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# Relevance of Surface Electromyography Assessment and Sleep Impairment in Scoliosis: A Pilot Study

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**Abstract:** Background: According to statistics, worldwide, the number of young persons diagnosed with idiopathic scoliosis has tripled in the last 10 years. This tendency seems to be related to the development of technological devices that induce vicious postures. Specialized literature shows that the predicted evolution will lead to a tripling of the population affected by scoliosis by 2050. Associated complications can be most varied, with functional or respiratory and cardiac impairment being the most severe. The purpose of this study is to objectify the effect of associating Schroth therapy with general elements of global postural reeducation (GPR) therapy in the treatment of scoliosis using electromyography, scoliosis assessment scales, and sleep quality evaluation. The present study is addressed to scoliotic patients. Methods: In order to assess the muscle imbalance installed in scoliosis, we have used SEMG, while Epworth, Baecke, and SAQ scales assessed sleepiness, physical activity levels, and self-perception of the scoliotic patient. Results: After performing a therapeutic protocol that combines Schroth and global postural reeducation (GPR) exercises, an improvement of the functional status was observed for the scoliotic patients. The statistical analysis presents a favorable symmetry index during flexion ($p = 0.042$), a significant difference in the Epworth score ($p = 0.002$), as well as a significant difference in the SAQ2 score ($p = 0.049$). Conclusion: Early detection of scoliosis prevents functional degradation. On the other hand, developing an adequate therapeutic protocol leads to an improved functional status and increased life quality.

**Keywords:** scoliosis; electromyography; sleep; sleepiness

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## 1. Introduction

The vertebral column, also seen as the axis of the human skeleton, involves essential functions assigned to the body's physiology and kinesiology [1].

In the case of young persons, the most widespread structural changes are represented by scoliosis and kyphosis. In scoliosis, the shape of the spine changes in the sense of the appearance of atypical curves that follow either the line of the letter *C* or of the letter *S* [2]. Also, Lehnert-Schroth (LS) played a significant role in the advancement and classification of these curve patterns.

The LS classification, according to Schroth terminology, is a system used in pattern-specific physiotherapy to distinguish between two main types of scoliosis: "functional 3-curve scoliosis" and "functional 4-curve scoliosis". These distinctions help tailor physiotherapeutic treatment for scoliosis patients.

Scoliosis is generally detected when the angulation of the vertebral curvature exceeds 10 degrees [3], mainly appearing in adolescents with an average age of 10 to 16; sometimes scoliosis may be discovered in adulthood [4].

The severity of the deformity is based on the scoliotic curvature, on the asymmetries of the shoulders and hips, as well as on the rotation of the vertebral bodies. Long debated in scoliotic cases were also the sleep quality and sleepiness. Since sleep is considered a state of physical and mental rest, its importance becomes crucial, especially in the case of children and adolescents. Their health and development are directly correlated with sleep quality [5].

A total of 91 patients diagnosed with idiopathic scoliosis and aged between 10 and 19 years were analyzed using the Pittsburgh Sleep Quality Index scales (PSQI) and Epworth Sleepiness Scale (EPSS). Of the participants, 64.8% indicated a low sleep quality, while the state of sleepiness during the day was described as normal by 85.7% of the participants [6].

Evaluated in numerous studies and associated with various pathologies, sleep and sleepiness were not clearly correlated with scoliotic attitudes. This fact indicates the need for continuous research in this direction [7].

Early detection and regular monitoring of idiopathic scoliosis prove to play a decisive role in preventing the progressive process of scoliosis as well as in the recovery process of spine dysfunctions [8].

For a reliable evaluation of the functional status, surface electromyography (EMG) can be used. In this sense, the activity of the paravertebral muscles, at the level of T8 and L3, for patients with idiopathic scoliosis proved to be increased, in terms of amplitude, in the convex region of the scoliotic curvature [9]. The same study shows that, compared to a control group, scoliotic patients do not show significant variations in the myoelectric parameters.

However, EMG evaluations are not based on reference values; this leads to a lack of standardization through electromyography evaluation. In this context, numerous studies are based on electrical muscle assessment completed before and after the application of a therapeutic protocol. Such a study took place in 2018 on five patients diagnosed with idiopathic scoliosis with an average age of 14.4 years. The result of the study showed that the EMG signal proved to be significantly different after completing the therapeutic protocol for all muscle groups [10].

Equally, studies based on the comparison of the electrical activity of the erector spinae on scoliotic patients as well as healthy subjects show noticeable EMG signal differences; in the convex region of the scoliotic curve, muscle activity proved to be increased [11].

From a therapeutic point of view, the approaches focused on the use of general Global postural reeducation (GPR) and Schroth therapy have not been intensely debated.

Global postural reeducation (GPR) is a method that focuses on adjusting and reorganizing the posture of the human body to achieve a rebalancing of the postural muscles. GPR identifies and stretches the specific muscles that are considered responsible for postural changes. The method emphasizes the holistic approach of addressing the entire body's posture rather than focusing on isolated areas or symptoms [12].

Since a limited number of studies refer to global postural reeducation as a therapy in idiopathic scoliosis, research in this direction has recently started to be carried out. Based on 16 patients diagnosed with idiopathic scoliosis and with an average Cobb angle of 33°, Dupuis et al. conducted a study analyzing the effectiveness of postural therapy. Exercises based on morphology and symptomatology and organized towards the correction of deformities can lead, according to the previously mentioned study, to a reduction of 11 percent of the Cobb angle [13].

Another method used in therapeutic intervention is the Schroth method. It is a physiotherapeutic approach that employs various exercises, including isometrics, to strengthen or lengthen asymmetrical muscles associated with scoliosis. The treatment program of the Schroth method focuses on correcting scoliotic posture and incorporates specific breathing patterns. The method utilizes proprioceptive and exteroceptive stimulations, as well as mirror control, to enhance body awareness and promote postural corrections. By combining these elements, the Schroth method aims to improve posture, reduce spinal curvature, and enhance overall functional abilities in individuals with scoliosis [14].

The purpose of the present study is to monitor the evolution of children diagnosed with idiopathic scoliosis, to whom a mixed program of GPR and Schroth therapy was applied, considering the following aspect: sleepiness and paravertebral muscular status the latter being assessed through surface electromyography.

The objectives of this study are as follows: to evaluate the paravertebral muscle balance, by EMG, before and after combined therapy; to evaluate the sleepiness according to the evolution of scoliosis and therapy; and to evaluate the perception of scoliosis using specific scales.

## 2. Materials and Methods

### *2.1. Subjects*

The study was conducted in a private practice clinic from Craiova/Romania, from May 2022 until May 2023. A total of 15 children, with an average of 11.9 yrs (SD $\pm$ 3.4) and an average BMI of 18.3 (SD $\pm$ 3.3), who were diagnosed with idiopathic scoliosis (IS) were invited to the study. All subjects had 3C scoliosis with a centered pelvis.

Inclusion criteria: having idiopathic scoliosis, S shape, with a present Cobb angle higher than 10°, being able to communicate with the therapist, and having the ability to understand their requirements. The included subjects were participating for the first time in a study and in a specific physical therapy program.

Exclusion criteria: unwillingness to participate in the study, no approval from the parents, prior musculoskeletal trauma, the existence of kyphoscoliosis, with a Cobb angle lower than 10°, and neurological disorders. The children and their families were informed about the purpose of the study and had to sign an informed consent form before participating in the study. This study has been conducted according to the Declaration of Helsinki (v. 2013).

This is a pilot study.

### *2.2. Evaluation*

#### 2.2.1. Clinical Evaluation

(1) The somatoscopic examination was performed for all subjects included in the study. To eliminate postural biases, the subjects were analyzed in an upright standing position, positioned at a distance of 1–2 m from the examiner. The evaluation was conducted in both the frontal and sagittal planes. In the case of scoliotic patients, the alignment of the body is particularly significant.

