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Original Article

Comparative Analysis of Thoracic Rotation Exercises: Range of Motion Improvement in Standing and Quadruped Variants

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There have been few investigations into the effectiveness of thoracic spine exercises for improving thoracic range of motion (ROM) in any plane. This study assessed the effectiveness of two thoracic spine exercises: one in the quadruped position and one in the thoracic standing position. We determined how these exercises affect thoracic spine mobility ROM over a 2-week intervention period. Thirty-nine healthy participants were enrolled and assigned to a Quadruped Thoracic Rotation group (n = 17 participants: 9 females and 8 males) or Flamenco Thoracic Spine Rotation group (n = 22: 14 females and 8 males). All participants were administered a KOJI AWARENESS™ screening test, and the initial thoracic spine ROM before intervention exercise was measured in a laboratory setting. Quadruped Thoracic Rotation was performed as the quadruped exercise and Flamenco Thoracic Spine Rotation as the standing exercise. The KOJI AWARENESS™ thoracic spine test and ROM were evaluated on the day after the first exercise session and again after the program. Despite their different approaches to thoracic mobility, the quadruped exercise and standing exercise achieved equivalent improvement in thoracic ROM after 2 weeks. Practitioners have a range of exercise options for enhancing thoracic mobility based on their environmental or task-specific needs.

Key words: thoracic spine, thoracic rotation range of motion, exercise intervention

The thoracic spine, located between the cervical and lumbar regions, plays a crucial role in spinal stability, facilitation of force transfer from the upper body to the lower body, and three-dimensional motion. Unlike the cervical and lumbar spine, which are mainly dependent on attachment to the musculature, thoracic spinal segments depend heavily on bony and ligamentous structures within the rib cage for stability. The rib cage protects internal organs and supports trunk muscles while also functioning as an auxiliary spinal column within the thoracic region [1]. The thoracic spine is both an integrated system onto itself and also an integrated part of the whole body; therefore, understanding thoracic spine movement is fundamental to all treatment approaches for different conditions [2]. Given its centrality to human physiology, the health of the thoracic spine, including with respect to range of motion (ROM) and other relevant parameters, can affect other parts of the body, confer a risk of injury, or affect sports performance.

A history of shoulder or elbow injury has been asso-

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ciated with trunk rotation flexibility in overhead athletes, suggesting that low trunk rotation flexibility may be a risk factor for such injuries [3]. In agreement with this finding, correct trunk rotation sequence during the pitching motion has been suggested to alleviate stress on the structures surrounding the shoulder joint, potentially preventing injury [4]. Moreover, limited ROM of the thoracic spine has been shown to cause shoulder impingement [5,6], and decreased of shoulder ROM, significant reductions in force output during shoulder abduction [7].

For all these reasons, a thorough understanding of thoracic spine movement, along with effective strategies to improve it, are essential for clinicians and sports trainers. While some intervention studies have focused on manipulation techniques [8,9], only a few have examined the impact of exercise on ROM. Thoracic spine exercise is critical for optimal functioning of the athletic kinetic chain, despite being frequently overlooked in evidence-based exercise prescriptions. A comprehensive approach to thoracic exercise is essential in order to address mobility, motor control, work capacity, and strength, and thereby enhance sports performance and reduce excessive load or stress on other components of the kinetic chain [10]. Various methods of rotational mobility exercise are available for different positions, such as side-lying, deep squats, and lunges [10]. Quadruped Thoracic Rotation is a popular exercise performed in the quadruped position [10].

The Flamenco Thoracic Spine Rotation exercise is one of the KOJI AWARENESS corrective exercises intended to mobilize the thoracic spine [11]. As shown in a YouTube video accessible from the home page of the Japan Sports Agency website https://www.youtube.com/watch?v=x2e9xHiW0gI (accessed November, 2023), this exercise involves thoracic rotation and is performed in the standing position. It employs a reverse action method, requiring participants to maintain the shape of a circle formed with one arm while turning the lower body.

Previous studies have utilized the Functional Movement Screen (FMS) assessment to determine whether intervention programs can enhance FMS scores [12]; some studies employed KOJI AWARENESS corrective exercises to evaluate improvements in KOJI AWARENESS points [11]. However, there is a dearth of research into the effectiveness of thoracic spine exercises for improving thoracic ROM in any plane [10]. Specifically, no intervention study has investigated how thoracic spine rotational ROM can be improved with either Quadruped Thoracic Rotation or Flamenco Thoracic Spine Rotation exercises.

