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# Impacts of chest wall mobilization combined with a breathing technique on thoracic kyphosis

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**Abstract**

**Background:** Thoracic kyphosis (TK) impairs spinal alignment and respiratory mechanics, yet evidence regarding mobility-oriented corrective exercise remains limited. This study examined whether chest wall mobilization combined with functional breathing enhances thoracic mobility and posture in individuals with TK.

**Design:** Randomized pretest-posttest controlled design

**Methods:** A total of 25 asymptomatic adults with TK were divided into the traditional group and the combined group. The traditional group performed thoracic strengthening and stretching exercises, and the combined group participated in the chest wall mobilization and expansion exercises combined with a breathing technique. Both programs were administered for 2 weeks (10 sessions, 40 minutes/session). Thoracic kyphotic angle, thoracic active extension angle, and thoracic extensor muscle strength were measured pre- and post-intervention using a dual inclinometer and a digital handheld dynamometer.

**Results:** Both the traditional exercise group (Group *A*) and the combined intervention group (Group *B*) demonstrated significant improvements in thoracic kyphotic angle and thoracic active extension angle following the intervention ($p<0.05$). Group *B*, which received chest wall mobilization combined with breathing exercises, showed greater improvements in spinal mobility compared to Group *A*. In addition, thoracic extensor muscle strength increased significantly in both groups, with Group *A* exhibiting a more pronounced improvement than Group *B* ($p<0.05$).

**Conclusion:** This study demonstrated that chest wall mobilization combined with a breathing technique effectively improved thoracic kyphotic angle, thoracic active extension angle, and thoracic extensor muscle strength in individuals with thoracic kyphosis. Breathing-based chest wall mobilization effectively improved thoracic alignment and mobility and may offer a feasible alternative to conventional strengthening-focused approaches. Further studies with larger and more diverse populations and longer intervention periods are warranted to confirm these results.

**Key words:** Breathing technique, chest wall mobilization, muscle strength, thoracic kyphosis

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# Ⅰ. Introduction

In the sagittal plane, the human spine comprises a series of reciprocal curvatures that extend from the cervical region to the pelvis. The cervical and lumbar segments are typically lordotic, whereas the thoracic spine is characteristically kyphotic (Berthonnaud et al, 2005). The primary determinants of the spine's sagittal alignment are the thoracic vertebrae, as the thoracic curve is largely shaped by the vertebral bodies (Macagno and O'Brien, 2006). A thoracic kyphotic angle of 〈 40 is considered within the normal range, whereas angles exceeding this threshold are diagnostic of thoracic kyphosis (TK) (Vaughn and Brown, 2007). Correct physiological configuration of the spine is essential for maintaining spinal balance and resisting gravitational forces (Zaina et al, 2009). In individuals with TK, the ground reaction force is transmitted directly to the spine during activities such as walking and stair climbing, exacerbating trunk instability and resulting in greater vertical displacement of the center of mass (COM) compared to individuals without TK (Cho et al, 2016). TK is associated with impaired pulmonary function, diminished performance of the activities of daily living, and reduced quality of life (Kado et al, 2004; Takahashi et al, 2005).

Various approaches have been attempted to manage TK. Among them, exercise therapy is the most commonly used non-invasive intervention (Ponzano et al, 2021; Yang et al, 2024). Exercise programs for TK typically include components of strengthening, stretching, endurance, and/or resistance training. Many clinicians prioritize stretching and strengthening exercises as core elements of these interventions, as TK is often associated with reduced flexibility of the anterior chest muscles and weakness in the paravertebral muscles (White and Panjabi, 1990). Numerous studies have demonstrated that thoracic stretching and strengthening exercises are effective in reducing thoracic curvature and improving posture (Ponzano et al, 2021; Yang et al, 2024). However, when these exercises are poorly regulated or improperly applied, they may result in the development of excessive lumbar lordosis due to anterior pelvic tilt and insufficient core engagement, thereby placing undue stress on the lower back (Hosseinifar et al, 2017).