In the standing position, waist asymmetry was evaluated by measuring the distance between the trunk and arm on the same horizontal line at the midpoint of each waist concavity.

The subjects underwent pre- and post-treatment postural evaluations using posturography, following established protocols to ensure reliable assessment. The postural evaluations, both at the beginning and end of the experiment, were conducted by a single examiner to minimize evaluation bias. The subjects' images were captured using the Samsung S21 FE® Smartphone Digital Camera, which has a resolution of 12 megapixels (MP).

(2) The Adams forward bend test was utilized to assess the presence of rib prominence or any alterations in the spine. The examiner noted the distance between the floor and the patient's fingertips. A positive test was indicated when the patient was unable to touch the floor with their fingertips.

All subjects included in the study were assessed using the Adams test at the beginning and end of the rehabilitation program (Figure 1).

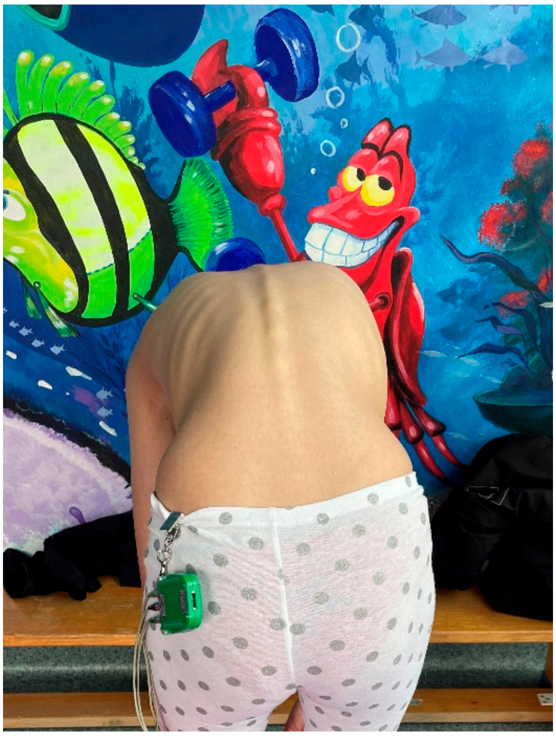


**Figure 1.** Adam's test.

(3) Chest elasticity circumference was used to verify the amplitude of chest expansion during neutral, maximum inhale, and maximum exhale. The test was conducted to determine thoracic elasticity using the formula "Chest perimeter in deep inspiration—Chest perimeter in expiration" with a normal value of 9 cm. This measurement helped evaluate the flexibility and expansion of the thoracic cage during deep inspiration, providing insights into thoracic mobility and respiratory function.

#### 2.2.2. Radiological Evaluation

The second evaluation involved a radiographic examination of the spine, specifically using a posteroanterior view X-ray. This X-ray was used to quantify the angulation of scoliosis based on the Cobb angle measurement [15].

#### 2.2.3. Functional Evaluation

(1) The Baecke Questionnaire was employed to assess the physical activity level of the participants. For this questionnaire, we included only the first section, ruling out the sections where specific sports were in question due to the fact that most of the adolescents and juveniles were advised to avoid intense sports activity [16].
(2) Epworth Sleepiness Scale for Children and Adolescents (ESS-CHAD)—for the sleep deficiencies and the impact of AIS on the overall quality of life. The Epworth Sleepiness Scale (ESS) is a concise and straightforward questionnaire used to subjectively measure sleepiness in everyday life situations. The Epworth Sleepiness Scale (ESS) is a widely used subjective measure for evaluating the level of sleepiness. It consists of 8 situations in which individuals rate their tendency to doze off or fall asleep during specific activities. The ratings range from 0 to 3, where 0 indicates no chance of dozing and 3 represents a high risk of dozing off. The total ESS score provides an overall assessment of an individual's daytime sleepiness level in ordinary life situations. The scale is commonly employed in the medical field to assess sleep-related issues and determine the need for further evaluation or intervention [17].

The Epworth Sleepiness Scale was applied under the ePROVIDE™ license agreement with the identifier Epworth Sleepiness Scale 82955.

(3) Patients had to complete the Scoliosis Appearance Questionnaire (SAQ) for the evaluation of the impact on the mental and physical health of those with idiopathic scoliosis. The Scoliosis Appearance Questionnaire (SAQ) was established as a valid and reliable measurement tool for patients with adolescent idiopathic scoliosis (AIS) [18]. The SAQ was derived from the Walter Reed Visual Assessment Scale [19] and is designed to evaluate a patient's perception of various aspects related to spinal deformity. It serves as a tool to assess how individuals perceive their own scoliosis and its impact on their lives. The SAQ consists of two domains: the appearance domain (Items 1–11) and the expectations domain (Items 12–32). The scoring for each item was between 1 and 5, except for item 31, where the response was strictly subjective and quantified in percentage.

#### 2.2.4. Electromyography Assessment

The examination also included an electrical activity assessment of the paravertebral muscles for all subjects included in the study. The evaluations were performed in orthostatic position and in flexion and hyperextension of the trunk. The data were collected in two distinct moments: before (T1) and after (T2) completing the therapeutic protocol. The rehabilitation program lasted 12 months.

The evaluation was performed using surface electromyography. The modular and portable BIOFEEDBACK 2000 X-Pert system(Biofeedback Xpert–the multi-media system from Schuhfried-Mödling, Austria) was used in the electromyography evaluation. The collected data was transmitted via Bluetooth to an associated computer. The software processed the information and then translated it into diagrams. The EMG module benefited from 2 channels (EMG 1 and EMG 2). EMG channel 1 was positioned on the right side of the rachis, while EMG 2 was positioned on the left side.

For a correct and unaltered measurement, adequate tegument cleaning (removal of dust or grease) and placement of electrodes were necessary. As electrodes are positioned on the surface of the skin, the method is noninvasive.

The position of the electrodes followed the paravertebral muscles at a distance of 2 cm from the spine's axis; electrodes were symmetrically placed on the right and left side of the scoliotic's curvature apex. A neutral electrode was positioned on the spinous process of the C7 vertebra (Figure 2).

Subjects were asked to perform one trunk flexion before valid measurement in order to confirm the correct placement of the electrodes.

The amplitude of the electrical signal was the parameter evaluated from the EMG spectrum. A mean value and a symmetry index (left/right) were calculated. The symmetry index could offer possible leads regarding the degree of muscle imbalance. The EMG evaluation process lasted for 1 min and had a frame frequency of 0.25 ms.

Strong amplitude variations of the collected EMG signal (mV) imposed the calculation of mean values in relation to maximum amplitude values. A range of $\pm$10% of the maximum amplitude was considered.

### *2.3. Statistical Analysis*

For statistical analysis, we utilized Microsoft Excel along with the XLSTAT software package (XLSTAT 2021.2.2.) [20].

The statistical analysis included descriptive statistics, which allowed us to analyze the normal distribution of the data, which is a finding that is present in our research. We used the Jarque–Bera test (JB test) for this purpose. The Jarque–Bera test is a statistical test that is used to determine whether a dataset has a normal distribution based on skewness and kurtosis values.

A Student *t*-test was applied to reveal any differences between parameter values: SAQ scale, Epworth scale, EMG recordings data, and Baecke score. The test indicates whether there is a significant difference. We applied the Student *t*-test for equal means. For evaluation the level of correlations between muscle activity and sleepiness (based on the Epworth scale), we used the Baecke score.