This intervention study comparatively assessed two exercises aimed at improving the thoracic spine rotational ROM: the Flamenco Thoracic Spine Rotation exercise, recommended by KOJI AWARENESS Corrective Exercises and performed in a standing position, and the Quadruped Thoracic Rotation exercise performed in a quadruped position.

We hypothesized that the Flamenco Thoracic Spine Rotation exercise would realize a level of ROM improvement equivalent to that by a popular thoracic spine exercise, the Quadruped Thoracic Rotation exercise. If the Flamenco Thoracic Spine Rotation exercise were to be proven equally effective, it could be a valuable option for athletes or patients seeking new exercises that incorporate reverse motion tasks.

Materials and Methods

Participants. This study was conducted at fitness centers affiliated with the authors' institutions from October 2019 to March 2022. Ethical approval was obtained from the Research Ethics Committee of the authors' affiliated institutions (research protocol identification number: M2019-168). All participants provided written informed consent before undergoing the KOJI AWARENESS™ screening thoracic movement test. Participants were instructed to wear comfortable athletic attire that allowed free movement. Individuals with a history of injuries within the last 3 months were excluded from the study. In addition, the participants were instructed to stop the test if they experienced any pain during execution. However, none of the participants discontinued their participation because of injuries or pain during the study.

Procedure. Thirty-nine healthy participants were enrolled and randomly assigned to a Quadruped Thoracic Rotation group (n = 17 participants; 9 females and 8 males) or Flamenco Thoracic Spine Rotation group (n = 22; 14 females and 8 males) (Fig. 1). Each group underwent a screening process using the KOJI AWARENESS Thoracic Spine Mobility test, and participants who passed Level 3 were excluded [11,12]. The KOJI AWARENESS Thoracic Spine Mobility test has three levels, and the test instructions are shown in

Fig. 2. Seventeen participants (8 females and 9 males) from the Quadruped Thoracic Rotation group (no points: 0 participants; Level 1: 2; Level 2: 15; Level 3: 9) and 22 (8 females and 14 males) from the Flamenco Thoracic Spine Rotation group (no points: 0 participants; Level 1: 4; Level 2: 18; Level 3: 6) did not meet the screening criteria. One group performed the Quadruped Thoracic Rotation exercise in the quadruped position, whereas the other group performed the Flamenco Thoracic Spine Rotation exercise in the standing position (Fig. 3). Furthermore, to verify the correct execution of the exercises, all participants

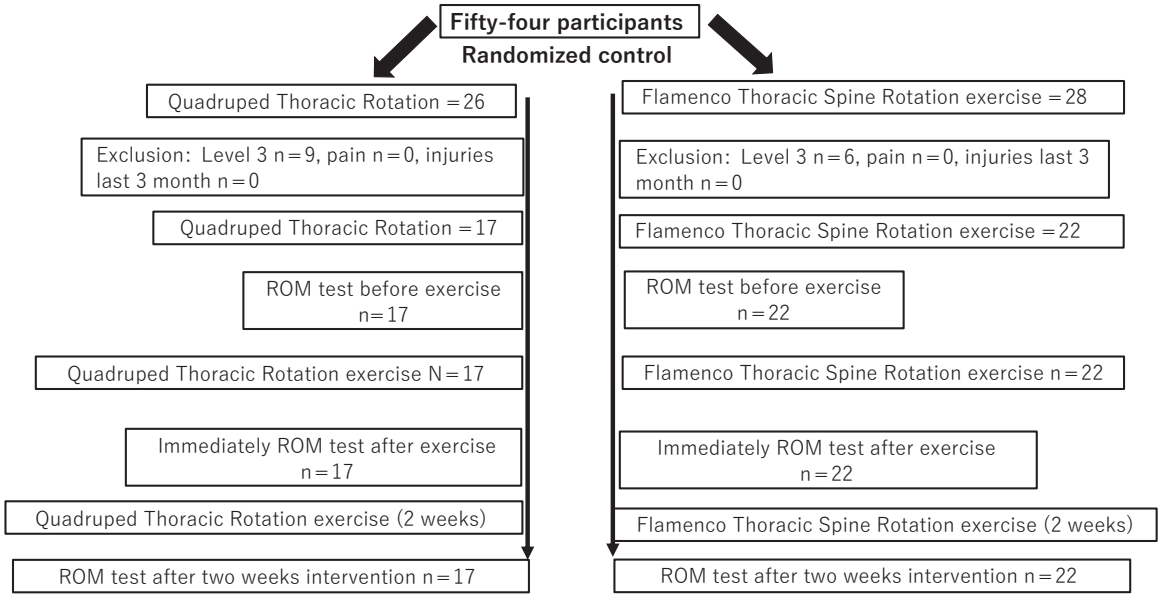
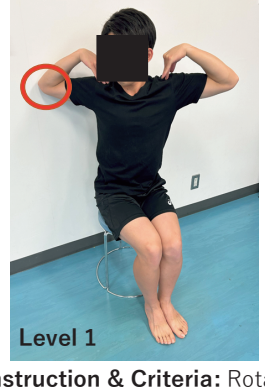
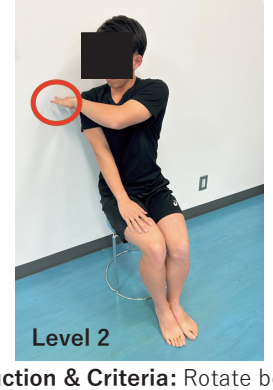


