2024; Jacek, 2021). Treatment is based on Physiotherapeutic Scoliosis-Specific Exercises (PSSE), such as the Schroth method, which uses targeted exercises to correct posture and muscle imbalance, improving spinal alignment (Nikos et al., 2024; Peng et al., 2023). Studies show PSSE is effective, especially when combined with patient education and home exercises (Hikmet et al., 2021). Early diagnosis and proper rehabilitation are essential to prevent scoliosis progression and improve outcomes (Karavidhas et al., 2024).

Discussion

Based on the literature review, research questions, and hypotheses, the conclusions are addressed according to the biomechanics and pathophysiology of idiopathic scoliosis and the clinical-biomechanical perspective.

This research project aims to answer the following questions:

1. **Research Question/Hypothesis 1:** What will be the rehabilitative impact of a specific exercise protocol on the severity of scoliosis?
2. **Research Question/Hypothesis 2:** What is the correlation between muscle strength indicators in various regions and the degree of scoliosis deformity?
3. **Research Question/Hypothesis 3:** What is the correlation between the degree of scoliosis and the level of balance and postural control?

In this section, we identify the research questions/hypotheses and explain the rationale for raising these questions, as summarized in Table 3.

N	Research Question	Rationale for Research
RQ1	What will be the rehabilitative impact of the specific exercise protocol on the severity of scoliosis?	To understand the specific effect of an exercise protocol,when combined with supervision by specialized physiotherapists and continuous medical monitoring to adjust exercise intensity and type according to individual needs.
RQ2	What is the correlation between muscle strength indicators in various regions and the degree of scoliosis deformity?	Understanding this correlation allows rehabilitation professionals to create specific exercise programs targeting necessary muscle regions to improve stability and posture.
RQ3	What is the correlation between the degree of scoliosis and the level of balance and postural control?	By understanding how scoliosis severity affects postural control, therapists can develop personalized exercise protocols to improve balance and stability.

Table 3: Research Questions

This section presents results based on each research question. The findings of this systematic review rely on the analysis of included scientific articles, focusing on the application of rehabilitative protocols and diagnostic tools.

Research Question / Hypothesis 1:

What will be the rehabilitative impact of a specific exercise protocol on scoliosis severity?

Studies have shown that specific exercise protocols can have a significant rehabilitative impact in improving posture and slowing the progression of spinal deformities. In particular, programs based on specialized methods such as Schroth and the Scientific Exercises Approach to Scoliosis (SEAS) have proven effective in reducing the Cobb angle and improving muscle strength and postural balance.

The Schroth method, for example, uses exercises targeting posture correction, balance development, and strengthening of asymmetrical muscles, resulting in substantial condition improvement. Various studies report that patients following this protocol enhance flexibility and stability and report pain reduction. In some cases, Cobb angle reduction by 5-10 degrees after several months of intensive treatment has been documented (CLEAR Scoliosis Institute).

The SEAS protocol focuses on personalized training to improve posture and postural control, emphasizing patient awareness of postural positioning in daily activities. Studies indicate SEAS effectively stabilizes scoliosis progression and improves overall spinal function, with patients experiencing less deformity progression compared to those undergoing standard physical therapy. A systematic review suggests these protocols are most effective when applied early. However, their long-term effectiveness remains a subject of further research to determine if Cobb angle improvements persist over extended periods (Day et al., 2019).

Research Question / Hypothesis 2:

What is the correlation between muscle strength indicators in various regions and scoliosis deformity severity?

Research shows a link between muscle strength and deformity severity in scoliosis, especially in trunk and paraspinal muscles supporting the spine. The body often develops asymmetry in muscle strength due to spinal curvature; muscles on the convex side of scoliosis tend to be weaker, while those on the concave side may be tighter or overactive to compensate (Qi et al., 2023).

Studies on scoliosis patients indicate those with greater deformity severity often have lower extensor muscle strength in the trunk. Furthermore, increased asymmetry in muscle strength correlates with greater difficulties in postural stability and balance.

Consequently, treatments involving trunk muscle strengthening can improve postural stability, reduce pain, and slow deformity progression, especially in degenerative scoliosis (Yang et al., 2020).

Research Question / Hypothesis 3:

What is the correlation between scoliosis severity and balance/postural control?