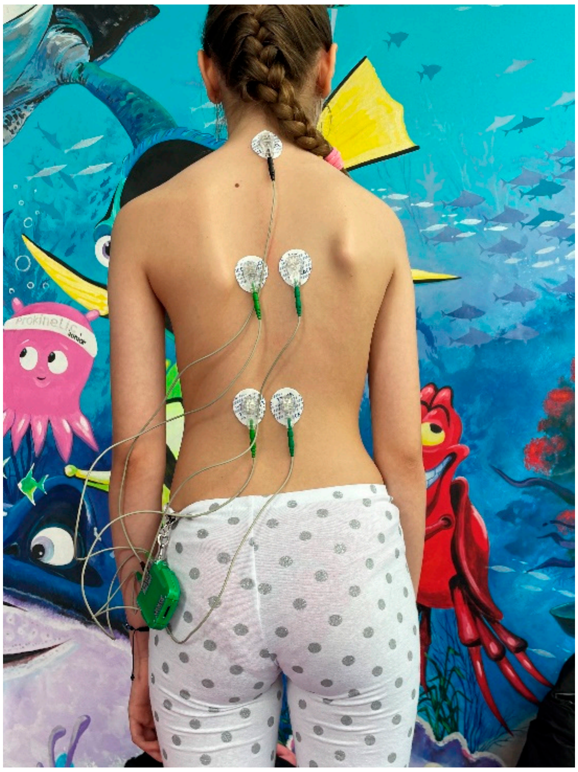


**Figure 2.** Electrode placement at a distance of 2 cm from the spine's axis on the right and left side of the scoliotic's curvature apex. A neutral electrode was positioned on the spinous process of the C7 vertebra.

*2.4. Therapeutic Intervention*

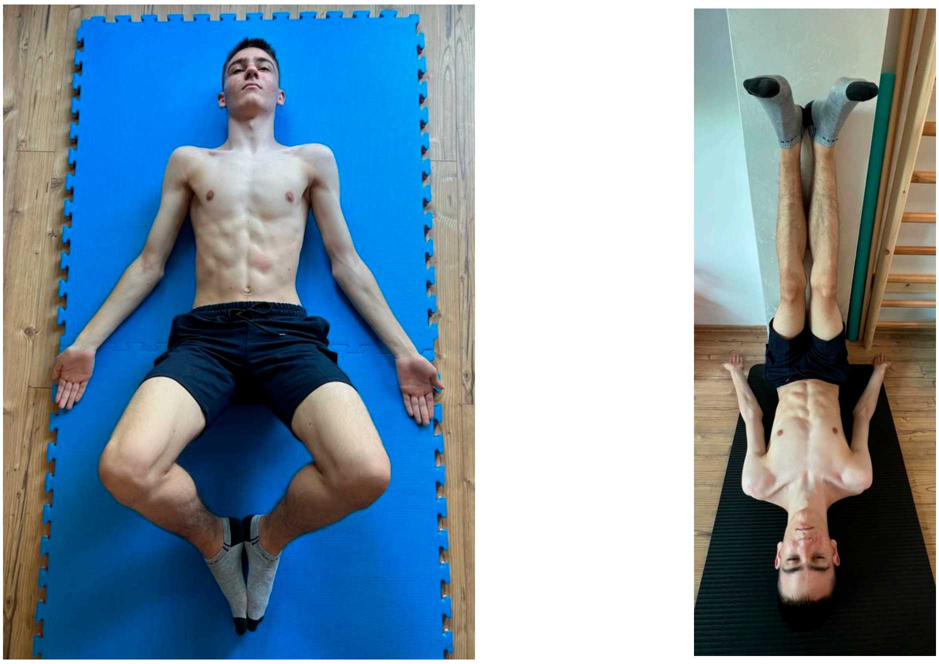
Our treatment regime included elements of global postural reeducation (GPR) combined with elements from Schroth therapy. The primary objective of this protocol was to address and prevent the progression of postural impairments by implementing appropriate corrective measures.

The objectives of the physical therapy program are as follows:

1. Correcting and reducing scoliotic curvatures.
2. Increasing and restoring joint mobility.
3. Strengthening the affected muscles through elongation and shortening exercises.
4. Correcting and maintaining muscle tone.
5. Reeducating the respiratory system.

These objectives aim to address and improve postural impairments, muscle imbalances, and respiratory function through targeted exercises and corrective measures. The kinetic program is designed to promote overall functional improvement and enhance the individual's quality of life.

The patients underwent treatment using the GPR (global postural reeducation) method, which involved performing two postures: "*frog on the ground*" (Figure 3a) and "*frog in the air*" (Figure 3b), both with open arms. These postures were implemented in two stages. The first stage lasted for 5 min, and the second stage lasted for 10 min. Rest intervals were provided as needed during the treatment sessions if necessary [21].



(a) (b)

**Figure 3.** (**a**) Frog on the ground (GPR) (**b**) Frog in the air (GPR).

During the "*Frog*" *posture on the floor*, individuals were instructed to lie supine on the stretcher with their hips in a partially flexed and externally rotated position. Their knees were flexed, and their feet were in dorsiflexion, with the heels together. Initially, the arms were positioned in 90° abduction, with the forearms supinated and fingers extended.

For the "*Frog*" *posture in the air*, participants were in a supine position on a GPR (global postural reeducation) stretcher, but we adopted a modified position with legs supported on the wall. Their hips were flexed at a 90° angle with external rotation, while the knees were semi-flexed. The feet were in dorsiflexion with the heels together. The shoulders were positioned at 90° abduction, and the forearms were supinated with the fingers extended [22].

These specific postures were performed as part of the treatment protocol to target and address postural impairments.

Each posture was carefully designed and customized by the physiotherapist based on the patient's specific spinal deformity and individual defense mechanisms. The therapist responsible for working with the patients underwent specific training (co-author IE) and is a certified GPR (global postural reeducation) physiotherapist. This specialized training and certification ensured that the therapist had the necessary expertise to develop and implement the postures effectively for each patient's condition.

Our patient's exercise program also included elements from Schroth therapy. The patients commenced their exercise program under the supervision of a physiotherapist who is certified in Schroth therapy (co-author IE). The Schroth exercises were performed in an asymmetric position to optimize correction and attain trunk symmetry (Figure 4). These exercises encompassed activities such as spinal elongation, de-rotation, de-flexion, stretching, strengthening, and rotational breathing exercises, all aimed at maintaining proper vertebral alignment [23].

Each posture was sustained for a duration of 10 min during the exercise sessions. This structured approach allowed for targeted engagement of specific muscle groups and facilitated the correction and improvement of postural alignment. The physiotherapist's expertise in Schroth therapy ensured that the exercises were appropriately administered and tailored to meet the needs of each patient.

(a) (b)

**Figure 4.** Schroth posture. (**a**) Schroth posture 1; (**b**) Schroth posture 2.

We have to mention that this program also consisted of a warm-up phase lasting 5 to 10 min, which included stretching, flexibility, and muscle strain exercises at the beginning of each session. At the end of the session, a 5–10 min recovery phase was conducted, involving stretching exercises and breathing exercises.

The entire program, including warm-up, GPR, and Schroth therapy elements and recovery, had a total duration of 1 to 1.5 h and was conducted twice a week for 12 months. Additionally, patients were encouraged to perform the exercises at home daily.

## 3. Results

### *3.1. Results of Clinical Assessment and Anthropometric Measurements of the Subjects*

Clinical assessment revealed an asymmetry in the shoulder level and muscle imbalance highlighted by the Adams test, which was positive for all 15 patients. By the end of the therapeutic protocol, only 6 patients (40%) still presented a positive Adam test.

Anthropometrical parameters were assessed before starting the therapeutic protocol (T1 moment), as presented in Table 1.