Fig. 1 Flowchart illustrating the procedures of this study.

Setup: Sit 2 knuckles away from wall with knees together
Movement: Thoracic spine rotation



Instruction & Criteria: Rotate body to reach towards wall. Can you touch wall with elbow while knees are together?
L) Yes: 1pt, No: 0pt
R) Yes: 1pt, No: 0pt



Instruction & Criteria: Rotate body to reach towards wall with opposite hand. Can you touch wall with hand by the shoulder while knees are together?
L) Yes: 2pt, No: 0pt
R) Yes: 2pt, No: 0pt

Instruction & Criteria: Rotate body. Can touch wall with an upper arm between shoulder and elbow while knees are together?
L) Yes: 3pt, No: 0pt
R) Yes: 3pt, No: 0pt

Fig. 2 Explanation of KOJI AWARENESS Thoracic Spine Mobility Test (LR total 6pt).

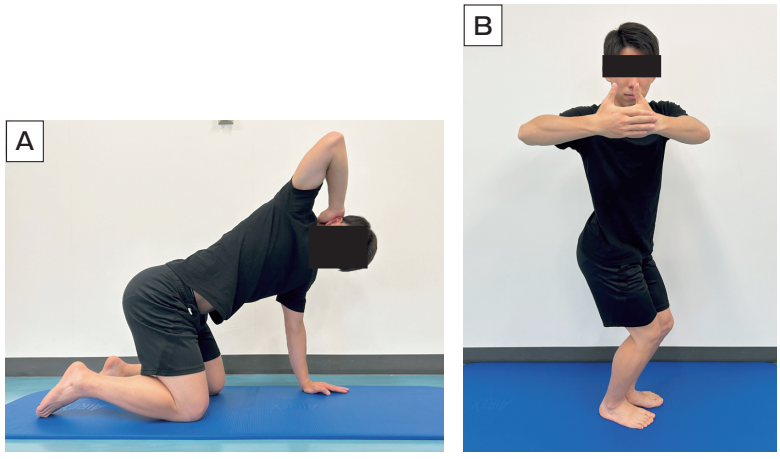


Fig. 3 Exercises performed in the present study. **A**, Quadruped Thoracic Rotation exercise (quadruped position); **B**, Flamenco Thoracic Spine Rotation exercise (standing position) from KOJI AWARENESS.

received instruction on the exercises and attended the fitness center for a technique assessment in the first exercise session by an Athletic Trainer Certified (ATC) [also certified by the Board of Certification, Inc. and for the FMS] after the first week of intervention.

After the first exercise session, the participants were assigned a 2-week exercise intervention to be completed at home, with sessions performed a total of six sessions at least 3 times per day. Each session consisted of three sets of eight repetitions. To track adherence to the exercise regimen, the participants were provided with a checklist and instructed to mark each completed session.

Both groups underwent the ROM test by an ATC three times: before and immediately after the first exercise session on the first day and a final time after the 2-week program.

The KOJI AWARENESS self-screening thoracic movement test. The KOJI AWARENESS Self-Screening Thoracic Movement test consists of three levels designed to assess thoracic spine mobility [13, 14] [we referenced this thoracic spine mobility screening information from the home page of the Japan Sports Agency website, YouTube <https://www.youtube.com/watch?v=1XfvF2KuKiY> (accessed November, 2023)]. Figure 2 shows the instructions for each level. The instructions for the Level 1 setup were as follows: Sit 2 knuckles away from the wall with the knees together and hands on shoulders with elbows in a straight line when viewed from the top; rotate the body to reach the wall with the elbow while keeping the knees together.

