

Changes in Thoracolumbar Spine Following a 10-Week Corrective Exercise Programme in Students of Performing Arts

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Keywords

Musculoskeletal disorders. Performing Arts Students. Posture improvements. Spinal function tests.

Abstract

Introduction: Students of performing arts, in particular, music students, are vulnerable to musculoskeletal disorders (MSDs) because of prolonged static postures and asymmetrical loading associated with instrument playing.

Objectives: The study aim was to evaluate the impact of a 10-week corrective exercise programme on improving thoracolumbar spine in female university-level students of performing arts.

Materials and Methods: A true experimental design was used with 25 female students of performing arts, divided into an experimental group (n = 15, 60%) and control group (n = 10, 40%). Pre- and post-intervention evaluations were conducted using Schober's, Stibor's and Otto's tests. Non-parametric statistical analyses were applied. This work was supported by the Scientific Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic – Grant No. 1/0512/24: Epidemiology of Musculoskeletal Disorders in Students of Performing Arts.

Results: The experimental group showed statistically significant improvements in all three spinal function tests: Schober's (from 3.06 ± 0.60 cm to 5.40 ± 0.82 cm), Stibor's (from 6.46 ± 0.64 cm to 9.20 ± 0.86 cm) and Otto's (from 4.12 ± 0.98 cm to 5.86 ± 0.36 cm), all with $p < 0.01$. No changes were observed in the control group. Between-group comparisons at Week 10 confirmed significant functional improvements in the experimental group (all $p < 0.01$).

Conclusions: The 10-week corrective exercise programme significantly enhanced thoracolumbar spine (function) in students of performing arts. These findings suggest that low-cost, targeted interventions can effectively address posture-related musculoskeletal risks in this population and should be integrated into the curricula for performing arts.

INTRODUCTION

Musculoskeletal health (i.e. thoracolumbar spine, in the present case) is of critical concern in students of performing arts, in particular, music students¹. Their intensive, often asymmetrical practice routines impose unique demands that may result in musculoskeletal disorders (MSDs)¹⁻². With many musicians beginning training at an early age and engaging in prolonged hours (± 20 hours) of repetitive movements, the thoracolumbar region is particularly vulnerable to mechanical overload

and postural strain. This has fuelled a growing interest in evaluating preventive and rehabilitative interventions, including structured physical activity programmes, to mitigate adverse spinal outcomes^{1,3-4}.

Students of performing arts, especially music students, are subjects to both psychological and psychological stressors⁴⁻⁵. Instrument-specific demands often result in prolonged static postures, asymmetrical loading and muscle imbalances. These factors significantly contribute to postural deviations, including excessive thoracic kyphosis or lumbar lordo-

sis, which may progress to chronic back pain and spinal dysfunction over time. In research, it is indicated that musculoskeletal complaints are exceedingly common among music students, with up to 80% experiencing pain related to their practice routine^{1-2,6-7}. The mechanics of the thoracolumbar spine are especially critical due to this region's transitional nature between the rigid thoracic and more mobile lumbar vertebrae⁸. The thoracolumbar junction (T10-L2) serves as a structural and functional pivot point for movement and posture maintenance. Abnormal loading

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from sustained seated positions, such as when playing the violin, piano or wind instruments, may lead to progressive spinal alterations and dysfunction⁹⁻¹⁰.

Thoracolumbar spinal adaptations in students of performing arts may manifest as reduced disc height, spinal curvature alterations and muscular imbalances⁸. These changes, in particular, when uncorrected, predispose musicians to degenerative spine conditions and chronic back pain¹¹⁻¹². Such spinal abnormalities may occur independently of obvious injury or trauma, underscoring the role of repetitive biomechanical stress. Degenerative changes in the thoracolumbar spine, including disc degeneration and facet joint overload, have been strongly linked with long-term physical inactivity¹³.

