Respiratory–Postural Interactions in Functional Scoliosis Following a 12-Week Respiratory Rehabilitation Program: A Prospective Controlled Study

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Abstract

The aim of this study was to investigate the effects of a 12-week respiratory rehabilitation program on respiratory function/postural outcomes in individuals with functional scoliosis. 75 individuals (aged 18–25 years) were allocated into three groups: functional scoliosis receiving rehabilitation (n=25), healthy participants (n=25) and untreated scoliosis (n=25). The intervention included diaphragmatic breathing, muscle training, breathing exercises, and postural correction. Outcomes included Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), Angle of Trunk Rotation (ATR), Visual Analogue Scale (VAS), Maximum Phonation Time (MPT), and postural parameters. Statistical analyses included paired t-tests, repeated-measures ANOVA, chi-square tests, Cohen's dz effect size, and Spearman's correlation. Significant time × group effects were observed for all respiratory outcomes ($p < 0.001$). The treated group showed improvements in FVC, FEV1, thoracic expansion, and MPT, along with a substantial reduction in pain (VAS−43.63%) and improvements in ATR and pelvic obliquity, while minimal changes occurred in the untreated group. ATR was significantly associated with FVC ($\rho = -0.52$), thoracic expansion ($\rho = -0.48$), and pelvic obliquity ($\rho = 0.58$). Regression analysis confirmed ATR and pelvic obliquity as negative predictors of FVC, and thoracic expansion as a positive predictor ($R^2 = 0.52$). Postural improvement was significantly greater in the treated group (68% vs 4%, $p < 0.001$). A significant functional relationship was observed between trunk asymmetry and pulmonary function in functional scoliosis. Respiratory rehabilitation may act as a complementary strategy influencing both ventilatory efficiency and postural alignment, supporting integrated multimodal rehabilitation approaches.

Keywords: ***Respiratory rehabilitation, functional scoliosis, ATR, FVC, FEV1, MPT, VAS***

1. Introduction

Scoliosis is defined as a lateral curvature of the spine exceeding 10° Cobb, which can lead to postural asymmetry and impaired musculoskeletal function (Scoliosis Research Society, 2024).

However, it is important to note that in young adults, a significant proportion of cases represent functional scoliosis ≥ 5°, where the curvature of the spine is measured with a scoliometer and is mainly influenced by modifiable factors, as in our case, rather than rigid structural deformities (Dunn et al., 2018). Functional scoliosis often presents with trunk asymmetry, negative changes in thoracic mobility, and altered respiratory function/mechanics (Negrini et al., 2018). These findings highlight the functional relationship between respiratory mechanics and postural control, suggesting that the targeted respiratory rehabilitation we have selected may improve thoracic expansion, postural stability, and overall trunk symmetry, in the absence of rigid structural changes. Understanding this interaction is essential in our work to design interventions that optimize both pulmonary function and postural alignment, where we also aim for clinically relevant findings. Thoracic deformity can limit chest wall expansion, reduce lung volumes, and reduce ventilatory efficiency (Lonner et al., 2009). Even mild curvature or postural contractures in young adults can lead to suboptimal respiratory mechanics and thoracic shoulder asymmetry that impact quality of life (Tsiligiannis & Grivas 2012). Physiotherapeutic approaches, such as Schroth method integrates breathing as part of a multimodal postural approach (Schreiber et al., 2017; Weiss, 2011). However, after extensive research in the scientific literature, this study proposes that these methods include breathing as a component and not as the main focus of rehabilitation, so it was hypothesized we would look at a new variant of rehabilitation with a main focus on respiratory rehabilitation. Including diaphragmatic control, breathing techniques, inspiratory and expiratory muscle training and airway clearance techniques, such as ELTGOL, (Lanza et al., 2015) but in this case directly targeting the respiratory muscles and thoracic mobility which are biomechanically linked to spinal posture. Despite our conclusion regarding the growing evidence, the role of respiratory rehabilitation as a primary intervention *remains unexplored*. Herein lies *the novelty* of our study, which investigates the impact of direct respiratory rehabilitation not only on pulmonary function but also on trunk asymmetry-Angle of Trunk Rotation (ATR) and overall postural outcomes. Our idea came from the fact that the respiratory muscles, especially the diaphragm and intercostal muscles, have a functional relationship with the vertebral column and ribs (Kolář et al., 2010, Hodges & Gandevia, 2000). Therefore, their activation supports thoracic expansion, postural control, and trunk stabilization. Dysfunction or impaired activation of core and respiratory muscles may disrupt postural control, contributing to spinal asymmetry and increased musculoskeletal strain (Donley et al., 2024, Waxenbaum et al., 2026). Evidence from rehabilitation research suggests that structured breathing training can improve pulmonary function and respiratory muscle efficiency, with potential benefits on postural control and musculoskeletal symptoms (Kocjan et al., 2017; Langer et al., 2020). In young adults with functional scoliosis, despite this growing evidence, the impact of respiratory rehabilitation on both functional respiratory outcomes and structural spine measurements remains unexplored. This study addresses this gap by evaluating the effects of a 12-week respiratory rehabilitation program not only on pulmonary function, but also on chest expansion, postural symmetry, Pelvic Obliquity (cm), ATR (measured by scoliometer), pain, and respiratory endurance. Scoliometry is a widely accepted clinical tool for assessing trunk asymmetry by measuring the Angle of Trunk Rotation (ATR) during the Adam's forward bend test. Unlike radiographic measurements of the Cobb angle, which are used to quantify spinal curvature (Horng et al., 2019), ATR (as measured by a scoliometer) reflects both the functional and rotational components of spinal asymmetry, making it particularly suitable for monitoring rehabilitation outcomes. Functional scoliosis may result from biomechanical asymmetries such as limb-length inequality, which can induce pelvic obliquity and vertebral rotation (Gurney et al., 2002). Despite this evidence, respiratory rehabilitation as a primary therapeutic target for postural correction remains underexplored. Therefore, this study proposes a respiratory-centered rehabilitation model and investigates its effects on both pulmonary and postural outcomes.