The instructions for the Level 2 setup were as follows: Sit 2 knuckles away from the wall with the knees together and rotate the body to reach the wall with the opposite hand; ensure that the touch is at shoulder height.

The instructions for the Level 3 setup were as follows: Place the knuckles away from the wall with the knees together, with the hands on opposite shoulders; set the elbows at shoulder height; and touch the wall with the upper arm between the shoulder and elbow, while keeping the knees together. Each participant was monitored by an ATC.

Thoracic spine rotation ROM test. For the Thoracic Spine Rotation ROM test, we chose the seated rotation test [15] (Fig. 4). For the setup, the hips and knees were placed at 90° with a ball (21-cm diameter) between the knees to minimize lower extremity movement during the examination. Bar-in-front position with arms crossed over the bar and in front of the chest. The goniometer (R-360-W International Goniometer; Tiger Medical Instruments, Osaka, Japan) was positioned parallel to the ground at the midpoint between the T1 and T2 spinous processes, with the spine of the scapula serving as the reference point. The stationary arm was oriented away from the side being measured, and it remained parallel to its initial position. The participants were instructed to maintain a forward gaze at an eye-level mark on the wall while rotating maximally to one side. The examiner closely monitored this motion using the moving arm of the goniometer. When the participants reached the end of their ROM, the goni-

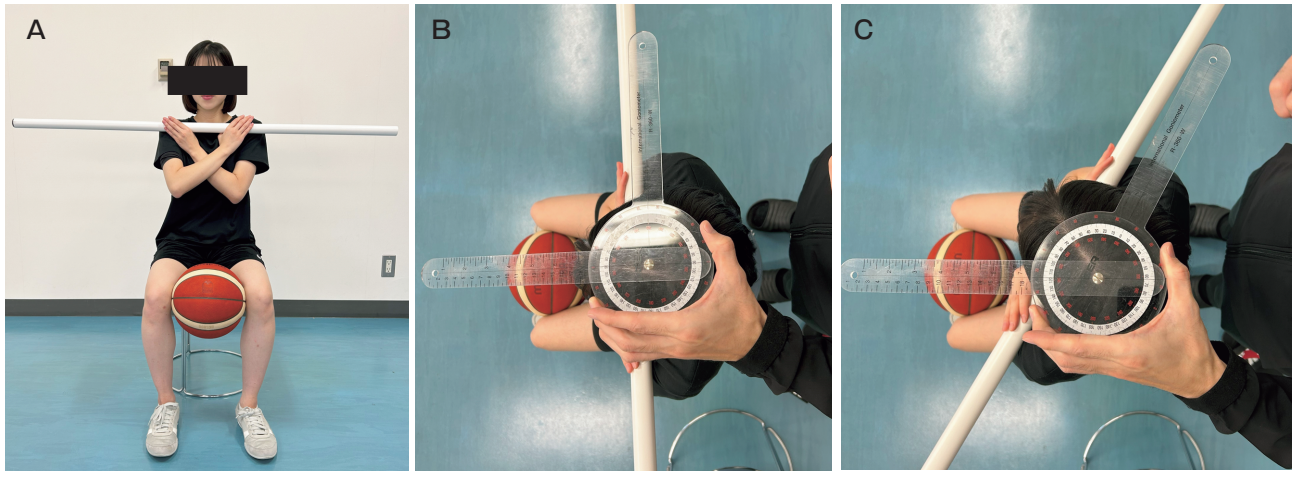


Fig. 4 Thoracic spine rotation ROM test. **A**, The hips and knees are at 90° with a ball placed between the knees. Bar-in-front position with arms crossed over the bar and in front of the chest; **B**, The goniometer is placed above the head parallel to the ground. The line perpendicular to the bar at the start position is the reference (the right rotation is shown); **C**, The mobile arm follows the rotary motion of the thoracic spine and remains parallel to the bar.

ometer's angle was fixed and the measurement was recorded. Each measurement was performed three times on both the right and left sides. The intraclass correlation coefficient was 0.87 [15]. In previous reports, the measured values were consistent with the standard values of thoracic spine rotational ROM, indicating the validity of thoracic spine rotational range of motion measurements [16, 17].