There is substantial evidence that structured physical activity, in particular, strength and mobility-focused programmes, may reverse or mitigate spinal adaptations in at-risk populations. For example, an 8-week intervention focused on posture correction led to significant improvements in spine alignment, abdominal-pelvic control and shoulder stabilisation in music students¹. Similar outcomes have been seen in athletes, whose spinal stressors share parallels with musicians, with functional rehabilitation improving posture and reducing pain¹⁴. Rehabilitation programmes focusing on thoracolumbar mobility, muscular endurance and posture re-training demonstrate positive changes in spinal curvature and pain reduction. These interventions often include corrective exercises, myofascial release, core strengthening and proprioceptive training, all tailored to individual postural patterns and movement deficits¹⁴⁻¹⁵.

Improved postural awareness and motor control through physical training have long-term benefits. Structured programmes may lead to neuromuscular re-education, reducing reliance on maladaptive compensation patterns. For instance, posture-focused interventions have reduced trunk asymmetry and improved spinal curvature in adolescents with scoliosis, a condition with parallels in

asymmetrically loaded spines alike those in musicians¹⁶⁻¹⁷. In MRI studies, significant improvements have been demonstrated in disc health and posture among individuals engaging in consistent, targeted physical activity, even after long durations of spinal stress^{13,18-19}.

OBJECTIVES

Despite growing evidence, research focused on music students remains limited. Most existing literature is centred around athletes or the general population, highlighting gaps in targeted research on students of performing arts. Music students form an exceptional group with distinct risk profiles and may benefit from tailored corrective exercise programmes which are addressed to the specific demands of their instruments¹.

While short-term outcomes appear promising, more longitudinal research is needed to determine the sustainability of musculoskeletal health benefits. In this study, we seek to provide practical insights into the musculoskeletal demands placed on students of performing arts by assessing the thoracolumbar spine. Therefore, the aim of this study is to evaluate the impact of a 10-week corrective exercise programme on the thoracolumbar spine in students of performing arts.

MATERIALS AND METHODS

Participants

The target population consisted of 25 female students (100%) enrolled in the Performing Arts and Composition Bachelor's degree programme (1st-3rd year) at the Faculty of Performing Arts, Academy of Arts in Banská Bystrica. A 10-week intervention programme was implemented from January 1 to March 5, 2025, consisting of two, 30-minute sessions per week (Wednesdays and Fridays). The objective of the programme was to improve the thoracolumbar spine (function) in 15 students (60%) assigned to the experi-

mental group (mean age: 20.20 ± 1.20 years; body mass: 52.20 ± 4.20 kg; body height: 168.40 ± 1.80 cm). The remaining 10 students (40%) were allocated to the control group, which did not receive the intervention (mean age: 20.40 ± 1.40 years; body mass: 55.80 ± 2.20 kg; body height: 168.60 ± 2.30 cm) (Table 1). The participants were recruited via convenience sampling, targeting female students enrolled in the elective course *Prevention of Musculoskeletal System 1-2*, with supplementary recruitment conducted through institutional email invitations²⁰.

Both the experimental and control groups formed demographically and academically homogenous samples, ensuring consistency in baseline characteristics. This sample was deemed appropriate due to its accurate representation of the target population, i.e. female bachelor's students in Performing Arts and Composition. Convenience and intentional sampling approaches were used, with deliberate selection based on key demographic factors such as age, gender and year of study to align with the study's objectives¹.

The study was conducted in accordance with ethical standards outlined in the 1964 Declaration of Helsinki and its later amendments. Ethical approval was obtained from the Ethics Committee of the Artistic and Pedagogical Council of the Faculty of Performing Arts, Academy of Arts in Banská Bystrica (Approval No. 001 March 24/25). All participants (25, 100%) provided written informed consent²¹.

Assessments, measures and procedures

The impact of the 10-week corrective exercise programme was evaluated in 15 (60%) students through a true experimental design²². The intervention was delivered over 10 weeks, with sessions held twice per week for 30 minutes each (Wednesdays and Fridays), from January 1 to March 5, 2025. The programme served as the experimental stimulus for the experimental group (n = 15, 60%), in particular, targeting a defined musculo-