2. Methods

Study Design: Prospective controlled intervention study (12 weeks).

Participants: Total: seventy-five (18–25 years); 3 groups (n=25 each)

Functional scoliosis characteristics were confirmed through clinical postural assessment, including Adam's forward bend test, scoliometer measurement, shoulder/rib asymmetry, and pelvic asymmetry evaluation.

Inclusion Criteria: Participants were eligible if they were aged 18–25 years and presented with functional spinal asymmetry consistent with functional scoliosis features (ATR ≥5° measured by scoliometer, without evidence of structural spinal deformity. Participants were required to be able to complete the 12-week rehabilitation program and

provide written informed consent.

Exclusion criteria: structural scoliosis, previous spinal surgery, severe cardiopulmonary disease, neurological disorders, lower limb fractures or significant musculoskeletal injuries, pregnancy, current participation in another rehabilitation program, inability to complete assessments.

Outcome Measures:

Variable	*Tool*	*Description*
FVC / FEV1	Spirometry	Pulmonary function
Thoracic Expansion (cm)	Tape measure	Chest mobility
ATR (°)	Scoliometer	Surface trunk rotation measured using a scoliometer
Pelvic obliquity (cm)	Tape measure (vertical difference between bilateral ASIS and PSIS landmarks)	Pelvic obliquity in the frontal plane was assessed as the vertical height difference between bilateral ASIS and PSIS landmarks to improve measurement validity and reduce postural bias.
MPT	Phonation test	Respiratory endurance
VAS	Pain scale	Pain intensity

2.1 Study Design

This prospective controlled study was conducted over 12 weeks. Ethical approval was obtained and informed consent was provided by all participants. Participants were allocated based on predefined clinical criteria (non-randomized design).

Participants: Seventy-five participants (18–25 years of age) were enrolled and divided into:

1. Functional treated scoliosis Group (n=25): ATR ≥ 5° (scoliometer) or postural deviations with clinical evidence of rib/shoulder elevation and pelvic asymmetry.
2. Healthy Participants Group (n=25): No functional scoliosis or significant postural deviation, engaged in mild respiratory/fitness activities.
3. Untreated Scoliosis (n=25): Postural deviations as in the functional scoliosis group but without respiratory rehabilitation and no other intervention.