Studies demonstrate a clear relationship between scoliosis severity and balance and postural control levels. Particularly in more severe scoliosis cases, changes in body

balance regulation lead to difficulties in maintaining stability and increased risk of balance loss during daily activities.

1. **In adolescent idiopathic scoliosis (AIS) patients:** Research shows that patients with Cobb angles > 30° often experience greater difficulty maintaining balance. This is linked to body asymmetries caused by scoliosis, where trunk muscles are asymmetric, making stable posture maintenance challenging. Recent studies reveal that young AIS patients have lower balance levels compared to healthy individual. (Nadia et al., 2021; Liu et al., 2022).
2. **The importance of 3D scoliosis and its impact on postural balance:** The degree of 3D spinal deformity (not only in the coronal plane but also sagittal and axial planes) greatly affects postural control. These deformities influence how the body manages loads and maintains balance. Some studies suggest that improving balance can be achieved through treatments focusing on correcting and enhancing coordination and postural stability (Liu et al., 2022).
3. **Effects of exercise protocols and rehabilitation:** Research suggests that exercise-based rehabilitation methods (such as Schroth or SEAS) help improve balance and postural control. Exercises targeting trunk muscle strengthening and posture correction are beneficial for scoliosis patients by helping them enhance postural control and reduce injury risk due to balance loss (Nadia et al., 2021).

Results and Conclusions

Based on the literature review, research questions, and hypotheses, we conclude with insights from the biomechanics and pathophysiology of idiopathic scoliosis, along with clinical-biomechanical viewpoints:

Etiological factors of idiopathic scoliosis are multifactorial, involving complex interactions between genetic, biomechanical, and neuromuscular elements. Studies have shown possible links between genetic mutations and vertebral deformity susceptibility.

Biomechanical disorders such as force imbalances acting on the spine play a key role in developing three-dimensional curvature.Advanced technologies like 3D analysis and enhanced imaging have improved the evaluation of postural deformities and their mechanisms.

Cobb angle analysis and scoliosis progression: Cobb angle remains the gold standard for measuring spinal curvature, offering a simple and repeatable method to monitor scoliosis progression. Progression is closely related to rapid skeletal growth phases, emphasizing the need for regular follow-up in adolescent patients.

Risk factors for progression include a high initial Cobb angle, young skeletal age, and female sex. These factors must be considered for personalized treatment decisions. Technologies such as EOS Imaging have enhanced measurement accuracy and reduced radiation exposure, offering safer options for long-term monitoring.

Postural asymmetry and muscle imbalance (causes and consequences): Postural asymmetry and muscle imbalance are not only consequences of spinal curvature but also contribute to its progression. These imbalances cause unequal load distribution on vertebrae and surrounding muscles.

Main causes include biomechanical deformities and neuromuscular disorders affecting balance and postural control. Consequences of muscle imbalance are multifaceted, including chronic pain, movement limitations, and psychological impacts. Treatments focusing on correcting muscle imbalance, such as postural exercises and brace use, have shown positive results in reducing progression and improving quality of life.

Regarding non-surgical treatment strategies and rehabilitation for spinal stabilization: The Schroth method is a non-invasive, multidimensional treatment focusing on restoring body balance through a combination of postural exercises, breathing techniques, and muscle control re-education. Studies show it effectively reduces Cobb angle, improves posture, and reduces chronic pain.

Individualized treatment and adaptation based on deformity severity are key to the success of the Schroth method. This approach helps prevent deformity progression and improves patients' daily function. Using this method as part of multidisciplinary therapy has been particularly successful in adolescent patients.

References

[1] Alghadier, Mshari & Basalem, Nourah & Elnaggar, Ragab & Sallam, Sallam & Abbas, Amany & Abuzaid, Ibrahim. (2023). Correlation between Vitamin D Level and the Development of Idiopathic Scoliosis in Pediatric Population: Early Detection. DOI:10.21203/rs.3.rs-3129122/v1

[2] Bal, E., & Batin, S. (2023). Comparison of morphometric measurements of lumbar muscles on the convex and concave sides of curvature in idiopathic scoliosis. Medicine, 102(41), e35667.

[3] Bucke, J., Mattiussi, A., May, K., & Shaw, J. (2024). The reliability, variability and minimal detectable change of multiplanar isometric trunk strength testing using a fixed digital dynamometer. Journal of sports sciences, 42(9), 840–846.