Table 1

| Anthropometric and demographic data for 25 students of performing arts (25, 100%) | | |
|---|--------------------|-------------------|
| | Experimental group | Control group |
| Age (years; $\bar{x} \pm SD$) | 20.20 \pm 1.20 | 20.40 \pm 1.40 |
| Body mass (kg; $\bar{x} \pm SD$) | 52.20 \pm 4.20 | 55.80 \pm 1.60 |
| Body height (cm; $\bar{x} \pm SD$) | 168.40 \pm 1.80 | 168.60 \pm 2.30 |
| Instruments | | |
| Wind (n; %) | 5; 33.33% | 3; 30% |
| String (n; %) | 5; 33.33% | 4; 40% |
| Keyboard (n; %) | 5; 33.33% | 3; 30% |
| Practice | | |
| Day (hours; $\bar{x} \pm SD$) | 2.62 \pm .60 | 2.42 \pm .58 |
| Career (years; $\bar{x} \pm SD$) | 14.86 \pm 1.26 | 13.90 \pm 1.64 |

\bar{x} – arithmetic mean; SD – standard deviation.

skeletal state (S). The control group, consisting of 10 students (40%), received no intervention and served as the baseline for comparison. Both groups were assessed at two time points: pre-intervention (Week 1, January 1) and post-intervention (Week 10, March 5, 2025), allowing measurement of changes in the specific state (S) over the 10-week period. The experimental group completed the intervention under the supervision of authors, who also provided them with detailed instruction on the principles and objectives of the programme (Table 2).

While playing instruments, performing arts students, in particular, those studying at the university level, often spend several hours daily in seated, asymmetrical positions. Over time, these habits can lead to poor posture, reduced spinal mobility and musculoskeletal discomfort, especially in the thoracolumbar region, which connects the mid-back to its lower segment. To address these issues proactively, we proposed a 10-week corrective exercise programme focused on thoracolumbar spine mobility, strength and postural control. The programme was designed for two, 30-minute sessions per week and required only a yoga mat, making it easy to implement in classrooms. The goal of programme was to progressively enhance mobility, core control and postural awareness, while reducing physical strain associated with long-term playing positions. Each session includ-

ed a five-minute warm-up to activate the spine and prepare the body, followed by a 20-minute main block of targeted mobility and strengthening exercises. The session concluded with

a five-minute cool-down to promote recovery and relaxation (*Appendix A*). Throughout the intervention period, the 15 students (60%) in the experimental group were encouraged to

Table 2

| 10-week intervention programme – overview | |
|---|--------------------------------------|
| Period | Aim |
| Week 1-2 | Mobility & postural awareness |
| Week 3-4 | Core activation & spinal control |
| Week 5-6 | Strengthening thoracolumbar support |
| Week 7-8 | Dynamic stability & integration |
| Week 9-10 | Functional application & maintenance |