The thoracic spine is the stiffest segment of the vertebral column, a characteristic attributed to structural differences compared to the cervical and lumbar regions, and the presence of the rib cage (Liebsch et al, 2017). Therefore, the thoracic spine contributes to rib cage movement during all functional activities, including respiration (Edmondston et al, 2012). Although the thoracic vertebrae exhibit minimal mobility due to the articulations with the rib cage and thorax, compared to other spinal segments they play crucial roles in facilitating cervical spine motion and rib-cage dynamics during activity (White and Panjabi, 1990). Anatomically, the movement of the thoracic vertebrae is significantly influenced by the ribs (Kendall and McCreary, 2005). In the context of thoracic mobility, the ribs can be structurally leveraged to induce efficient movement of the thoracic vertebrae (Neumann, 2016).

Rib cage movement refers to the biomechanical excursion of the ribs in multiple directions—including superior, inferior, lateral, and medial motions—during inspiration and expiration (De Troyer and

Boriek, 2011). This dynamic action alters the volume of the thoracic cavity, thereby facilitating effective pulmonary ventilation (De Troyer and Boriek, 2011). When rib cage mobility is restricted, respiratory efficiency diminishes due to limited thoracic expansion (Strunce et al, 2009). To address this, chest wall mobilization techniques have been proposed as an intervention to enhance the mobility of the costovertebral joints and surrounding soft tissues, thereby promoting rib motion (Heneghan et al, 2016). A more compliant chest wall allows for more efficient expansion and recoil of the ribs during breathing, contributing to improved respiratory mechanics. Enhancing rib cage mobility through chest wall mobilization not only improves respiratory function but also positively affects thoracic spine mobility, owing to the anatomical and functional interdependence between the ribs and thoracic vertebrae (Moon et al 2023). Additionally, breathing exercises involving the diaphragm, intercostal muscles, and abdominal muscles serve to further activate and stabilize rib cage motion by promoting the rhythmic excursion of the thoracic wall (Beeckmans et al, 2016). In this integrative framework, chest wall mobilization provides the structural precondition for improved rib cage movement, while breathing exercises functionally reinforce this movement and contribute to thoracic mobility gains. Ha (2023) reported that thoracic mobility exercises led to improvements in both thoracic motion and dysfunctional breathing patterns among individuals with restricted thoracic excursion.

Despite this conceptual linkage, relatively few studies have applied a combined approach of chest wall mobilization and breathing exercises to enhance thoracic mobility in individuals with TK. Most prior interventions targeting these strategies were limited to populations with pulmonary conditions such as chronic obstructive pulmonary disease (COPD) (Engel et al, 2016; Yelvar et al, 2016). Given this academic gap, the present study hypothesizes that a structured chest wall mobility and expansion exercise program, when integrated with functional breathing exercises, may enhance thoracic vertebral mobility and lead to favorable changes in the thoracic curvature among individuals with TK.

# II. Methods

## 1. Subjects

This study included asymptomatic adults (13 men and 12 women) aged 20 ~ 40 years who exhibited a thoracic kyphotic angle 〉 40° were recruited for this study. Participants were excluded if they presented with pain or restricted range of motion in the trunk or lower extremities, a history of musculoskeletal or neurological disorders, or a history of surgery or medical treatment for the lower extremities within the preceding 6 months. Prior to participation, all individuals were informed of the study's purpose and procedures. The study was conducted according to the guidelines of the Declaration of Helsinki. Participants were allocated to two groups by drawing lots, following a simple randomization procedure. Table 1 summarizes the characteristics of the study participants.

Table 1. Baseline demographic data (mean ± SD, $N$ = 25)

| | Group A[a] ($n$ = 13) | Group B[b] ($n$ = 12) | $p$-value |
|---|---|---|---|
| Age (y) | 32.4 ± 6.2 | 30.0 ± 5.9 | 0.334 |
| Height (cm) | 165.1 ± 8.4 | 168.4 ± 7.7 | 0.175 |
| BMI[c] (kg/$m^2$) | 20.8 ± 4.5 | 22.1 ± 5.2 | 0.542 |
| Sex (male/female) | 7/6 | 6/6 | 0.425 |
| Thoracic kyphotic angle (°) | 42.0 ± 2.1 | 42.1 ± 1.9 | 0.456 |
| Thoracic extensor muscle strength (kgf) | 21.0 ± 6.7 | 19.3 ± 5.2 | 0.239 |

[a]the group of the thoracic strengthening and stretching exercise, [b]the group of the chest wall mobility and expansion exercises combined with a breathing, [c]body mass index.