**Table 1.** Anthropometrical parameter values in T1 before starting the therapeutic protocol.

| Patient Code | Gender | Age | Height [cm] | Weight [kg] | BMI [kg/m$^2$] |
|---|---|---|---|---|---|
| P1 | F | 15 | 160 | 50 | 19.5 |
| P2 | F | 15 | 162 | 52 | 19.8 |
| P3 | F | 15 | 160 | 48 | 18.8 |
| P4 | F | 14 | 157 | 50 | 20.2 |
| P5 | M | 15 | 176 | 68 | 21.9 |
| P6 | F | 7 | 132 | 21 | 12 |
| P7 | M | 7 | 134 | 23 | 12.8 |
| P8 | F | 10 | 142 | 39 | 19.3 |

**Table 1.** *Cont.*

| Patient Code | Gender | Age | Height [cm] | Weight [kg] | BMI [kg/m$^2$] |
|---|---|---|---|---|---|
| P9 | F | 10 | 140 | 41 | 20.9 |
| P10 | F | 12 | 160 | 47 | 18.4 |
| P11 | F | 8 | 132 | 28 | 16 |
| P12 | M | 14 | 175 | 65 | 21.2 |
| P13 | F | 14 | 159 | 55 | 21.7 |
| P14 | M | 16 | 178 | 63 | 19.9 |
| P15 | M | 7 | 136 | 29 | 12.8 |
| Minimum | | 7 | 132 | 21 | 12.0 |
| Maximum | | 16 | 178 | 68 | 21.9 |
| Mean | | 11.9 | 153.5 | 45.3 | 18.3 |
| Standard deviation | | 3.4 | 16.3 | 14.9 | 3.3 |

The mean value of the BMI was determined to be 18.3, which indicates a normal weight for all patients.

The chest elasticity index, a parameter that highlights the behavior of chest dynamics, which can be affected in idiopathic S-type scoliosis, is presented from an evolutionary point of view in Table 2.

**Table 2.** Evolution of the chest elasticity index (T1—moment of initial assessment; T2—moment of final assessment).

| Patient Code | T1 Chest Circ. N [cm] | T2 Chest Circ. N [cm] | T1 Chest Circ. Ins [cm] | T2 Chest Circ. Ins [cm] | T1 Chest Circ. Exp [cm] | T2 Chest Circ. Exp [cm] | T1 Chest Elasticity Index | T2 Chest Elasticity Index |
|---|---|---|---|---|---|---|---|---|
| P1 | 68 | 69 | 71.5 | 71.5 | 65 | 66 | 6.5 | 5.5 |
| P2 | 69 | 69 | 73 | 73 | 66 | 66 | 7 | 7 |
| P3 | 66.5 | 67.5 | 70 | 71.2 | 64.5 | 65.5 | 5.5 | 5.7 |
| P4 | 63 | 64 | 66 | 67 | 60 | 61 | 6 | 6 |
| P5 | 68 | 68 | 72 | 72 | 64.5 | 64 | 7.5 | 8 |
| P6 | 54 | 55 | 55 | 56 | 52 | 53 | 3 | 3 |
| P7 | 56 | 57 | 60 | 61.5 | 54 | 55 | 6 | 6.5 |
| P8 | 64 | 65 | 67 | 68.5 | 62.5 | 62.5 | 4.5 | 6 |
| P9 | 65 | 66.5 | 69.5 | 70.5 | 64 | 65 | 5.5 | 5.5 |
| P10 | 66.5 | 67 | 72 | 73 | 63 | 64 | 9 | 9 |
| P11 | 56 | 58 | 58 | 60.1 | 54 | 55 | 4 | 5.1 |
| P12 | 69 | 71 | 73 | 75 | 66 | 68 | 7 | 7 |
| P13 | 63 | 65 | 66 | 68 | 60 | 61 | 6 | 7 |
| P14 | 68 | 69 | 70 | 71.5 | 65 | 66 | 5 | 5.5 |
| P15 | 58 | 60 | 61 | 63.5 | 56 | 57 | 5 | 6.5 |

N—neutral; Ins—inspiration (inhale); Exp—expiration (exhale).

Based on the above data, we may conclude that eight out of fifteen subjects (53.3%) had a higher chest elasticity index after completing the rehabilitation program; for one subject (6.66%) the chest elasticity index decreased, while the chest elasticity index did not change value for the remaining six (40%).

### *3.2. Results of Epworth and Baecke Scales*

The assessment process also involved using the Epworth and Baecke scales in the T1 and T2 moments; Table 3 presents the scores of both scales.

**Table 3.** Results of the Epworth and Baecke scales, during therapeutic intervention.

| Patient Code | T1 Epworth Score | T2 Epworth Score | T1 Total Baecke Score | T2 Total Baecke Score |
|---|---|---|---|---|
| P1 | 3 | 3 | 11 | 5 |
| P2 | 7 | 6 | 10 | 10 |
| P3 | 12 | 10 | 13 | 9 |
| P4 | 9 | 7 | 12 | 13 |
| P5 | 8 | 8 | 15 | 15 |
| P6 | 4 | 4 | 14 | 14 |
| P7 | 6 | 6 | 15 | 15 |
| P8 | 7 | 5 | 9 | 10 |
| P9 | 6 | 6 | 16 | 16 |
| P10 | 5 | 5 | 15 | 16 |
| P11 | 10 | 8 | 7 | 11 |
| P12 | 4 | 2 | 9 | 12 |
| P13 | 9 | 7 | 10 | 12 |
| P14 | 8 | 8 | 16 | 16 |
| P15 | 6 | 4 | 11 | 11 |
| Minimum | 3 | 2 | 7 | 5 |
| Maximum | 12 | 10 | 16 | 16 |
| Mean Value | 6.93 | 5.93 | 12.2 | 12.33 |
| Standard Deviation | 2.46 | 2.15 | 2.88 | 3.13 |

The above values present a mean Epworth score with a decreased value in the T2 moment versus the T1 moment and a significant decrease for eight subjects (53.3%).

The Baecke score had an increased mean value in T2 compared to T1 but with a significant increase for six subjects (40%).

### *3.3. Results of the SAQ Scale*

The SAQ scale underlines the mental perception of each subject. This is related to the physical impairment of the scoliotic patient, as detailed in Table 4.

**Table 4.** SAQ scale results at moment T1 and moment T2 of evaluation.

| Patient Code | T1 SAQ Score 1 | T2 SAQ Score 1 | T1 SAQ Score 2 | T2 SAQ Score 2 |
|---|---|---|---|---|
| P1 | 23 | 26 | 86 | 86 |
| P2 | 27 | 23 | 69 | 69 |
| P3 | 39 | 28 | 87 | 87 |
| P4 | 33 | 24 | 70 | 72 |
| P5 | 39 | 29 | 69 | 71 |
| P6 | 31 | 24 | 71 | 71 |
| P7 | 31 | 24 | 59 | 60 |
| P8 | 38 | 28 | 87 | 89 |
| P9 | 28 | 26 | 67 | 69 |
| P10 | 20 | 20 | 49 | 49 |
| P11 | 38 | 28 | 85 | 87 |
| P12 | 36 | 23 | 71 | 83 |
| P13 | 39 | 28 | 87 | 87 |
| P14 | 40 | 23 | 59 | 60 |
| P15 | 31 | 24 | 59 | 60 |
| Minimum | 20 | 20 | 49 | 49 |
| Maximum | 40 | 29 | 87 | 89 |
| Mean | 32.87 | 25.20 | 71.67 | 73.33 |
| Standard Deviation | 6.31 | 2.60 | 12.32 | 12.64 |

Score 1 represents the summation of the values distributed for the 11 images.

Score 2 represents the summation of all values obtained in the 20-item questionnaire.

It can be noticed that for 14 out of 15 subjects (93.33%), the SAQ score 1 has a decreased value in T2 compared to the T1 moment.

It can be also noticed that for 9 out of 15 subjects (60%), the SAQ score 2 has an increased value in T2 compared to the T1 moment.

Both the decrease and the increase tendencies of scores 1 and 2 of the SAQ scale indicate a beneficial evolution of the functional and emotional status of the scoliotic patient.

The interpretation of the SAQ scale also implies choosing the most relevant question out of the 20-item questionnaire, as presented in Table 5. The results show that the same question was chosen both before and after the completion of the therapeutic protocol for all subjects.