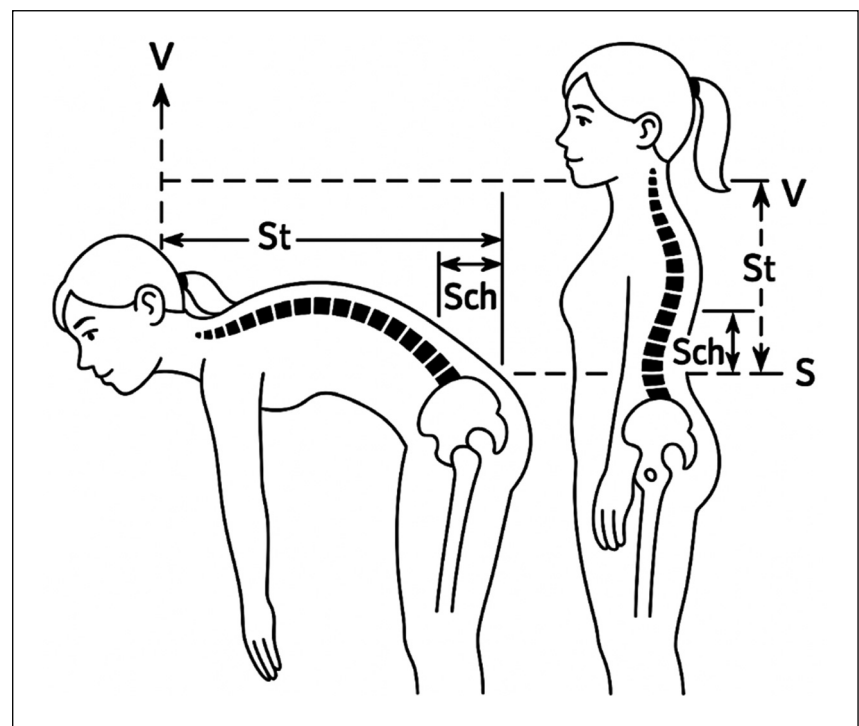


Figure 1
Thoracolumbar spine assessments

report any musculoskeletal discomfort or potential pain to the authors, who closely monitored signs of physical fatigue, such as muscle shaking or loss of motor control. The intervention was delivered in a group setting, selected for its cost-effectiveness, the benefits of peer support and its potential to enhance student engagement²²⁻²³. The 10-week programme was carefully designed to optimise physical benefits while minimising the risk of injury¹.

A standardised measure was used to evaluate the thoracolumbar spine, in particular, its function, based on established protocols²⁴⁻²⁵ (Figure 1). These assessments were conducted at two time points: before (Week 1, January 1) and after the 10-week corrective exercise programme (Week 10, March 5, 2025). The standardised measure allows to evaluate the following:

1. **Schober’s test (Sch, lumbar Spine)**
 - from the 5th lumbar vertebra, a mark is made upwards – 10 cm and the given location is marked.
 - Norm:** When leaning forward, the distance increases by 4-6 cm.
 - Deviation:** If the elongation is less than the norm.
2. **Stibor’s test (St, lumbar & thoracic spine)** – the distance is measured from the 7th cervical vertebra to the 5th lumbar vertebra.
 - Norm:** When leaning forward, the distance increases by 7.50-10 cm.
 - Deviation:** If the elongation is less than the norm.
3. **Otto’s Test (Ot, thoracic spine)**
 - from the 1st thoracic vertebra, a mark is made downwards

– 30 cm and the given location is marked.

Norm: When leaning forward, the distance increases by 2-3 cm. When leaning back, the distance decreases by 2.5-3 cm, and the sum of deviations should be 6 cm.

Deviation: If the sum of deviations is less than the norm.

Statistical methods

Data from all 25 female students (100%) in the performing arts programme were organised and presented in a structured database format (see *Tables 1-4*)²⁶. The impact of the 10-week corrective exercise programme was assessed using non-parametric statistical methods, in particular, the Wilcoxon Rank-Sum test was used to compare two independent samples, and the Wilcoxon Signed-Rank test was applied for comparing two related samples. Both tests were conducted with significance levels set at $p = 0.01$ and $p = 0.05$ ²⁷⁻²⁸, and the effect size ($r = z/\sqrt{n}$) was calculated using Wilcoxon tests (Rank-Sum and Signed-Rank), which is the z value, divided by the total number of observations (IBM SPSS Modeler²⁹). In this study, effect sizes ranged from $r = 0.54$ to $r = 0.86$, which indicates large effects according to Cohen’s thresholds ($r \geq 0.50$). Descriptive statistics, including percentages (%), arithmetic means (\bar{x}) and standard deviations (*Std*), were calculated to characterise the key features of the entire 25-student sample (see *Tables 3-4*)³⁰.

RESULTS

At baseline, both the experimental and control groups demonstrated similar thoracolumbar spine levels across all three tests, with no statistically significant differences noted between the groups. This homogeneity in initial functional capacity provided a robust foundation for assessing the efficacy of intervention. The experimental group then underwent a supervised corrective exercise programme, targeting the thoracolumbar region. The programme was delivered over a 10-week period, with sessions designed to progressively challenge the thoracolumbar spine’s functional range of motion while minimising the risk of overuse.

The results of the post-intervention evaluations revealed statistically significant improvements in the thoracolumbar spine (function) of the experimental group, with no comparable changes observed in the control group. In Schober’s test, which is used to measure the mobility of lumbar spine, the experimental group exhibited an increase in mean score from 3.06 cm at Week 1 to 5.40 cm at Week 10. This change was statistically significant, with the Wilcoxon Z-value of 3.48 ($p < 0.01$) and large effect size ($r = 0.54$), indicating meaningful clinical improvements (Table 3). These findings suggest that the intervention was effective in enhancing lumbar spine, an important (crucial) component of movement quality in students of performing arts. The results of Stibor’s test, which evaluates