## 2. Experimental methods

### 1) Intervention for traditional exercise group (Group *A*)

The traditional exercises consisted of thoracic extension strengthening and stretching exercise. The first component of this program involved an upper-back extension strengthening exercise. Participants began by lying prone, face down, with their hands placed behind their heads. They were instructed to lift their elbows off the floor while squeezing their shoulder blades together and extending the upper thoracic spine. It was emphasized that the lower ribs should remain in contact with the ground to minimize involvement of the lumbar spine. The second component consisted of thoracic stretching exercises using a foam roll. These included foam roll stretches, marching on the roller, and thoracic stretching against the foam roll in the supine position. This exercise program for Group A began with a 5-minute warm-up of light walking, followed by 15 minutes of the thoracic extension strengthening exercises and 15 minutes of the thoracic stretching exercises, and concluded with a 5-minute cool-down.

### 2) Intervention for combined exercise group (Group *B*)

The combined exercises were made up of the chest wall mobilization exercise combined with a breathing technique and the chest wall expansion exercise. The first component of the chest wall mobilization exercise consisted of thoracic extension combined with a breathing, performed for 15 minutes. While in a seated position, participants were instructed to cover their cervical spine with both hands and slowly lift their upper body until they felt the occipital bone being pushed upward, while simultaneously drawing the chin inward. During this movement, the therapist used palpation to guide the participant through a breathing technique. The breathing technique used was piston breathing, which emphasizes coordinating the diaphragm, pelvic-floor, and core muscles to enhance breathing efficiency and strengthen the core. The steps in this technique are to inhale deeply through the nose, allowing the belly to rise while keeping the chest relatively still, hold breath for a few seconds, then exhale slowly through pursed lips, feeling the belly fall. The second component focused on a chest wall expansion exercise. This was performed while participants were lying supine on a cushion (3 cm in height) to facilitate thoracic expansion. Participants were instructed to breathe deeply into the abdomen, allowing the chest to expand, and to identify the area of the rib cage that felt tightest during deep inhalation. Participants in Group B performed a 5-minute warm-up, followed by a 15-minute chest wall mobilization exercise program that included deep-breathing techniques. This was followed by 15 minutes of chest wall expansion exercises and concluded with a 5-minute cool-down.

### 3) Procedures

All exercises were part of a 2-week program consisting of 5 sessions per week, totaling 10 sessions. For TK individuals, each exercise session did not exceed 40 minutes. Participants were instructed to take rest breaks between exercises, and a physical therapist monitored the sessions to prevent musculoskeletal fatigue. Evaluations were conducted twice – before (pre-intervention) and after (post-intervention) the training program. All participants were advised to refrain from vigorous activity until the final assessment was completed following the 2-week training period. All sessions were supervised and managed by an experienced physical therapist and conducted in an exercise room located within the University.

## 3. Outcome measurements

### 1) Measurement of thoracic angles: the thoracic kyphotic angle and active extension angle

The thoracic kyphotic angle and the thoracic active extension angle were measured using a dual inclinometer (Acumar; Lafayette Instrument Co., Lafayette, USA). To assess thoracic curvature, one inclinometer was aligned over the spinous process of T1, and a second device was positioned at T12. The relative angle between the two measurement points was then measured. The average intraclass correlation coefficients (ICCs) for thoracic angle measurements obtained with the inclinometer were 0.94 ~ 0.98, indicating excellent reliability.

For measurement of the thoracic kyphotic angle, participants were instructed to stand with their feet shoulder-width apart, remain relaxed, and look forward. The examiner evaluated the thoracic kyphotic angle three times and calculated the mean value. The thoracic active extension angle was measured in the seated position. This angle was determined by calculating the difference between the neutral position and the active end-range extension. Lumbar movement was not restricted in seated position, as achieving maximal thoracic extension without some degree of lumbar involvement is not feasible. An examiner, blinded to group allocation, recorded each measurement three times and calculated the mean values for all measurements.