**Table 5.** Scala SAQ: Which is the most relevant question?

| Patient Code | T1 the Most Relevant Question | T2 the Most Relevant Question |
|---|---|---|
| P1 | 12 | 12 |
| P2 | 25 | 25 |
| P3 | 14 | 14 |
| P4 | 14 | 14 |
| P5 | 25 | 25 |
| P6 | 25 | 25 |
| P7 | 18 | 18 |
| P8 | 25 | 25 |
| P9 | 12 | 12 |
| P10 | 12 | 12 |
| P11 | 25 | 25 |
| P12 | 12 | 12 |
| P13 | 25 | 25 |
| P14 | 12 | 12 |
| P15 | 12 | 12 |

### *3.4. Statistical Analysis of the Obtained Results throughout Scale Assessment for the 15 Subjects Included in the Study*

The statistical analysis of the results are shown in three scales (Epworth scale and Baecke scale in Table 6 and SAQ scale in Table 7, for the group of 15 subjects).

**Table 6.** Statistical indexes obtained from Epworth and Baecke scales, for the 15 subjects, before (T1) and after (T2) completion of the therapeutic protocol.

| Statistical Indexes Obtained by Difference (after–before) | | | *t*-Test Bilateral Dependence | | |
|---|---|---|---|---|---|
| Scale Type | Mean Difference | Range of Confidence | *t* obs | df | *p* * |
| Epworth | 1 | 0.44; 1.55 | 3.873 | 14 | **0.002** |
| Baecke | −0.133 | −1.49; 1.22 | −0.21 | 14 | 0.836 |

* Threshold value 0.05.

**Table 7.** Statistical indexes obtained from SAQ scale answers, for the 15 subjects, before (T1) and after (T2) completion of the therapeutic protocol.

| Statistical Indexes Obtained by Difference (after–before) | | | *t*-Test Bilateral Dependence | | |
|---|---|---|---|---|---|
| Scale Type | Mean Difference | Range of Confidence | *t* obs | df | *p* * |
| SAQ scor 1 | 7.66 | −4.78; 10.53 | 5.73 | 14 | **0.000** |
| SAQ scor 2 | −1.66 | −3.32; −0.01 | −2.16 | 14 | **0.049** |

* Threshold value 0.05.

Table 6 details the statistical indicators of the answers collected for the Epworth and Baecke scales, for the group of 15 subjects, before (T1) and after (T2) the therapeutic protocol.

Through statistical analysis of the Epworth scale, significant differences can be observed between the two moments (T1—before the kinetic rehabilitation program; T2—after completion of the rehabilitation program), while no significant difference was noticed for the Baecke scale.

Table 7 underlines the statistical analyses of SAQ scale results.

Through statistical analysis of the SAQ scale, significant differences can be observed between the two moments (T1—before the kinetic rehabilitation program; T2—after completion of the rehabilitation program). Score 1 on the SAQ scale has a decreasing tendency, which is translated into a better perception of own physical image, while SAQ score 2 has an increasing tendency, which is again translated through limited desired self-body changes.

As the answers offered for the item "Which is the most relevant question" did not show any modification in time, no signification test was applied for this section.

### *3.5. Results of the EMG Assessment for the 15 Subjects Included in the Study*

The EMG assessment was carried out before performing the rehabilitation program (T1) and 12 months later, after completing the rehabilitation protocol (T2). Dynamic EMG assumed assessment during flexion and hyperextension of the torso, while static EMG was performed in orthostatic position. The voluntary muscular activity was assessed through surface EMG.

The collected data were analyzed considering symmetry by calculating the symmetry index (right side/left side). The utilized formula was based on the ratio of the EMG amplitude signal right/left for the mean maximal amplitude of the EMG signal. This reflects the motor unit activity. Value 1 is considered a reference value and indicates paravertebral muscle symmetry.

The collected data present an improvement of the symmetry index for 12 out of 15 patients and also an improvement of the mean symmetry index value during flexion movement, as shown in Table 8.

**Table 8.** Symmetry index right/left during flexion.

| Patient Code | T1 EMG 1 | T1 EMG 2 | T1 Symmetry Index | T2 EMG 1 | T2 EMG 2 | T2 Symmetry Index |
|---|---|---|---|---|---|---|
| P1 | 34.86 | 32.69 | 1.07 | 92 | 62 | 1.48 |
| P2 | 68.21 | 75.72 | 0.90 | 77.69 | 71 | 1.09 |
| P3 | 100 | 125 | 0.80 | 220 | 220 | 1.00 |
| P4 | 34 | 44 | 0.77 | 220 | 205 | 1.07 |
| P5 | 59 | 73 | 0.81 | 74.66 | 77.87 | 0.96 |
| P6 | 49.65 | 51.03 | 0.97 | 73.15 | 67.90 | 1.08 |
| P7 | 119.37 | 127.30 | 0.94 | 73.15 | 67.90 | 1.08 |
| P8 | 27.70 | 16.47 | 1.68 | 90.19 | 76.95 | 1.17 |
| P9 | 46.09 | 57.70 | 0.80 | 72.45 | 66.70 | 1.09 |
| P10 | 54.33 | 119.88 | 0.45 | 76.40 | 100.03 | 0.76 |
| P11 | 13 | 17.31 | 0.75 | 91.80 | 76.95 | 1.19 |
| P12 | 90 | 110 | 0.82 | 71.00 | 68 | 1.04 |
| P13 | 100 | 118 | 0.85 | 76.00 | 95 | 0.80 |
| P14 | 18.46 | 14.97 | 1.23 | 24.95 | 30 | 0.83 |
| P15 | 74.85 | 82.15 | 0.91 | 72.45 | 56.75 | 1.28 |
| Minimum | 13 | 14.96 | 0.45 | 24.94 | 30 | 0.76 |
| Maximum | 119.37 | 127.29 | 1.68 | 220 | 220 | 1.48 |
| Mean | 59.30 | 71.01 | 0.91 | 93.72 | 89.47 | 1.06 |
| Deviation Standard | 32.21 | 41.51 | 0.27 | 53.54 | 52.5 | 0.18 |

Symmetry index values for the hyperextension movement of the torso are detailed in Table 9.

**Table 9.** Symmetry index right/left during hyperextension.

| Patient Code | T1 EMG 1 | T1 EMG 2 | T1 Symmetry Index | T2 EMG 1 | T2 EMG 2 | T2 Symmetry Index |
|---|---|---|---|---|---|---|
| P1 | 30.71 | 30.84 | 1.00 | 52.59 | 53.75 | 0.98 |
| P2 | 71.23 | 125.95 | 0.57 | 56 | 56 | 1 |
| P3 | 14 | 18 | 0.78 | 150 | 200 | 0.75 |
| P4 | 49 | 59 | 0.83 | 186 | 204 | 0.91 |
| P5 | 29.25 | 29.49 | 0.99 | 37.37 | 40.98 | 0.91 |
| P6 | 38 | 50 | 0.76 | 41.97 | 33.97 | 1.24 |
| P7 | 92.87 | 90 | 1.03 | 40 | 34 | 1.18 |
| P8 | 28.90 | 28.08 | 1.03 | 52.59 | 55.23 | 0.95 |
| P9 | 39.83 | 48.28 | 0.83 | 39.35 | 33.97 | 1.16 |
| P10 | 28.87 | 27.92 | 1.03 | 17.13 | 29.62 | 0.58 |
| P11 | 13 | 17.31 | 0.75 | 54.07 | 56.83 | 0.95 |
| P12 | 23 | 16 | 1.44 | 34.04 | 36.19 | 0.94 |
| P13 | 40.60 | 27.36 | 1.48 | 14.43 | 27.26 | 0.53 |
| P14 | 23.58 | 19.37 | 1.22 | 33 | 33 | 1 |
| P15 | 52.68 | 56.65 | 0.93 | 39.35 | 33.97 | 1.16 |
| Minimum | 13 | 16 | 0.56 | 14.43 | 27.25 | 0.52 |
| Maximum | 92.86 | 125.94 | 1.48 | 186 | 204 | 1.23 |
| Mean | 38.36 | 42.94 | 0.97 | 56.52 | 61.91 | 0.94 |
| Standard Deviation | 21.36 | 30.71 | 0.25 | 47.33 | 57.77 | 0.20 |

During hyperextension movement, the muscular imbalance was maintained in 8 out of 15 subjects, which means there is a majority of 53.33% with poor spine alignment.