Table 3

| Changes in thoracolumbar spine among experimental and control groups | | | |
|--|-------------|-------------|--|
| Experimental group | | | |
| Test | Week 1 | Week 10 | Wilcoxon S-R Test |
| Schober ($\bar{x} \pm SD$) | 3.06 ± 0.60 | 5.40 ± 0.82 | Z = 3.48, $p < 0.01$, $r = 0.54^{**}$ |
| Stibor ($\bar{x} \pm SD$) | 6.46 ± 0.64 | 9.20 ± 0.86 | Z = 3.54, $p < 0.01$, $r = 0.58^{**}$ |
| Otto ($\bar{x} \pm SD$) | 4.12 ± 0.98 | 5.86 ± 0.36 | Z = 3.46, $p < 0.01$, $r = 0.56^{**}$ |
| Control group | | | |
| Test | Week 1 | Week 10 | Wilcoxon S-R Test |
| Schober ($\bar{x} \pm SD$) | 3.20 ± 0.56 | 3.20 ± 0.56 | n/a |
| Stibor ($\bar{x} \pm SD$) | 6.40 ± 0.68 | 6.40 ± 0.68 | n/a |
| Otto ($\bar{x} \pm SD$) | 4.00 ± 1.05 | 4.00 ± 1.05 | n/a |

** – significance (p) = 0.01; n/a – no answer; \bar{x} – arithmetic mean; SD – standard deviation.

combined thoracic and lumbar spine, showed an increase in the mean score from 6.46 cm to 9.20 cm in the experimental group. This change was also statistically significant ($Z = 3.54, p < 0.01$) with an effect size of $r = 0.58$, further supporting the intervention's impact on thoracolumbar spine. The integration of thoracic and lumbar measurements in this test reflects the functional interdependence of spinal segments, and the observed gains suggest improved segmental coordination and extension capacity in the experimental group following the intervention. In terms of thoracic spine, Otto's test results mirrored the positive trends seen in the other two assessments. Students of performing arts from the experimental group showed an increase in mean score from 4.12 cm to 5.86 cm ($Z = 3.46, p < 0.01, r = 0.56$), representing significant gains in upper back (function). This enhancement is, in particular, relevant to performing arts students who require dynamic control of thoracic region for expressive and functional movement patterns. However, the control group demonstrated no measurable improvements across any of the three assessments. The mean scores for Schober's, Stibor's and Otto's tests remained unchanged between the pre- and post-intervention evaluations, underscoring the necessity of a targeted corrective exercise programme for achieving improvements in the thoracolumbar spine. The lack of spontaneous improvement in the control group suggests that regu-

lar performance alone is insufficient to elicit the gains in the thoracolumbar spine observed in the experimental group.

Further supporting the effectiveness of intervention, between-group comparisons at the conclusion of the 10-week programme revealed statistically significant differences in the thoracolumbar spine (function) across all three measures. The experimental group significantly outperformed the control group in Schober's ($Z = -4.12, p < 0.01, r = -0.84$), Stibor's ($Z = -4.24, p < 0.01, r = -0.84$) and Otto's tests ($Z = -4.28, p < 0.01, r = -0.86$) (Table 4). These large effect sizes reflect substantial improvements attributable to the intervention rather than to natural variation or external confounding factors.

DISCUSSION

The aim of this study was to evaluate the impact of a 10-week corrective exercise programme on the thoracolumbar spine in students of performing arts. The results demonstrated statistically significant improvements in the thoracolumbar spine (function) for the experimental group ($n = 15, 60\%$), measured by Schober's, Stibor's and Otto's tests, while the control group ($n = 10, 40\%$) showed no comparable changes. These findings highlight the potential of a targeted corrective exercise programme to address the exceptional musculoskeletal challenges experienced by students of performing

arts, who often engage in prolonged seated, asymmetrical postures.