[4] Byl, N. N., & Gray, J. M. (1993). Complex balance reactions in different sensory conditions: adolescents with and without idiopathic scoliosis. *Journal of orthopaedic research: official publication of the Orthopaedic Research Society*, *11*(2), 215–227.

[5] Cordeiro T.L., Duarte A., Collucci A., Frade M. (2014). Baropodometer as a Clinical Tool for Evaluating and Following Treatment of Postural Deviations - A Case Report. J Spine.

[6] Cosma G., Ilinca I., Rusu L., Nanu C., Burileanu A. (2015). Physical exercise and

its role in a corect postural alignment. Physical Education, Sport and Kinetotherapy Journal. Vol. 9 No. 1. Pg. 39.

[7] de Sire, A., Ferraro, E., & Leigheb, M. (2022). Advance in the Diagnostics and Management of Musculoskeletal Diseases. Diagnostics (Basel, Switzerland), 12(7), 1588.

[8] Dimitrios LYTRAS [2], Konstantinos KASIMIS [2], Athanasios KYRKOUSIS [2], Thomas APOSTOLOU [2]. (2024) Physiotherapeutic Scoliosis-Specific Exercises (PSSE- Schroth) can reduce the risk for progression during early growth in curves below 25°: prospective control study. European Journal of physical and rehabilitation Medicine Vol. 60. DOI: 10.23736/S1973-9087.24.08177-2

[9] FLEMING, J. (2018) Treating Scoliosis [www] Available from: ttps://www.brianmac.co.uk/articles/article350.htm [Accessed 9/11/2024]

[10] Florentina Nechita. (2022). The Effect of Physiotherapy in Assessing the Amplitude of Spine Movement in Patients with Scoliosis. Bulletin of the Transylvania University of Braşov Series IX: Sciences of Human Kinetics • Vol. 15(64) No. 2

[11] Fortin, C., Grunstein, E., Labelle, H., Parent, S., & Ehrmann Feldman, D. (2016). Trunk imbalance in adolescent idiopathic scoliosis. *The spine journal: official journal of the North American Spine Society*, *16*(6), 687–693.

[12] He, Wei & Li, Jialong & Wang, Jiayu & He, Da & Song, Kai. (2024). Optimization of traction parameters for lumbar scoliosis. 10.21203/rs.3.rs-4035407/v1.

[13] Horng, J., Liu, X. C., Thometz, J., Tassone, C., & Duey-Holtz, A. (2021). Evaluation of plantar pressures and center of pressure trajectories in Adolescent Idiopathic Scoliosis. Studies in health technology and informatics, 280, 131–135.

[14] Horng, Jonathan & Liu, Xue & Thometz, John & Tassone, Channing & Escott, Benjamin. (2020). Potential Clinical Application For Comprehensive Evaluation of Adolescent Idiopathic Scoliosis Using Surface Topography. Journal of Musculoskeletal Research. 23. DOI:10.1142/S0218957720300021

[15] Ida Ayu Jelantik Ari Parmitha[1*,] Gede Parta Kinandana[2], Ni Luh Nopi Andayani[2], Ni Luh Putu Gita Karunia Saraswati[2.] (2024). The relationship between body mass index and vertebral rotation deformity in adolescents with idiopathic scoliosis. Physical Therapy Journal of Indonesia (PTJI) 2024, Volume 5, Number 1: 38-42 E-ISSN : 2722-6034 ; P-ISSN : 2722-0125.

[16] Joseph M. Day[1*], Jeremy Fletcher[2], Mackenzie Coghlan[3] and Terrence Ravine[4] (2019) Review of scoliosis-specific exercise methods used to correct adolescent idiopathic scoliosis. Archives of Physiotherapy volume 9, Article number: 8.

[17] Kang, B., Lee, C., Kim, D., Lee, H. J., Lee, D., Jeon, H. G., Kim, Y., & Kim, D. (2024).

[18] Karam, M., Ghanem, I., Vergari, C., Khalil, N., Saadé, M., Chaaya, C., Rteil, A., Ayoub, E., Saad, E., Kharrat, K., Skalli, W., & Assi, A. (2022). Global malalignment in adolescent idiopathic scoliosis: the axial deformity is the main driver. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *31*(9), 2326–2338.