The symmetry index values during orthostatic position are detailed in Table 10.

**Table 10.** Symmetry index right/left in orthostatic position.

| Pacient Code | T1 EMG 1 | T1 EMG 2 | T1 Symmetry Index | T2 EMG 1 | T2 EMG 2 | T2 Symmetry Index |
|---|---|---|---|---|---|---|
| P1 | 31.32 | 28.30 | 1.11 | 56 | 54 | 1.04 |
| P2 | 77.69 | 113.31 | 0.69 | 58 | 55 | 1.05 |
| P3 | 14 | 38.00 | 0.37 | 100 | 82 | 1.22 |
| P4 | 40 | 40.00 | 1.00 | 113 | 80 | 1.41 |
| P5 | 47.10 | 62.96 | 1.00 | 47.10 | 62.96 | 0.75 |
| P6 | 45.49 | 59.93 | 0.76 | 35.29 | 54.97 | 0.64 |
| P7 | 65.80 | 53.19 | 1.24 | 47.54 | 45.73 | 1.04 |
| P8 | 20.31 | 19.64 | 1.03 | 100.82 | 79.70 | 1.26 |
| P9 | 34.89 | 37.55 | 0.93 | 35.29 | 45.00 | 0.78 |
| P10 | 27.43 | 21.68 | 1.27 | 14.64 | 17.76 | 0.82 |
| P11 | 14.86 | 17.31 | 0.86 | 60.40 | 56.34 | 1.07 |
| P12 | 24.90 | 20.00 | 1.25 | 46.00 | 63.00 | 0.73 |
| P13 | 65 | 46.00 | 1.41 | 14.64 | 17.76 | 0.82 |
| P14 | 34.57 | 33.24 | 1.04 | 29.16 | 31.83 | 0.92 |
| P15 | 89.74 | 59.00 | 1.52 | 38.27 | 50.40 | 0.76 |
| Minimum | 14 | 17.30 | 0.36 | 14.64 | 17.76 | 0.64 |
| Maximum | 89.73 | 113.31 | 1.52 | 113 | 82 | 1.41 |
| Mean | 42.20 | 43.34 | 1.03 | 53.07 | 53.09 | 0.95 |
| Standard Deviation | 22.99 | 24.72 | 0.29 | 30.06 | 19.92 | 0.22 |

During orthostatic position, symmetry index values lead towards a muscular imbalance for 11 out of 15 patients.

Such results led to a differentiated statistical analysis for establishing the significance threshold. The complexity of the EMG recordings and their variability imposed an approach that allows an electrical muscle behavior analysis (action potential of the motor unit) within a dynamic EMG.

The statistical analyses of the EMG signal collected from the right paravertebral muscles (EMG 1) and left paravertebral muscles (EMG 2) for the 15 subjects included in the study were developed for the flexion and hyperextension movement as well as for the orthostatic posture.

Table 11 presents statistical indexes of the EMG electrical signal variation collected before and after the completion of the therapeutic protocol.

**Table 11.** Statistical indexes of the EMG electrical signal variation (mean amplitude) during flexion, hyperextension, and orthostatic posture collected before and after the completion of the therapeutic protocol.

| | | Statistical Indexes Obtained by Difference (after–before) | | | *t*-Test Bilateral Dependence | | |
|---|---|---|---|---|---|---|---|
| | | **Mean Difference** | **Threshold Value** | **Range of Confidence** | ***t* obs** | **df** | ***p* *** |
| Flexion | EMG 1 | −34.4 | 0.05 | −67.44; −1.39 | −2.236 | 14 | 0.042 |
| | EMG 2 | −18.47 | 0.25 | −36.1; −0.80 | −1.255 | 14 | 0.230 |
| Hyperextension | EMG 1 | −18.15 | 0.22 | −35.7; −0.58 | −1.32 | 14 | 0.206 |
| | EMG 2 | −18.97 | 0.30 | −37.36; −0.58 | −1.11 | 14 | 0.286 |
| Orthostatic positionr | EMG 1 | −10.87 | 0.36 | −21.55; −0.18 | −0.96 | 14 | 0.352 |
| | EMG 2 | −9.76 | 0.26 | −19.40; −0.112 | −1.19 | 14 | 0.255 |

EMG-electromiography, $p$ * = 0.005.

The threshold values are related to the situation in which the null hypothesis is rejected, meaning that EMG results obtained before and after completion of the therapeutic protocol are statistically significantly different (improvement).

A favorable evolution was noticed during the flexion of the torso. This represents an activation of the paravertebral muscles that stabilize the spine. This result was obtained by strengthening and postural reeducation exercises.

Table 12 presents statistical indexes of the symmetry index variation (right/left) before and after performing the therapeutic protocol.

The threshold values are related to the situation in which the null hypothesis is rejected, meaning that symmetry indexes (right/left) obtained before and after completion of the therapeutic protocol are statistically significantly different (improvement).

As before, a favorable symmetry index can only be noticed during flexion movement of the torso. The explanation could derive from the effect of the methods used in the therapeutic approach.

**Table 12.** Statistical indexes of the symmetry index variation during flexion, hyperextension, and orthostatic posture collected before and after the completion of the therapeutical protocol.

| | Statistical Indexes Obtained by Difference (After–Before) | | | *t*-Test Bilateral Dependence | | |
|---|---|---|---|---|---|---|
| | Mean Difference | Threshold Value | Range of Confidence | *t* obs | df | *p* * |
| Flexion | −0.145 | 0.18 | −0.279; −0.011 | −2.04 | 14 | 0.061 |
| Hyper extension | 0.029 | 0.22 | 0.00043; 0.057 | 0.289 | 14 | 0.777 |
| Orthostatic position | 0.076 | 0.49 | 0.001; 0.151 | 0.681 | 14 | 0.507 |

*p* * = 0.005.

As per the statistical analysis, during hyperextension movement and in orthostatic position, the effect of the therapeutic protocol is limited.

### *3.6. Statistical Analysis through MANOVA Test*

Subjects were classified into five groups. The groups were related to the Epworth score as detailed in Table 13.

**Table 13.** Group intervals or Epworth score.

| Group Intervals | Epworth Sore |
|---|---|
| A | 1–3 |
| B | 4–6 |
| C | 7–9 |
| D | 10–12 |
| E | 13–15 |

Based on this structure, we will detail the distribution of subjects for T1 and T2 moments in Tables 14 and 15.

**Table 14.** Distribution of the subjects based on the Epworth score T1 moment.

| Variable | Categories | Counts | Frequencies | % |
|---|---|---|---|---|
| T1 Epworth category | A | 1 | 1 | 6.66 |
| | B | 6 | 6 | 40 |
| | C | 6 | 6 | 40 |
| | D | 2 | 2 | 13.33 |

**Table 15.** Distribution of the subjects based on the Epworth score T2 moment.

| Variable | Categories | Counts | Frequencies | % |
|---|---|---|---|---|
| T2 Epworth category | A | 2 | 2 | 13.33 |
| | B | 7 | 7 | 46.66 |
| | C | 5 | 5 | 33.33 |
| | D | 1 | 1 | 6.66 |

The most frequently used test is the Wilks' Lambda test. Using the MANOVA test, we performed the analysis and obtained the values of the Wilks' Lambda parameter test (lambda, *p*, F observed and critical values) for T2 and T1 moments. The results are presented in Tables 16 and 17.