At baseline, the experimental and control groups showed no significant differences in the thoracolumbar spine. For example, in the Schober's test (which is used to evaluate the lumbar spine), the experimental group recorded mean scores of 3.06 ± 0.60 cm, while the control group scored 3.20 ± 0.56 cm ($p > 0.05$). Following the intervention, the experimental group improved to 5.40 ± 0.82 cm, representing significant increases ($Z = 3.48, p < 0.01, r = 0.54$). Mean scores of Stibor's test also increased significantly in the experimental group, from 6.46 ± 0.64 cm to 9.20 ± 0.86 cm ($Z = 3.54, p < 0.01, r = 0.58$), and Otto's test mean scores improved from 4.12 ± 0.98 cm to 5.86 ± 0.36 cm ($Z = 3.46, p < 0.01, r = 0.56$). No statistically significant changes occurred in the control group ($p > 0.05$). These findings are in line with those achieved in previous research, emphasizing the role of rehabilitation exercises in improving the thoracolumbar spine and reducing pain. Structured corrective exercise programmes targeting thoracolumbar spine have been shown to enhance range of motion and muscular strength in patients with degenerative spinal conditions¹⁴. Physical inactivity is strongly associated with disc degeneration in the thoracolumbar spine, accenting the need for consistent movement-based interventions to prevent musculoskeletal decline¹³.

Musculoskeletal complaints are highly prevalent in students of per-

Table 4

| Changes in thoracolumbar spine for Week 1 and Week 10 | | | |
|---|--------------------|-----------------|---------------------------------------|
| Week 1 | | | |
| Test | Experimental group | Control group | Wilcoxon R-S Test |
| Schober ($\bar{x} \pm SD$) | 3.06 ± 0.60 | 3.20 ± 0.56 | $Z = -0.14, p > 0.05, r = -0.02$ |
| Stibor ($\bar{x} \pm SD$) | 6.46 ± 0.64 | 6.40 ± 0.68 | $Z = -0.34, p > 0.05, r = -0.06$ |
| Otto ($\bar{x} \pm SD$) | 4.12 ± 0.98 | 4.00 ± 1.05 | $Z = -0.32, p > 0.05, r = -0.06$ |
| Week 10 | | | |
| Test | Experimental group | Control group | Wilcoxon R-S Test |
| Schober ($\bar{x} \pm SD$) | 5.40 ± 0.82 | 3.20 ± 0.56 | $Z = -4.12, p < 0.01, r = -0.84^{**}$ |
| Stibor ($\bar{x} \pm SD$) | 9.20 ± 0.86 | 6.40 ± 0.68 | $Z = -4.24, p < 0.01, r = -0.84^{**}$ |
| Otto ($\bar{x} \pm SD$) | 5.86 ± 0.36 | 4.00 ± 1.05 | $Z = -4.28, p < 0.01, r = -0.86^{**}$ |

** – significance (p) = 0.01; \bar{x} – arithmetic mean; SD – standard deviation.

forming arts, with research reporting rates as high as 87%^{1,31}. These students are exposed to unique biomechanical stressors due to instrument-specific demands that often lead to postural asymmetries and muscle imbalances⁷. The thoracolumbar junction is, in particular, vulnerable due to its transitional location between the thoracic and lumbar vertebrae and its role in supporting both movement and posture³². The statistically significant improvements in our study, including mean score increases of 2.34 cm in Schober's test, suggest that targeted interventions may yield meaningful clinical outcomes, even in a rather short time frame.

The structure of the intervention, which progressed from postural awareness and mobility training to dynamic spinal strengthening and functional integration, likely contributed to these outcomes. Research in athletic populations has shown similar benefits. For example, tennis players recovering from lumbar injuries demonstrated enhanced stability and reduced reinjury rates when enrolled in progressive rehabilitation programmes addressing spinal control and flexibility³³. Biomechanical modelling of adolescents indicated that trunk-strengthening exercises significantly reduced spinal loading and improved segmental muscle function in the thoracolumbar region³⁴. Comparable benefits have been observed in dancers and school-aged populations. In a study of Latin and standard dancers, regular physical activity was associated with improved sagittal spinal curvature and reduced postural asymmetry¹². Corrective exercises performed on vibration platforms resulted in significant improvements regarding spinal strength and mobility among adolescents with scoliosis³⁵. These studies reinforce the premise that spine-focused interventions may generate measurable benefits across diverse high-risk groups.