Intervention Protocol: The treated scoliosis group underwent a 12-week respiratory rehabilitation program:

- Weeks 1–4 (Baseline phase focusing on diaphragmatic breathing and thoracic-pelvic mobility.
- Weeks 5–8 (Strengthening): controlled expiration including (ELTGOL) technique and postural activation
- Weeks 9–12 (Integration): phase that combines functional breathing with dynamic trunk movement.
- The Healthy Rehabilitation Group underwent low-intensity aerobic exercise along with structured respiratory muscle training, focusing on diaphragmatic and thoracic breathing patterns, while the untreated scoliosis received no therapeutic intervention throughout the study.
- The rehabilitation program was designed to achieve the goal of functional interaction between breathing and postural control. Diaphragmatic breathing was chosen to improve diaphragmatic excursion and better trunk stabilization, segmental breathing exercises to increase thoracic mobility, respiratory muscle training to increase respiratory muscle strength, while postural correction exercises aimed to optimize spinal alignment and neuromuscular control. Therefore, the intervention was designed based on the hypothesis that improving respiratory muscle function and thoracic mobility may positively influence postural control through the functional interaction between breathing and spinal stabilization mechanisms. As for ELTGOL, this technique was included only as a complementary technique to facilitate chest wall mobility and improve ventilation mechanics.

Outcome Measures

- Pulmonary function: Forced Vital Capacity (FVC) and Forced Expiratory Volume in 1 second (FEV1) were measured using a spirometer.
- Chest expansion: The measures consisted of chest expansion measurement at axilla, fourth intercostals and xiphoid levels. The measurements were taken in the standing position with the arms hanging sideways at all the three different anatomical landmarks. (Mohan et al., 2012).
- Spinal alignment: Angle of Trunk Rotation (ATR) was assessed using a scoliometer ≥ 5°. (Dunn et al., 2018, Kuznia et al., 2020)
- Maximal Phonation Time (MPT): Sustained vowel phonation was measured in seconds as an indicator of

respiratory-phonatory control. (Benner et al., 2023)

- Pain intensity: Pain was assessed using the Visual Analogue Scale (VAS, 0–10). (Alghadir et al., 2015)

Postural assessment: Postural alignment was assessed using the Adam's forward bend test, assessing trunk asymmetry, rib hump deformity, shoulder elevation, and pelvic symmetry.

2.2 Statistical Analysis

- Within-group comparisons before and after were performed using ANOVA, paired t-tests. Effect sizes were calculated using mean difference (MD), Cohen's d_z, and corresponding p-values.
- Associations between categorical postural variables were analyzed using Chi-square (χ^2) tests.
- Relationships between postural symmetry and functional outcomes were assessed using Spearman's rank correlation coefficient.
- A significance level of $p < 0.05$ was considered statistically significant. Secondary analyses were interpreted cautiously to avoid inflation of type I error. No conflicts of interest exist.

3. Results

Table 1. Baseline demographic characteristics of participants

Variable	*Healthy Participants (n=25) Mean ± SD*	*Treated scoliosis (n=25) Mean ± SD*	*Untreated Scoliosis (n=25) Mean ± SD*	*p-value*
Age (years)	21.0 ± 2.0	21.2 ± 2.1	21.4 ± 2.2	0.74
Female (%)	16 (64%)	18 (72%)	17 (68%)	0.77 (χ^2 test)

The table shows the baseline demographic characteristics of the participants in the three study groups: No significant differences were observed between groups at baseline in terms of age (p = 0.74) and in terms of gender distribution (p = 0.77), suggests comparable demographic characteristics between groups. All three groups started from the same demographic conditions, so the results after the intervention are comparable and reliable.
Gender Female % (Male=100 - Female).