**Table 16.** Parameter values of the Wilks' Lambda test, T1 moment.

| Dependent Variables | Explanatory Variables | Lambda | F Observed | F Critical Value | *p*-Value |
|---|---|---|---|---|---|
| Flexion Symmetry Index<br>Hyperextension symmetry index<br>Orthostatic position symmetry index | Epworth categories | 0.465 | 0.906 | 2.341 | 0.537 |

**Table 17.** Parameter values of the Wilks' Lambda test, T2 moment.

| Dependent Variables | Explanatory Variables | Lambda | F Observed | F Critical Value | *p*-Value |
|---|---|---|---|---|---|
| Flexion Symmetry Index<br>Hyperextension symmetry index<br>Orthostatic position symmetry index | Epworth categories | 0.403 | 1.108 | 2.341 | 0.397 |

The null hypothesis Wilks' Lambda test is as follows: the explanatory variables have no significant effect on the dependent variables.

As we can see in Table 8, *p* values are higher than the significance level (alpha = 0.05), for all tests, so the null hypothesis cannot be rejected.

The conclusion, based on multivariate tests, shows that all aspects regarding sleep cannot be used as predictors of the evolution of symmetry indexes.

## 4. Discussion

Indeed, several studies have demonstrated the effectiveness of scoliosis pattern-specific exercises in improving or stabilizing scoliotic curves in patients with adolescent idiopathic scoliosis (AIS). These targeted exercises, designed to address the specific curvature patterns observed in individual patients, have shown promising results in terms of curve reduction and better postural alignment. Implementing such exercise programs, along with other forms of conservative treatments, can be beneficial in managing and optimizing the outcome of AIS. However, it is essential to consider individual variations and seek professional guidance to tailor exercises to each patient's unique condition [24–26].

Due to the possibility of improper postures leading to the progression of spinal curvatures, certain scoliosis treatment programs have integrated postural training, but there are no evidence-based studies about the combined therapeutic intervention Schroth and GPR. This emphasizes the importance of tailored exercise programs and professional supervision to ensure safe and effective approaches for scoliosis patients, taking into account individual needs and potential risks associated with specific activities. However, this should not discourage patients to move. It is essential for individuals, including those with scoliosis, to follow their athletic passions and engage in physical activity in general.

This observation is also evident in our study, where the decline in the Baecke Questionnaire score, which is relatively low, may be attributed to the way that the participation in other physical activities related to sports or leisure activities is perceived by the patients and their parents. There are controversies regarding the safety and involvement of children diagnosed with scoliosis in sports activities. These concerns might influence their engagement in physical activities, leading to lower scores on the Baecke Questionnaire, according to our result.

Currently, physical activity surveys are the most practical method for assessing activity levels in large epidemiological studies exploring the health consequences of inactivity. The Baecke Questionnaire was selected due to its brevity, ease of completion, and established validity and repeatability across various populations [27]. Taking all of the above into consideration, we approached only the first section of the questionnaire, regarding physical activity.

Furthermore, in this study, by combining elements from two very discussed treatment programs in the literature, we gain perspective on a complex approach to treatment for AIS. Conservative methods, which rely on exercise approaches like Schroth exercises [28] or global postural reeducation (GPR) [13], can be beneficial and seem to cause fewer adverse effects as they enable patients to move freely without constraints. Notably, GPR utilizes active muscle stretching postures, motor control, and sensory integration exercises. The reduction in scoliotic curves after GPR treatment has been observed during GPR active and assisted self-correction sessions. It has been shown that exercise-based studies have indicated reductions in Cobb angle and improvements in chest expansibility, vital capacity, and respiratory muscle strength [29]; we also find these remarks in our study because the chest elasticity showed improvement after therapeutic intervention.

GPR is grounded on the concept that postural muscles function as coordinated "muscle chains" positioned both anteriorly and posteriorly to the spine. GPR targets these muscle chains to restore balance and improve overall postural alignment [30]. Treatment with an active muscle stretching method not only influences the spine but also has physiological effects at the motor cortical level.

In previous studies, pain and functionality were commonly explored as outcome variables [13], while specific variables related to postural balance and muscle efficiency with electromyography (EMG) were relatively less frequently investigated [31].

EMG is also widely used in studies of the paraspinal muscles in scoliotic patients. Over two decades ago, EMG signals were recorded from the paravertebral muscles in adolescents diagnosed with idiopathic scoliosis. These signals were compared with EMG signals from subjects without this condition. The results showed that the EMG signals from the left lumbar paravertebral muscles were increased compared to those from the right lumbar paravertebral muscles at the beginning and during the early stages of muscle contraction in scoliosis patients [32]. The results of this study demonstrate the role of EMG in monitoring the evolution and also in the development of the physical therapy intervention for increasing muscle balance at the paravertebral level. Also in our study, EMG recording helped us to analyze the evolution. In relation to this study, our results also indicate marked muscular asymmetry, as demonstrated by electromyography recordings. The statistical analysis revealed the persistence of this imbalance in both standing and hyperextension situations.

Our results are supported by the EMG recordings, and, recently, additional examinations focusing on EMG signals have been conducted, specifically targeting the paravertebral muscles during exercises involving both symmetric loading and asymmetric stretching.

Furthermore, an accelerated progression of idiopathic scoliosis has been found to be correlated with an increased proportion of type 1 muscle fibers in the convex region of the scoliotic curvature. These findings raise questions about the interplay between asymmetry in the paraspinal musculature and the incidence of idiopathic scoliosis in adolescents [33]. This study correlates with our findings regarding the symmetry index, which indicates significant right–left asymmetries. These asymmetries may be explained, in part, by changes in muscular composition, specifically, the predominance of certain types of muscle fibers.

The documentation regarding the subject addressed in this research allowed us to conclude that the studies related to the muscle behavior in idiopathic scoliosis were carried out on a small number of subjects; therefore, our research highlights an innovative approach in which the muscle behavior was correlated with evaluations that involve three important aspects that can accompany the child with idiopathic scoliosis, namely, sleepiness, the mental perception of the installed physical deficit, and the participation in physical activities with character sporty. The significant statistical evolution of the Epworth Sleepiness Scale results from our study indicates a correlation with physical status, which is represented by the improvement in symmetry indices and thoracic elasticity. These improvements signify enhanced trunk dynamics and, consequently, an increase in oxygen intake during respiration. This suggests that as the physical aspects, such as symmetry and thoracic flexibility, improve; there is a positive impact on respiratory function, resulting in reduced sleepiness and enhanced overall well-being. This relationship highlights the importance of addressing physical aspects in scoliosis management to improve respiratory capacity and the overall quality of life.

To predict the tendency of scoliotic conditions, asymmetric EMG signals recorded in the paravertebral musculature of adolescents may not be conclusive. In this context, the relevance of these variables may become more apparent upon completion of the growth process, providing a clearer picture of their impact on scoliotic development [34]. This study supports our results, which indicate minimal evolutions of the restoration of symmetry in the three situations considered by us. While there is a cohort of studies linking muscular electrical activity to the functional status of scoliotic patients, many aspects remain unclear. The lack of standardized values for recorded EMG parameters makes research findings a reference point or means of support for previous studies rather than a provider of definitive conclusions.

Therapies combining symmetrical muscle loading and asymmetrical stretching exercises were used to assess the effectiveness of optimal physical exercises for patients with scoliosis. The results showed significant differences in EMG values before and after completing the rehabilitation program. These findings suggest that tailored exercise regimens can lead to notable changes in muscle activity, potentially improving muscular balance and postural control in scoliosis patients [35]. Another one of the therapies we explored in this study that relates to the information above is Schroth therapy.