Our findings also align with clinical literature on thoracolumbar rehabilitation. For instance, exercise therapy after thoracolumbar fractures has been shown to improve vertebral height and correct kyphotic angles, thereby enhancing overall spinal

alignment³⁶⁻³⁷. These findings underscore the universal importance of rehabilitation principles across diverse populations.

From an educational standpoint, our intervention offers practical, cost-effective solutions for integrating musculoskeletal health promotion into performing arts. The programme's simplicity, requiring only two 30-minute sessions per week and minimal equipment, makes it highly feasible for incorporation into conservatory or university curricula. This recommendation is supported by previous research in which early preventive strategies have been noted to reduce playing-related injuries³¹.

Nevertheless, some limitations must be acknowledged. The sample size was modest ($n = 25$) and comprised only female participants, limiting the generalisability of findings. While the observed improvements were statistically and clinically significant, long-term follow-up to assess the durability of effects was not included. The absence of subjective outcome measures, such as self-reported pain or quality of life, limits our understanding of the intervention's broader impact. Moreover, an important limitation is the lack of consideration for the specific instruments played by the participants during recruitment. Playing string instruments for several hours daily, for instance, imposes biomechanical loads on the musculoskeletal system that substantially differ from those generated by playing the piano or wind instruments. Failure to account for such instrument-specific demands may have influenced both baseline spinal function and the responsiveness to the intervention. The importance of assessing both physical and psychological outcomes in post-rehabilitation evaluations has been emphasized³⁸.

In future research, these limitations should be addressed by incorporating larger, mixed-gender samples and by extending the follow-up period to evaluate long-term outcomes. Studies to date often involve small, homogeneous groups or lack sufficient duration to capture sustained effects, limiting generalisability. The

integration of qualitative measures would provide more comprehensive insights into how such interventions influence overall wellbeing, including emotional resilience, practice habits and perceived performance quality, dimensions particularly relevant to students in the performing arts. Furthermore, hybrid delivery models, incorporating digital platforms or app-based guidance, may enhance accessibility and adherence, especially for students balancing rigorous academic and practice commitments. These approaches could increase intervention reach and personalisation, while maintaining consistency and user engagement. Additionally, in future studies, it should be specified which types of exercises are particularly effective in strengthening postural muscles and reducing ligamentous-muscular overloads caused by instrument-specific demands. Recommendations regarding starting positions, ranges and planes of movement would provide valuable practical guidance for tailoring interventions to the everyday activities and musculoskeletal risks of musicians.

CONCLUSIONS

In the current study, it was demonstrated that a 10-week corrective exercise programme significantly improved thoracolumbar spine (function) in female students of performing arts. The experimental group, which underwent bi-weekly, structured sessions focusing on spinal mobility, postural control and core strength, showed statistically and clinically significant gains across all three assessment measures (Schober's, Stibor's and Otto's tests), while the control group showed no comparable improvement.

These results support the effectiveness of short-term, low-resource interventions in addressing the exceptional musculoskeletal challenges experienced by music students, who are regularly exposed to asymmetrical and static postures due to their instrument-specific demands. The findings align with existing literature on spinal rehabilitation, posture correc-

tion and neuromuscular training, and underscore the value of integrating such programmes into the curricula of performing arts.

Despite the limitations related to sample size, gender homogeneity and short-term follow-up, in the study, promising models are offered for preventive and rehabilitative care in performing arts education. Future studies should include broader samples, longer monitoring periods and subjective outcome measures to better understand the lasting impact of such interventions on both physical health and overall wellbeing.

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Conflicts of interest

The authors declare no conflict of interest.

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APPENDIX A

10-Week Thoracolumbar Spine Corrective Exercise Programme for Music Students

Frequency: 2x/ week Duration: 30 minutes Equipment: Yoga mat (optional: resistance bands, foam roller)

General format:

- 5 min warm-up
- 20 min main set (exercises)
- 5 min cool-down

Week 1-2: Mobility & Postural Awareness

Aim: Increase spinal mobility, promote neutral posture, raise awareness of body alignment.