Table 2. Repeated Measures ANOVA (FVC, FEV1, Thoracic Expansion)

Outcome	*Effect*	*F (df1, df2)*	*p*	*η^2p*
FVC	Time	F (1, 72) = 121.10	< .001	0.627
	Group	F (2, 72) = 45.57	< .001	0.559
	Time × Group	F (2, 72) = 12.22	< .001	0.253
FEV1	Time	F (1, 72) = 98.44	< .001	0.578
	Group	F (2, 72) = 39.12	< .001	0.521
	Time × Group	F (2, 72) = 10.91	< .001	0.232
Thoracic Expansion (cm)	Time	F (1, 72) = 132.08	< .001	0.647
	Group	F (2, 72) = 52.44	< .001	0.593
	Time × Group	F (2, 72) = 14.36	< .001	0.286

Overall, the results show large time-dependent improvements in respiratory function, with significantly greater benefits in the treated scoliosis group compared to controls and untreated participants. Furthermore, a significant main effect of Group was found on all outcomes (all p < .001) indicating differential responses to the intervention. Note: η^2p = partial eta squared.

Table 3.a Respiratory outcomes (within-group pre–post changes)

Group	Variable	Pre Mean ± SD	Post Mean ± SD	Δ (95% CI)	p-value	Cohen's d_z
Healthy Participants	FVC (L)	3.22 ± 0.42	3.55 ± 0.45	+0.33 (0.22 to 0.44)	<0.001	0.75
	FEV1 (L)	2.88 ± 0.38	3.15 ± 0.40	+0.27 (0.18 to 0.36)	<0.001	0.72
	Thoracic Exp (cm)	3.15 ± 0.44	3.50 ± 0.46	+0.35 (0.24 to 0.46)	<0.001	0.78
Treated scoliosis	FVC (L)	2.79 ± 0.41	3.16 ± 0.43	+0.37 (0.26 to 0.48)	<0.001	0.83
	FEV1 (L)	2.37 ± 0.38	2.78 ± 0.40	+0.41 (0.27 to 0.55)	<0.001	0.96
	Thoracic Exp (cm)	2.50 ± 0.51	3.12 ± 0.53	+0.62 (0.47 to 0.78)	<0.001	1.02
Untreated Scoliosis	FVC (L)	2.79 ± 0.39	2.82 ± 0.40	+0.03 (-0.02 to 0.08)	0.180	0.08
	FEV1 (L)	2.37 ± 0.36	2.40 ± 0.37	+0.03 (-0.02 to 0.08)	0.220	0.10
	Thoracic Exp (cm)	2.50 ± 0.48	2.52 ± 0.49	+0.02 (-0.03 to 0.07)	0.300	0.05

Within-group changes in respiratory outcomes after 12 weeks of intervention. Note: Δ = post − pre; CI = confidence interval; Cohen's dz = within-subject effect size.

Table 3.b Postural outcomes (within-group pre–post changes)

Group	Variable	Pre Mean ± SD	Post Mean ± SD	Δ (95% CI)	p-value	Cohen's d_z
Healthy Participants	ATR (°)	2.98 ± 0.53	2.69 ± 0.52	−0.29 (-0.45 to -0.13)	0.008	0.55
	Pelvic Obliquity (cm)	0.60 ± 0.15	0.50 ± 0.20	−0.10 (-0.18 to -0.02)	0.040	0.52
	MPT (s)	12.50 ± 1.20	14.20 ± 1.30	+1.70 (1.10 to 2.30)	<0.001	1.10
Treated scoliosis	ATR (°)	9.94 ± 1.26	9.13 ± 1.20	−0.81 (-1.10 to -0.52)	<0.001	0.68
	Pelvic Obliquity (cm)	1.80 ± 0.25	1.30 ± 0.30	−0.50 (-0.62 to -0.38)	<0.001	1.05
	MPT (s)	10.80 ± 1.10	13.40 ± 1.20	+2.60 (1.90 to 3.30)	<0.001	1.45
Untreated Scoliosis	ATR (°)	7.69 ± 2.34	7.43 ± 2.32	−0.26 (-0.62 to 0.10)	0.200	0.12
	Pelvic Obliquity (cm)	1.70 ± 0.40	1.60 ± 0.40	−0.10 (-0.25 to 0.05)	0.080	0.25
	MPT(s)	10.7 ±1.0	11.0 ±1.1	+0.30 (-0.10to 0.70)	0.080	0.27

Note: Δ = post − pre. Negative Δ values indicate improvement for ATR and pelvic obliquity.

The treated scoliosis group showed significant improvements in postural outcomes ($p < 0.001$), whereas only minimal changes were observed in the healthy participants and untreated scoliosis groups. The untreated scoliosis group demonstrated no statistically significant changes in pelvic obliquity ($p = 0.080$), indicating stability of the condition in the absence of intervention.