2) Measurement of thoracic extensor muscle strength

Thoracic extensor muscle strength was evaluated using a digital handheld dynamometer (PowerTrack II; JTech Medical, Salt Lake City, USA). This device quantifies muscle strength, identifies areas of weakness, and supports reliable manual muscle testing (Roy and Macdermid, 2009). A digital handheld dynamometer was used to measure the maximal voluntary strength of the upper thoracic region (Jung et al, 2020). For the assessment, participants were positioned in a prone position on a height-adjustable table with their knees flexed at 90°. The lumbar spine was stabilized using an orthopedic belt, and the dynamometer was placed at the T6–T7 vertebral level. Participants were instructed to perform a maximal thoracic extension against the device. Each participant completed two maximal 5-second isometric contractions, with a 30-second rest interval between attempts. An examiner, blinded to group allocation, recorded and calculated the mean values for all measurements.

## 4. Data analysis

Data were analyzed using SPSS for Windows (version 22.0; IBM Corp., Armonk, NY, USA). p-values $< 0.05$ were considered statistically significant. The Kolmogorov–Smirnov test was employed to assess the normality of data distribution. To evaluate the effects of the intervention within each group, paired t-tests were conducted. Independent t-tests were used to analyze the differences between groups. Within-group effect sizes were calculated using Hedges' g, a bias-corrected version of Cohen's d for paired samples, and interpreted according to Cohen's established guidelines.

# Ⅲ Results

## 1. Comparison of the thoracic kyphotic angle and the thoracic active extension angle

Pre–post comparisons demonstrated significant improvements in both the thoracic kyphotic angle and thoracic active extension angle in the traditional exercise group (Group *A*, which performed thoracic strengthening and stretching exercises) and the combined exercise group (Group *B*, which engaged in chest wall mobilization and expansion exercises combined with breathing) (Table 2).

Post-intervention thoracic kyphotic angles were significantly lower than pre-intervention values in both groups ($p < 0.05$), with medium-to-large effect sizes (Group *A*: Hedges' g = 0.68, 95% CI 0.10 ~ 1.25; Group *B*: $g$ = 1.18, 95% CI 0.45 ~ 1.88). Similarly, thoracic active extension angles were significantly greater after the intervention compared to baseline in both Group A and Group *B* ($p < 0.05$), with effect sizes in the medium-to-large range (Group *A*: $g$ = 0.62, 95% CI 0.05 ~ 1.17; Group *B*: $g$ = 1.07, 95% CI 0.37 ~ 1.74).

Between-group comparisons of the thoracic kyphotic and active extension angles at baseline revealed no significant differences ($p > 0.05$). However, post-intervention, Group B showed significantly greater reductions in thoracic kyphotic angle and greater increases in thoracic active extension angle compared to Group *A* ($p < 0.05$) (Table 3).

## 2. Comparison of the thoracic extensor muscle strength

A significant increase in thoracic extensor muscle strength was observed in both Group *A* and Group *B* following the intervention ($p < 0.05$) (Table 2). The within-group effect sizes indicated medium improvements (Group *A*: Hedges' g = 0.60, 95% CI 0.03–1.15; Group *B*: *g* = 0.63, 95% CI 0.04–1.20).

However, the between-group comparison at post-intervention showed higher extensor strength in Group *A* than Group *B* (26.2 ± 4.7 vs 22.9 ± 4.4 kgf; $p = 0.040$), indicating a greater improvement in Group *A* compared with Group *B* (Table 3).