Warm-up:

- Cat-cow stretch – 1 min
- Pelvic tilts – 1 min
- Arm circles – 1 min
- Deep diaphragmatic breathing – 2 min

Main set – exercises:

1. Wall angels 3 sets of 10 reps Promotes shoulder mobility and thoracic extension.
2. Thread the needle stretch (thoracic rotation) 2 sets each side, 5 reps Mobilises thoracic spine and improves rotational range.
3. Standing forward fold with spinal roll-up 3 sets of 5 slow reps Encourages lumbar flexion and controlled extension.
4. Seated posture drill (hip & spinal alignment) 2 sets of 60-second holds Reinforces awareness of neutral spine in seated posture.

Cool-down:

- Supine knee-to-chest stretch – 1 min
- Child's pose with reach – 2 min
- Box Breathing – 2 min

Week 3-4: Core Activation & Spinal Control

Aim: Activate deep core muscles and improve spinal stability.

Warm-up:

- Bird dog (alternating) – 2 sets of 8 reps
- Glute bridges – 2 sets of 10 reps

Main set – exercises:

1. Dead bug (controlled arm/leg lowering) 3 sets of 8 reps per side Builds coordination and core control with neutral spine.
2. Side plank (modified or full) 2 sets of 30 seconds per side Targets obliques and spinal stabilisers.
3. Segmental cat-cow (slow vertebral mobilisation) 2 sets of 5 reps Focus on spinal articulation and control.
4. Supine march with core brace 3 sets of 10 reps Emphasizes transverse abdominis engagement.

Cool-down:

- Happy baby pose – 1 min
- Spine twist (supine) – 2 min
- Diaphragmatic breathing – 2 min

Week 5-6: Strengthening Thoracolumbar Support

Aim: Build muscular endurance and support structures for postural maintenance.

Warm-up:

- Inchworms – 1 min
- Shoulder rolls – 1 min
- Dynamic hamstring stretch – 2 min
- Marching in place with arm swings – 1 min

Main set – exercises:

1. Superman lifts (arms + legs) 3 sets of 10 reps Strengthens erector spinae and gluteal muscles.
2. Resistance band row (seated or standing) 3 sets of 12 reps Reinforces postural back muscles.
3. Bird dog hold (3-sec pause) 3 sets of 6 reps per side Boosts spinal stability.
4. Wall sit with spinal elongation 2 sets of 30 seconds Promotes lumbar awareness and isometric strength.

Cool-down:

- Prone sphinx pose – 1 min
- Kneeling hip flexor stretch – 1 min per side
- Seated forward fold – 2 min

Week 7-8: Dynamic Stability & Integration

Aim: Integrate core control and spinal mobility into dynamic, functional patterns.

Warm-up:

- Arm swings + spinal twist – 1 min
- Knee hugs to high knees – 1 min
- Scapular push-ups – 2 sets of 10

Main set – exercises:

1. Standing march with arm drive (focus: posture) 2 sets of 20 steps Improves coordination and posture during movement.
2. Single-leg Romanian deadlift (bodyweight) 2 sets of 8 reps per leg Engages posterior chain with spinal control.
3. Bear crawl (short distance) 3 sets of 20 seconds Combines core control, shoulder stability and thoracolumbar awareness.
4. Standing resistance band rotation 2 sets of 10 reps per side Enhances controlled rotation through thoracolumbar region.

Cool-down:

- Spinal twist lying down – 1 min per side
- Cat-cow – 1 min
- Standing shoulder rolls – 1 min
- Breathwork (box breathing) – 2 min

Week 9-10: Functional Application & Maintenance

Aim: Apply improvements in posture and mobility to instrument playing and daily activities.

Warm-up:

- Full-body stretch sequence (dynamic flow) – 3 min
- Breath-to-movement flow (spinal wave) – 2 min

Main set – exercises:

1. Instrument-specific postural drills *Seated with instrument (or mock position), mirror feedback, 3 sets of 1 min holds*
Applies postural control in context.
2. Modified Turkish get-up (bodyweight) 2 sets of 3 reps per side Integrates core, shoulder and thoracolumbar control.
3. Wall squat with overhead reach 2 sets of 10 reps Promotes alignment and dynamic range.
4. Dynamic balance reach (Y-balance style) 2 sets of 5 reps per leg Engages the core in functional balance contexts.

Cool-down:

- Full-body relaxation (supine) – 2 min
- Thoracic foam roll (optional) – min
- Deep breathing with arm elevation – 2 min