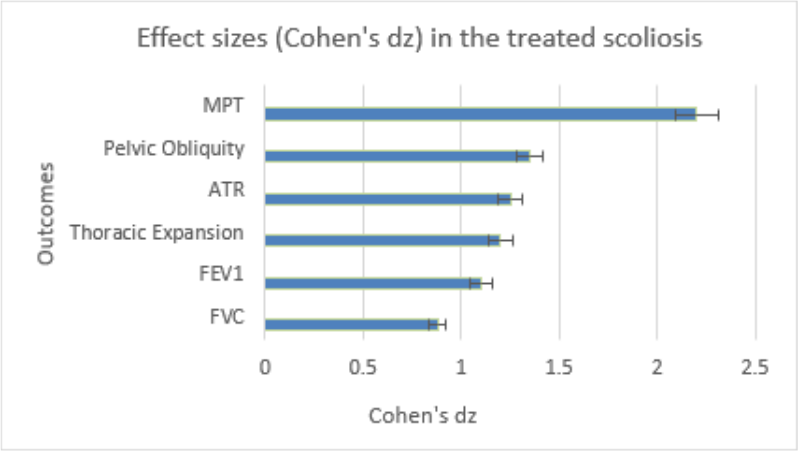


Figure 1. Effect sizes Cohen's d_z (paired-samples) for within-group changes in the treated scoliosis group

Large to very large effect sizes were observed in the treated scoliosis group, particularly for MPT, thoracic expansion, and FEV1, indicating substantial improvements in respiratory function. While moderate-to-large effects in ATR and pelvic obliquity suggest clinically meaningful improvements in postural alignment.

Table 4: Spearman Correlation Analysis (N = 75)

Variables	*Spearman ρ*	*p-value*
ATR (°) vs FVC (L)	−0.52	<0.001
ATR (°) vs Thoracic Expansion (cm)	−0.48	<0.001
ATR (°) vs Pelvic Obliquity (cm)	+0.58	<0.001
Pelvic Obliquity (cm) vs FVC (L)	−0.49	<0.001

Note: Spearman correlation analysis revealed significant associations between trunk rotation and functional parameters. ATR was moderately negatively correlated with FVC (ρ = −0.52, p < 0.001) and thoracic expansion (ρ = −0.48, p < 0.001), while a moderate positive correlation was observed between ATR and Pelvic Obliquity (cm) (ρ = 0.58, p < 0.001). Note: Spearman's ρ indicates the strength and direction of the correlation.

Table 5.a Multiple Linear Regression (Outcome: FVC)

Predictor	*β*	*SE*	*t*	*p-value*
ATR (°)	−0.46	0.11	−4.18	<0.001
Pelvic Obliquity (cm)	−0.31	0.09	−3.44	0.002
Thoracic Expansion (cm)	+0.42	0.10	4.20	<0.001

(N=75)
Model fit: $R^2 = 0.52$ Adjusted $R^2 = 0.50$
$F(3,71) = 25.90$, $p < .001$

Trunk asymmetry (ATR) and pelvic obliquity were independently and negatively associated with FVC, while thoracic expansion was a significant positive predictor. The model explained 52% of the variance in FVC ($R^2 = 0.52$).

Note: β = standardized regression coefficient; SE = standard error.

Table 5.b Multiple Linear Regression (Outcome: ATR)
(N=75)

Predictor	*β*	*SE*	*t*	*p-value*
FVC (L)	−0.49	0.10	−4.90	<0.001
Thoracic Expansion (cm)	−0.37	0.11	−3.36	0.001
Pelvic Obliquity (cm)	+0.33	0.12	2.75	0.007

Model fit: $R^2 = 0.48$, Adjusted $R^2 = 0.46$
$F(3, 71) = 21.86$, $p < 0.001$

Reduced pulmonary function (FVC) and thoracic expansion were independently associated with higher ATR values, whereas pelvic obliquity showed a positive association with ATR. The regression model explained 48% of the variance in ATR ($R^2 = 0.48$). Note: β = standardized regression coefficient; SE = standard error.