[19] Karavidas, N., Iakovidis, P., Chatziprodromidou, I., Lytras, D., Kasimis, K., Kyrkousis, A., & Apostolou, T. (2024). Physiotherapeutic Scoliosis-Specific Exercises (PSSE- Schroth) can reduce the risk for progression during early growth in curves below 25°: prospective control study. European journal of physical and rehabilitation medicine, 60(2), 331–339.

[20] Khaledi, A., Minoonejad, H., Daneshmandi, H., Akoochakian, M., & Gheitasi, M. (2024). Outcomes of 12 Weeks of Schroth and Asymmetric Spinal Stabilization Exercises on Cobb Angle, Angle of Trunk Rotation, and Quality of Life in Adolescent Boys with Idiopathic Scoliosis: A Randomized-controlled Trial. *The archives of bone and joint surgery*, *12*(1), 26–35.

[21] Kocaman, H., Bek, N., Kaya, M. H., Büyükturan, B., Yetiş, M., & Büyükturan, Ö. (2021). The effectiveness of two different exercise approaches in adolescent idiopathic scoliosis: A single-blind, randomized-controlled trial. PloS one, 16(4), e0249492.

[22] Kubat, O., & Ovadia, D. (2020). Frontal and sagittal imbalance in patients with adolescent idiopathic deformity. *Annals of translational medicine*, *8*(2), 29. Liu Y, Li X, Dou X, Huang Z, Wang J, Liao B and Zhang X (2022), Correlational analysis of three-dimensional spinopelvic parameters with standing balance and gait characteristics in adolescent idiopathic scoliosis: Apreliminary research on Lenke V. Front. Bioeng. Biotechnol. 10:1022376. DOI: 10.3389/fbioe.2022.1022376

[23] Marin, L., Kawczyński, A., Carnevale Pellino, V., Febbi, M., Silvestri, D., Pedrotti, L., Lovecchio, N., & Vandoni, M. (2021). Displacement of Centre of Pressure during Rehabilitation Exercise in Adolescent Idiopathic Scoliosis Patients. Journal of clinical medicine, 10(13), 2837.

[24] Multivariable analysis for predicting lower limb muscular strength with a hip-joint exoskeleton. Frontiers in bioengineering and biotechnology

[25] Nadia L. Radwan, Marwa M. Ibrahim and Waleed S. Mahmoud (2021) Comparison of two periods of Schroth exercises for improving postural stability indices and Cobb angle in adolescent idiopathic scoliosis. Journal of Back and Musculoskeletal Rehabilitation 35(5):1-10. DOI:10.3233/BMR-200342

[26] Naseer, Qadir & Ullah, Rafi & Ahmad, Mushtaq & Sardar, Bakht & Khan, Muhammad & Hakim, Yasir. (2023). FREQUENCY OF SAGITTAL IMBALANCE IN PATIENTS WITH IDIOPATHIC ADOLESCENT SCOLIOSIS. Journal of Medical Sciences. 31. 331-336. DOI:10.52764/jms.23.31.4.15

[27] Nikos KARAVIDAS [1 *,] Paris IAKOVIDIS [2], Ioanna CHATZIPRODROMIDOU [2],

[28] Nikouei F, Ghandhari H, Ameri E, Mokarami F. Shoulder Imbalance in Adolescent Idiopathic Scoliosis: A Systematic Review of the Current State of the Art. Arch Bone Jt Surg. 2022 Dec;10(12):992-1003. doi: 10.22038/ABJS.2022.64282.3086. PMID: 36721654; PMCID: PMC9846726.

[29] Quka, Najada & Selenica, Rigerta & Shehu, Marsela & Taylor, George. (2023). Body Posture Awareness and Its Application in the Seated Position. International Journal of Human Movement and Sports Sciences. 11. 1349-1360. DOI:10.13189/saj.2023.110620

[30] Quka.N., Kaçurri A. (2016). A Cross-sectional study on postural deviations among Albanian children aged 10–13 years old. 10th European Conference on Education and Applied Psychology. Section 11. Physical Education. Proceedings. Vienna. Pg: 92-99.

[31] Quka.N., Stratoberdha.Dh., Selenica.R. (2015). Risk Factors of Poor Posture in Children and Its Prevalence. Journal of Interdisciplinary Studies.Rome, Italy. Vol. 4, No. 3, Pg. 104-109.