Table 2. Within-group pre–post changes in thoracic outcomes (mean ± SD).

| Variable | Group | Pre | Post | *p*-value | Hedges' g | 95% CI |
|---|---|---|---|---|---|---|
| Kyphotic angle (°) | A[a] | 42.0 ± 2.1 | 40.6 ± 1.5 | 0.021 | 0.69 | 0.10 ~ 1.25 |
| | B[b] | 42.1 ± 1.9 | 37.2 ± 4.7 | 0.001 | 1.18 | 0.45 ~ 1.88 |
| Active extension angle (°) | A | 17.6 ± 3.4 | 21.2 ± 5.1 | 0.033 | 0.62 | 0.05 ~ 1.17 |
| | B | 19.2 ± 4.9 | 25.8 ± 7.6 | 0.002 | 1.07 | 0.37 ~ 1.74 |
| Thoracic extensor strength (kgf) | A | 21.0 ± 6.7 | 26.2 ± 4.7 | 0.039 | 0.60 | 0.03 ~ 1.15 |
| | B | 19.3 ± 5.2 | 22.9 ± 4.4 | 0.037 | 0.63 | 0.04 ~ 1.20 |

[a]the group of the thoracic strengthening and stretching exercise ($n$ = 13), [b]the group of the chest wall mobility and expansion exercises combined with a breathing ($n$ = 12).

Table 3. Between-group comparisons of pre- and post-intervention outcomes (mean ± SD).

| | Kyphotic angle (°) | | Active extension angle (°) | | Thoracic extensor strength (kgf) | |
|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After |
| Group A[a] ($n$ = 13) | 42.0 ± 2.1 | 40.6 ± 1.5 | 17.6 ± 3.4 | 21.2 ± 5.1 | 21.0 ± 6.7 | 26.2 ± 4.7 |
| Group B[b] ($n$ = 12) | 42.1 ± 1.9 | 37.2 ± 4.7 | 19.2 ± 4.9 | 25.8 ± 7.6 | 19.3 ± 5.2 | 22.9 ± 4.4 |
| *p*-value | 0.456 | 0.011 | 0.157 | 0.043 | 0.239 | 0.040 |

[a]the group of the thoracic strengthening and stretching exercise, [b]the group of the chest wall mobility and expansion exercises combined with a breathing.

# Ⅳ. Discussion

This study tested a novel exercise intervention for TK that involved chest wall mobilization and expansion based on thoracic extension combined with a breathing technique. Thoracic kyphosis disrupts spinal alignment and leads to structural deformities (Macagno and O'Brien, 2006). If left unregulated, it may result in intervertebral space narrowing and a reduction in the thoracic cavity size over time (Kado et al, 2004; Yang et al, 2024). A decreased thoracic cavity directly impacts respiratory function, leading to reductions in both vital capacity and overall pulmonary function (Kamali et al, 2016). In this study, the author applied chest wall mobilization exercises in patients with TK in conjunction with respiratory therapy to investigate how thoracic movement and chest expansion through breathing influence thoracic kyphotic angle, thoracic active extension angle, and thoracic extensor muscle strength.

In this study, both the traditional strengthening/stretching program (Group *A*) and the combined chest wall mobilization with breathing program (Group *B*) produced significant pre–post improvements in thoracic alignment and mobility. Notably, the within-group effect sizes demonstrated meaningful changes in both groups, but were larger in Group B for reductions in thoracic kyphotic angle (Group *A*: Hedges' $g$ = 0.68, 95% CI 0.10–1.25; Group *B*: $g$ = 1.18, 95% CI 0.45–1.88) and increases in thoracic active extension angle (Group *A*: $g$ = 0.62, 95% CI 0.05–1.17; Group *B*: $g$ = 1.07, 95% CI 0.37–1.74). Although the overlapping confidence intervals indicate that these between-group differences may not be statistically significant, the greater magnitude of improvement observed in Group B suggests a tendency toward enhanced thoracic mobility when breathing-based chest wall mobilization is incorporated.

Chest wall mobilization and expansion exercises are designed to maintain or improve the mobility of the chest wall, trunk, and shoulder girdle when ventilation or postural alignment is compromised (Park et al, 2020). In addition, chest wall mobilization reinforces the depth of inspiration and the control of expiration (Yelvar et al, 2016). Chest wall mobilization exercises combined with a breathing positively affect thoracic mobility by stretching the respiratory muscles and promoting thoracic joint mobilization (Engel et al, 2016). Therefore, chest wall mobilization combined with a breathing technique based on rib-cage expansion may be more effective in improving TK-related thoracic angles than traditional thoracic strengthening and stretching exercises. Exercise difficulty is an important factor in adherence, as individuals with relatively weak muscle strength are more likely to engage in regular exercise when the regimen is of relatively low difficulty (Collado-Mateo et al, 2021). Assuming equal effectiveness, chest wall mobilization and expansion exercises are more accessible and easier to apply than thoracic strengthening and stretching exercises. Moreover, this protocol, including a breathing technique, is believed to reduce lumbar loading and minimize compensatory cervical spine movement (Cefali et al, 2025).