Table 6. Chi-square analysis of postural improvement between treated and untreated scoliosis groups

Outcome	*Treated scoliosis*	*Untreated Scoliosis*
Improved	17	1
Not Improved	8	24
Total	25	25

Test	*χ^2 (df, N)*	*p-value*
Postural improvement	χ^2 (1, N = 50) = 22.22	p < 0.001

A significant association was observed between treatment allocation and postural improvement (χ^2 (1, N = 50) = 22.22, p < 0.001, φ = 0.66), indicating a large effect size. Participants in the treated scoliosis group demonstrated substantially

higher rates of postural improvement than those in the untreated scoliosis group. The analysis included only participants with functional scoliosis. Note: Improvement was defined as a reduction in ATR following rehabilitation.

Table 7. Percentage Change Summary (Δ% Change – Reviewer Requirement)

Outcome	*Healthy Δ%*	*Treated Scoliosis Δ%*	*Untreated Scoliosis Δ%*
FVC (L)	+10.25%	+13.26%	+1.07%
FEV1 (L)	+9.38%	+17.30%	+1.27%
Thoracic Expansion (cm)	+11.11%	+24.80%	+0.80%
MPT	+13.60%	+24.07%	+2.80%
ATR (°)	−9.73%	−8.15%	−3.38%
Pelvic Obliquity (cm)	−16.67%	−27.80%	−5.90%
VAS (Pain)	—	−43.63%	−3.29%

The treated scoliosis group demonstrated the greatest relative improvements in both pulmonary function and postural alignment compared with the untreated scoliosis group.
Note: Δ = Post – Pre; Δ% = [(Post − Pre)/Pre] × 100. Percentage changes should be interpreted in the context of baseline differences between groups (see Table 3). VAS was assessed only in the scoliosis groups.

4. Discussion

The current findings are consistent with previous evidence supporting the role of structured rehabilitation in improving respiratory and postural function. Pulmonary rehabilitation and physiotherapy approaches have demonstrated beneficial effects on respiratory capacity, exercise tolerance, and neuromuscular control in diverse clinical populations (Argjiri et al., 2018; Zotaj et al., 2024a; Zotaj et al., 2024b). These findings may be particularly relevant in scoliosis, where respiratory mechanics and spinal alignment represent functionally interconnected systems. The diaphragm contributes not only to ventilation but also to trunk stabilization, suggesting that changes in respiratory function may influence postural control (Hodges & Gandevia, 2000; Kolar et al., 2012). This study extends previous evidence by examining the relationship between pulmonary function, trunk asymmetry, and postural alignment across healthy individuals, treated functional scoliosis, and untreated scoliosis groups The statistical analysis presented in Table 2, demonstrated significant main effects of Time, Group, and the Time × Group interaction on all primary respiratory outcomes The medium-to-large effect sizes (η^2p = 0.232–0.647) further support the clinical relevance of these changes, indicating that the intervention produced meaningful differences beyond statistical significance.

The treated scoliosis group demonstrated significant improvements in FVC, FEV1, thoracic expansion, MPT, ATR, and pelvic obliquity, whereas the untreated group showed minimal changes. These findings suggest that some functional impairments associated with scoliosis may be modifiable through targeted rehabilitation, although the absence of long-term follow-up prevents conclusions regarding the persistence of these effects.

Correlation analysis (Table 4) further revealed a moderate negative association between ATR and FVC ($\rho = -0.52$, $p < 0.001$) and between ATR and thoracic expansion ($\rho = -0.48$, $p < 0.001$), along with a positive correlation between ATR and pelvic obliquity ($\rho = 0.58$, $p < 0.001$). These findings suggest that greater trunk asymmetry is associated with reduced ventilatory capacity and increased postural imbalance. This is consistent with previous evidence indicating that thoracic deformities in scoliosis are associated with restrictive pulmonary patterns and reduced lung volumes (Weinstein et al., 2008; Kearon et al., 1993).

Regression models further supported a functional relationship between respiratory and postural variables. ATR and pelvic obliquity were negatively associated with FVC, whereas thoracic expansion showed a positive association with pulmonary function. Conversely, reduced FVC and thoracic expansion were associated with increased ATR, suggesting a bidirectional interaction between respiratory mechanics and postural control rather than a simple one-directional effect.