Quadruped Thoracic Rotation exercise. The Quadruped Thoracic Rotation is a quadruped thoracic spinal mobility exercise [10] (Fig. 3A). The instructions for this exercise were as follows: Begin in the quadruped position, aligning the knees under the hips and hands under the shoulders with a neutral spine; place one hand on the back of the neck without applying any pressure; rotate, leading with the eyes, head, and shoulder towards the hand, and then reverse the motion, maintaining alignment of the lumbar, thoracic, and cervical spines. After completing the exercise, the hand was returned to its start point in the full quadruped position. For this exercise, we referenced the information on the Functional Movement Screen website <https://www.functionalmovement.com/Exercises/30/quadruped_t-spine_rotation> (accessed November, 2023)].

Flamenco Thoracic Spine Rotation exercise. The Flamenco Thoracic Spine Rotation exercise is a KOJI AWARENESS corrective exercise that mobilizes the thoracic spine [11] [we referenced this corrective exercise information from a YouTube video on the Japan Sports Agency website, <https://www.youtube.com/watch?v=x2e9xHiW0gI> (accessed November, 2023)] (Fig. 3B). The exercise employs a reverse action method, requiring participants to engage in a cognitive task to maintain the shape of a circle formed with one arm while turning the lower body and creating torque to stretch the muscles of the thoracic spine and rib cage. The instructions for the exercise were as follows: Begin in a standing position, bend your knees and slightly lower your body; form a circle with your arm in front of you, parallel to the ground, and hold it in position; take a small step backward until you feel the maximum stretch, and then return with a small step forward, while maintaining the shape of the circle.

Statistical analyses. Statistical analysis was performed to assess the normality of the variable distributions using histograms and the Shapiro–Wilk normality test. Descriptive statistics are presented as means ± standard deviation for normally distributed variables and medians (interquartile range) for non-normally distributed variables.

Group differences in participant characteristics were analyzed using the non-paired *t*-test, Mann–Whitney *U* test, or χ^2 test. Two-way analysis of variance (ANOVA) was performed to analyze the improvement in ROM with two factors: group and period of measurement. Bonferroni's method was used as a post-hoc test for main effects and interactions.

IBM SPSS Statistics version 27 for Windows (IBM, Armonk, NY, USA) was used for statistical analyses, with the significance level set at 5%. For the Bonferroni method analysis of the main effects and interactions, the significance level was set at 0.6% with Bonferroni's adjustment.

Results

The demographic characteristics of the participants are presented in Table 1. There were no significant differences in demographic characteristics between the groups. A two-way ANOVA showed no interaction effects ($p = 0.655$). However, a main effect was found in the factor of period of measurement ($p < 0.001$), and the ROM immediately and 2 weeks after the intervention was significantly higher than that before the intervention in the post-hoc test (Table 2). In addition, the ROM 2 weeks after the intervention was significantly higher than that immediately after the intervention (Table 2). There was no main effect of group factor ($p = 0.013$, Table 2).

Table 1 Participant demographics

Status	Flamenco Thoracic Spine Rotation	Quadruped Thoracic Rotation	*P*-value
Gender, female : male	14 : 08	9 : 08	0.531
Age, years※	27.0 (9.8)	26.0 (8.0)	0.19
Height, cm	169.4 ± 8.7	167.0 ± 10.0	0.434
Weight, kg※	66.5 (25.8)	60.0 (14.0)	0.172
BMI, kg/m^2※	25.2 (6.6)	22.1 (3.2)	0.19

※Data are represented as median (interquartile range).

Discussion

This study aimed to assess the effectiveness of two thoracic spine exercises respectively performed in the quadruped and standing positions and how Quadruped Thoracic Rotation exercise affect thoracic spine mobility over a 2-week intervention period. The Quadruped Thoracic Rotation exercise was performed in the quadruped position and the Flamenco Thoracic Spine Rotation exercise was performed in a standing position; thus the exercises employed discrete strategies for achieving thoracic mobility. The results showed that both the Quadruped Thoracic Rotation exercise and Flamenco Thoracic Spine Rotation exercise realized an improvement in thoracic spine rotation range of motion over time, and there was no difference in the degree of improvement between them. Therefore, the results of this study supported our hypothesis.

Exercise and stretching can improve ROM. Overhead athletes with glenohumeral internal rotation deficits show improved glenohumeral IR ROM with stretching [18]. Dynamic hamstring stretching increases muscle flexibility, reduces muscle stiffness, and increases hip ROM [19]. A six-week home exercise program was reported to increase hip ROM in young men with limited hip mobility [20]. Therefore, in this study, we hypothesized that interventional exercises would improve thoracic rotational ROM.