Exercise rehabilitation helps patients understand their unique spine and learn postural modifications for improved symmetry and spinal stabilization. This knowledge becomes valuable for managing scoliotic curves, especially for young patients, as they can apply these techniques throughout their lives if necessary [14].

The study of Kuru et al. (2016), reported a Schroth treatment regime that was in accordance with ours. In that study, treatment regimens lasted for six weeks, with 18 sessions conducted either as outpatient visits or as a home-based program. Patients in the Schroth exercise group began their exercise program under physiotherapist supervision, dedicating 1.5 h a day, three days per week. The Schroth exercises were performed in an asymmetric position to maximize correction and achieve trunk symmetry. There are only small differences in the concept of our treatment regime regarding the period of time, which lasted longer for our study (12 months), and the consistency, which was actually lower (two times per week) in our study [36].

Another study [37] assessed patients before and after 6 weeks of Schroth exercises using optical topography, electromyography, and stabilometry. The EMG detail was also explored in our study. However, the sustainability of the improvement over a longer period was not investigated.

Otman et al. reported a significant increase in muscle strength after 1 year of intervention [38]. This fact is directly related to our study. From what we have researched, Schroth exercises combined with the standard of care have been shown to increase back extension endurance. Other studies have, similarly, observed ceiling effects in patients with smaller curves who undergo conservative treatment, similar to the treatment program that we suggested in our study, as evidenced by SAQ scores.

In another study, it is shown that the success of Schroth therapy is attributed to its proprietary Schroth rotational angular breathing (RAB) technique [39].

By using the elements from Schroth therapy and GPR, with their specific breathing techniques, we obtained a better outcome in the measurements of the chest circumference coefficient, something that is related to the information obtained from previous studies.

The results of our study try to provide answers regarding sleepiness and scoliosis, which were generated in a long debate. Since sleep is considered a state of physical and mental rest, its importance becomes crucial, especially in the case of children and adolescents. Their health and development are directly correlated with sleep quality [5].

The children involved in our study have no pain, but the evolution during the combined intervention of Schroth and GPR demonstrated an improvement in sleep quality and a reduction of sleepiness. This, in accordance with the study of Ugur et al. that speaks about the sleep profile and its association with pain, should be considered during the rehabilitation process in patients with IS [6].

Regarding the Epworth scale, significant differences can be observed between the two moments, as statistical analysis demonstrates. The evaluation of sleepiness in the study of Schneider et al. [40] evaluated symptoms and treatment effectiveness/satisfaction in participants with idiopathic hypersomnia using the Epworth scale. The results of this study reported a presence of high disease burden despite differences in symptom management with off-label medications and other means. Their findings indicate that the classical treatment does not respond to the needs of the persons suffering from IS. This sustains our results that demonstrate a reduction of sleepiness after the combined therapy including Schorth and GPR therapy.

Regarding our approach in the pilot study, we can say that some other studies provide information about the quality of sleep and scoliosis. One of these is the Yakut et al. study, which speaks about the intricate connection between obstructive sleep apnea (OSA) risk and scoliosis attitude as well as adolescent idiopathic scoliosis. The results of this study demonstrate a significant disruptive impact of OSA on sleep, coupled with its extensive cardiovascular, cognitive, and metabolic effects, and underscores the urgency of early diagnosis and intervention. At the same time, the study emphasizes the importance of evaluating spinal attitude when assessing the subject. It highlights the necessity to investigate hypoxia, particularly intermittent hypoxia when combined with OSA, as a risk factor for spinal attitude. This underscores the significance of exploring the relationship between these factors [41].

Idiopathic scoliosis has a specific impact on daily life and, for this reason, each child has their own response regarding life quality, including sleepiness. The mechanism that could be involved is based on the interaction and work in tandem with the brain and spine. In this context, scoliosis could reduce or disrupt the communication between the brain and body and generate a lot of effects including sleep troubles. These troubles could be like sleepiness. Moreover, our subjects have an average age of 11.9 yrs, and this is the period that assists in growth processes and skeletal maturity development. This could generate a painful condition that disturbs the night's sleep, and one of the consequences is sleepiness. As a growing spine experiences a constant lengthening motion, it can counteract the compressive force of an abnormal spinal curve, which is known to be the main source of condition-related pain. Postural changes developed in idiopathic scoliosis also can affect the function of the lung, and some children could have a scoliotic curve that can disrupt the position of the rib cage and cause restricted joints and ligaments. In this way, we can find an impact on the quality of sleep and the development of sleepiness.

The aetiology of AIS remains largely unknown; however, several studies show the possible role of genetics, oestrogen, calmodulin, melatonin, vitamin D, and low bone mineral density [42]. Regarding melatonin, Sadat-Ali et al. found that serum melatonin was significantly lower in AIS patients [43].

The ESS-CHAD scale used in our study is based on subjective answers, but it helps us to apply the physical therapy program and monitor the evolution in terms of how the children participate in the program. As we said before, the possible sleepiness could be linked to melatonin levels and physical therapy, but physical exercise also modulates the serotonin system and can promote increased concentrations of serotonin, as muscle activation needs higher amounts of tryptophan. At the same time, we used the Baecke scale to assess the physical activity level of the children to monitor their evolution in terms of habitual activity. We used the Scoliosis Appearance Questionnaire (SAQ) for the evaluation of the impact on mental and physical health; we considered that it could help the design of the physical therapy program due to the possibility of evaluating how the children with idiopathic scoliosis accept participation in the physical therapy program.

## 5. Conclusions

A multifactorial assessment of scoliosis offers concrete information regarding potential connections of muscle imbalance and the clinical status of the scoliotic patient.

The patterns of muscle activity are different depending on the assessment posture (flexion, hyperextension, or orthostatic posture).

In the majority of subjects with double-curve scoliosis, significant differences were noticed for flexion movement before and after completing an adapted therapeutic protocol.

Variations noticed in the paravertebral muscles' electrical activity reveal the high importance of a correct EMG measurement. While static EMG evaluations did not differentiate subjects with scoliosis from non-pathological individuals, dynamic EMG signals provided distinct interpretations, which align with our study findings.

The results showed significant differences in EMG values before and after completing the rehabilitation program. These findings suggest that tailored exercise regimens can lead to notable changes in muscle activity, potentially improving muscular balance and postural control in scoliosis patients.

It can be noticed that for 14 out of 15 subjects (93.33%), the SAQ score 1 has a decreased value in T2 compared to the T1 moment.

It can be also noticed that for 9 out of 15 subjects (60%), the SAQ score 2 has an increased value in T2 compared to the T1 moment.

Through statistical analysis of the Epworth scale, significant differences can be observed between the two moments (T1—before the kinetic rehabilitation program; T2—after completing the rehabilitation program), while no significant difference was noticed for the Baecke scale. The physical aspects, such as symmetry and thoracic flexibility, improved, and there was a positive impact on respiratory function, resulting in reduced sleepiness and enhanced overall well-being. This relationship highlights the importance of addressing physical aspects in scoliosis management to improve respiratory capacity and the overall quality of life.

Statistical analysis reveals correlations of the assessment scales with the clinical status of the patient after performing an individualized therapeutic protocol; this fact proves the efficiency of the combined Schorth and GPR exercises in the rehabilitation process of the scoliotic patient.

As the present study was conducted on a limited number of subjects, further research is needed to extend the obtained results regarding the efficiency of Schroth and GPR exercises in the rehabilitation of scoliotic patients. The limitations of our study are linked with the ESS-CHAD scale as the test cannot be used to predict how likely a person is to fall asleep in any given situation in the future; also, the other two scales used are based on the children's responses and could be affected by their understanding and availability to provide real answers. At the same time, we consider that our study, like a pilot study, opens a way for new research in the study of idiopathic scoliosis and helps to provide a holistic approach that includes not only treatment but also a complex evaluation of the impact of scoliosis on the life of these children.

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