The intervention findings also support this respiratory–postural relationship. The chi-square analysis demonstrated a significantly higher proportion of postural improvement in the treated scoliosis group compared with untreated participants (68% vs 4%), with a large effect size. Furthermore, percentage change analysis demonstrated greater improvements in respiratory and postural outcomes in the treated group, including FVC (+13.26%), FEV1 (+17.30%), thoracic expansion (+24.80%), MPT (+24.07%), and reductions in pelvic obliquity (-27.80%) and pain (-43.63%).

From a mechanistic perspective, the observed improvements may be explained by the integrated role of the diaphragm and respiratory muscles in both ventilation and postural control. Through its attachments to the rib cage and

lumbar spine, the diaphragm contributes to trunk stabilization via regulation of intra-abdominal pressure (Donley et al., 2024).

Previous studies have demonstrated synchronization between diaphragmatic activation and postural adjustments (Hodges & Gandevia, 2000; Janssens et al., 2015; Kocjan et al., 2017).

ELTGOL was included as a complementary breathing technique and may have contributed indirectly by improving ventilation distribution and chest wall mobility through controlled expiration (Lanza et al., 2015).

Therefore, its potential role should be interpreted as supportive of respiratory mechanics and thoraco-pelvic stability rather than as a primary therapeutic mechanism. Improvements observed also in healthy participants suggest that respiratory rehabilitation may enhance functional respiratory efficiency beyond pathological conditions, consistent with previous evidence on respiratory muscle training and exercise performance (Illi et al., 2012).

5. Clinical Implications

From a clinical perspective, the observed improvements indicates that respiratory-focused rehabilitation may represent a a potentially valuable complementary approach for individuals with functional scoliosis. The magnitude of improvement in thoracic expansion (+24.80%), MPT (+24.07%), and reduction in pelvic obliquity (-27.80%) suggests clinically meaningful functional changes, although these findings should be interpreted as short-term adaptations rather than definitive structural correction.

6. Study Limitations

This study has several limitations. The sample size was relatively small and included only young adults, limiting generalizability to other populations. The non-randomized design may have introduced selection bias, and baseline differences between groups may have influenced comparisons. In addition, the absence of radiographic assessment, including Cobb angle measurement, limits conclusions regarding structural spinal changes.

The 12-week intervention period does not allow evaluation of long-term effects or potential structural adaptations. Future randomized controlled studies with larger samples, longer follow-up periods, and imaging-based assessments are required to confirm these findings.

7. Conclusion

This study demonstrates evidence of a significant functional relationship between respiratory mechanics, trunk asymmetry, and postural alignment in individuals with functional scoliosis. A 12-week respiratory-focused rehabilitation program was associated with improvements in pulmonary function, thoracic expansion, and postural parameters, supporting the concept of respiratory–postural coupling.

The findings suggest that respiratory rehabilitation may influence functional adaptations through mechanisms involving diaphragmatic function, respiratory muscle efficiency, and thoraco-pelvic stability. However, the proposed approach should be considered exploratory and complementary rather than a replacement for established scoliosis-specific rehabilitation strategies.

Further research is required to determine the long-term effects and clinical applicability of respiratory-centered rehabilitation models in functional scoliosis.

8. Acknowledgment

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8.1 Abbreviations:

ATR = Angle of Trunk Rotation;
FVC = Forced Vital Capacity;

FEV1 = Forced Expiratory Volume in 1 second;
MPT = Maximum Phonation Time;
VAS = Visual Analogue Scale;
ELTGOL = Slow Expiration with Glottis Opened in Lateral Posture;
ANOVA = Analysis of Variance;
SD = Standard Deviation;
Cohen's dz = within-subject effect size;
CI = Confidence Interval;
Δ = Mean Change;
Δ% = Percentage Change;
η^2p = Partial Eta Squared;
β = Standardized Regression Coefficient;
SE = Standard Error;
χ^2 = Chi-square Test;
ρ = Spearman's Rank Correlation Coefficient;
φ = Phi Coefficient;
df = Degrees of Freedom;
N = Sample Size;
L = Liters;
cm = Centimeters;
s = Seconds.

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