Both of the exercises used here achieve their improvement in thoracic ROM through the combination of fixed upper or lower extremities and movement of the thoracic spine. However, they adopt different strategies. In the Quadruped Thoracic Rotation exercise, the lower extremities are fixed in the quadruped position while the upper extremities remain mobile,

Table 2 Changes in range of motion of thoracic spine rotation following intervention

	Pre-intervention	Post-intervention (immediately)	Post-intervention (2 weeks after)	Total	Main effect		Intreraction
					Group	Period of measurement	
Quadruped Thoracic Rotation	51.9 ± 6.8	60.0 ± 6.7	63.2 ± 10.1	58.4 ± 9.6	0.013	<0.001	0.655
Flamenco Thoracic Spine Rotation	47.6 ± 7.1	54.8 ± 7.3	60.2 ± 6.3	54.2 ± 9.1			
Total	49.5 ± 7.9	57.1 ± 7.8 †	61.5 ± 8.7 §,*				

†, Compared to Pre-intervention ($p < 0.001$); §, Compared to Pre-intervention ($p < 0.001$); *, Compare to Post-intervention (immediately) ($p < 0.001$).

allowing the thoracic spine to open and stretch. In contrast, in the Flamenco Thoracic Spine Rotation exercise performed in a standing position, the upper extremity is fixed by creating a circle with one arm parallel to the ground in front of the participant, and then the shape of the circle is maintained while the lower extremities are moved by the participant taking small steps to achieve a stretch. The Quadruped Thoracic Rotation exercise stabilizes and fixes the lumbar–pelvic complex, allowing movement of the thoracic spine, whereas the Flamenco Thoracic Spine Rotation exercise stabilizes and fixes the thoracic area and enables movement of the lumbar–pelvic complex. Thoracic stabilization exercise programs can effectively address postural pain, spinal misalignment issues related to core weaknesses, and balance disorders [21].

Combining postural perception with corrective exercise programs for thoracic kyphosis represents a comprehensive approach, and integrating postural perception training can enhance the effectiveness of the intervention [22].

However, there have been only limited studies on the improvement of thoracic rotational ROM by specific exercises. Therefore, this study contributes the novel finding that both of the examined exercises improve thoracic rotation ROM.

Clinical implications. The Flamenco Thoracic Spine Rotation exercise showed effectiveness equivalent to that of a well-known thoracic spine exercise, the Quadruped Thoracic Rotation exercise, and thus the Flamenco exercise could be a valuable option for athletes or patients seeking new exercises. This exercise is performed in the standing position, includes cognitive and reverse motion tasks, and is an exercise in a closed kinetic chain. On the other hand, the Quadruped Thoracic Rotation exercise is performed on an open kinetic chain. Therefore, the movement style is different between the two exercises. Since the degree of improvement in range of motion was comparable between the two exercise modalities, the practitioner may choose the most suitable program based on environmental or task-specific considerations. During the rehabilitation period following procedures such as ACL reconstruction or total knee replacement surgery, patients may experience pain in the surgical wound area, hindering their ability to assume a quadruped position. Additionally, individuals with shoulder issues such as osteoarthritis or rheumatoid arthritis may face difficulty accepting a quadruped position. The standing position adopted in thoracic exercises could present a new alternative for these cases.

Limitations. This study had some limitations. First, none of our participants were experiencing pain, and therefore were are unable to draw conclusions regarding the ability of the exercise to reduce pain. Second, the absence of a control group limited our ability to compare improvements with and without exercise intervention. Third, the study had a relatively short intervention period of 2 weeks, making it difficult to determine the long-term effectiveness of the exercises. Finally, we did not analyze differences in the degree of improvement in range of motion by gender. Future studies should consider these factors to further investigate the effectiveness of exercise interventions.

The Quadruped Thoracic Rotation exercise, performed in a quadruped position, and the Flamenco Thoracic Spine Rotation exercise, executed in a standing position, represent distinct approaches to thoracic mobility enhancement. However, the two exercises demonstrated equal effectiveness in improving thoracic mobility over a 2-week intervention period. This finding suggests that practitioners may choose any of these exercises based on environmental or task-specific considerations, thereby broadening the range of exercise options available for thoracic mobility enhancement. Notably, we only focused on rotational movement exercise and rotational ROM.

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