Regarding changes in extensor muscle strength, significant improvements were observed both in the Group A performing traditional thoracic strengthening and stretching exercises and in the Group B engaged in the chest wall mobilization and expansion exercises. The findings demonstrate that both exercise programs administered to the two groups had therapeutic effects. To prevent deformity associated with TK, thoracic extensor strengthening exercises are applied to reduce kyphosis by promoting stretching of the chest and abdominal muscles, and improving the tone of the thoracic extensors (Park et al, 2020). Thoracic extensor strengthening exercises, adapted from prone trunk lift protocols, have been modified to target improvements in thoracic mobility more effectively (Beneck et al, 2016). Thoracic extensor strengthening exercises are recommended to improve thoracic strength; however, caution should be taken, as excessive thoracic extension may induce lower back pain and potentially worsen lumbar lordosis (Beneck et al, 2016).

In contrast, chest wall mobilization and expansion exercises incorporating deep-breathing techniques focus on the structural characteristics of the ribs connected to the thoracic spine and their associated joints, based on the biomechanical hypothesis that the ribs may function similarly to levers (De Troyer and Boriek, 2011). In particular, attention is given to the role of respiratory muscles—such as the diaphragm, intercostal, and scalene—whose activation and development induce rib movement (Heneghan et al, 2016). This process expands the intercostal space and generates new force vectors directed upward and posteriorly toward the thoracic vertebrae (McGill, 2007). Such dynamics may contribute to enhancing the functional mobility of the thoracic spine. Unlike conventional passive correction methods, this approach emphasizes breathing-based active postural control, marking a notable differentiation. While both programs improved extensor strength, the traditional strengthening protocol likely produced greater gains due to its direct mechanical loading and higher neuromuscular recruitment of the paraspinal extensors, as reflected by the significant between-group difference at post-test ($p$ = 0.040). By contrast, the breathing-based mobilization emphasized mobility and rib-cage control rather than progressive resistance, suggesting relative limitations for eliciting larger strength adaptations. To date, research addressing the thoracic spine from this perspective remains scarce, and this study aims to propose a novel attempt and explore its potential.

In this study, a chest wall mobilization exercise incorporating deep-breathing techniques contributes to the correction of TK while simultaneously strengthening of the thorax. Furthermore, these exercises can facilitate rib-cage expansion, increase lung capacity, and improve overall respiratory function (Alaparthi et al, 2021). In TK individuals, active exercise of the respiratory muscles is essential to combat the decline in lung function associated with aging and the degeneration of spinal muscles and skeletal structures (Janssens et al, 1999). Therefore, chest wall mobilization combined with a breathing technique, in conjunction with active chest extension, abdominal muscle stretching, and thoracic spine extension exercises, is anticipated to exert a synergistic effect, not only on the musculoskeletal system but also on the cardiopulmonary system.

This study has several limitations. First, the total sample size was relatively small, which may limit the generalizability of the findings. Second, the 2-week intervention period was insufficient to assess fully the short-term and long-term effects of the exercise program. Third, the study population comprised relatively young individuals, precluding generalization of the findings to populations with senile kyphosis.

## V. Conclusion

This study introduced a combined exercise regimen for the management of TK, incorporating chest wall mobilization based on thoracic extension and a controlled breathing technique. The effects of these exercises on the thoracic kyphotic angle, active extension angle, and muscle strength in individuals with TK were analyzed. The findings demonstrate therapeutic benefits across all exercise programs administered to both groups. Notably, chest wall mobilization combined with a breathing technique appeared to be more accessible than traditional thoracic extension strengthening and stretching exercises.

Consequently, chest wall mobilization combined with breathing techniques, offers an integrated approach for correcting TK while simultaneously strengthening the thorax.

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