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Original Research Article

Relationship Between Thoracic Flexibility and Spinal Curvature During Trunk Extension in Healthy Adults

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ABSTRACT

Background: Non-specific lower back pain is a common medically and economically impactful condition that affects patients' quality of life.

Purpose: This study aimed to determine the relationship between thoracic expansion and spinal curvature angle during trunk extension in healthy participants.

Results: The participants comprised 24 men aged 18–21 years. The measurement items included the lateral and longitudinal diameters of the thorax, measured at the level of the xiphoid process and 10th rib, and spinal curvature angle, measured in the upright posture and trunk extension position. The difference in thoracic expansion levels during trunk extension tended to be greater in the lower thorax than in the upper thorax, with the lateral diameter higher than the longitudinal diameter. The inferior thoracic and lumbar curvatures increased with trunk extension. Regarding the relationship between the difference in thoracic expansion and the amount of change in the spinal curvature, the difference in the expiratory lateral diameter of the lower thorax during trunk extension was positively correlated with the superior thoracic curvature during trunk extension.

Conclusions: These results indicate that expansion of the lower thoracic lateral diameter increased the thoracic curvature during trunk extension exercises. Consequently, the lumbar curvature may be suppressed. Reduced lower thorax flexibility may enhance lumbar curvature during trunk extension. Therefore, flexibility of the lower lateral thoracic diameter may be a factor when preventing lower back pain.

KEY WORDS: Thorax, Lateral Diameter, Longitudinal Diameter, Trunk Extension, Chest Griping.

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INTRODUCTION

Non-specific low back pain (NLBP) is a common disorder and one of the most medically and economically impactful health problems [1].

The site of NLBP can be categorized as myofascial, discogenic, or intervertebral joints. The causes are related to the mechanical stress caused by movement. Thus, it is important to understand the kinetic characteristics of the spine, including the lumbar-pelvic rhythm (LPR), to elucidate the mechanism of mechanical lower back pain [2]. LPR occurs during trunk extension and flexion [3]. When the LPR pattern is interrupted, mechanical stress on the lumbar region increases, which can cause lower back pain [2].

Shortening of the iliopsoas, rectus femoris, and psoas muscles during trunk extension movements limits hip extension, resulting in compensatory enhancement of the lumbar lordosis. In addition, shortening the lower extremity muscles causes hypermobility of the pelvis, subsequently causing lower back pain [4,5].

A phenomenon called 'chest gripping' has been reported in relation to lower back pain, which is associated with reduced thoracic flexibility [6]. Chest gripping is a phenomenon in which the trunk flexors' flexibility is reduced, resulting in narrowing of the infrasternal angle. This phenomenon may result in excessive curvature of the lumbar spine and increased mechanical stress as the inferior thoracic spine limits the extension motion during trunk extension. Thus, reduced thorax flexibility may limit thoracic spinal extension and cause lower back pain. Therefore, it is important to clarify the effects of thoracic extension on spinal column motion during trunk extension. Regardless, it is unclear how thorax flexibility during trunk extension is related to the movement of the thoracic and lumbar spine.0

This study aimed to clarify the relationship between spinal curvature and thoracic flexibility during trunk extension in healthy participants. In particular, we focused on the difference between the longitudinal and lateral diameters of the thorax during extension and examined its relationship with the spinal curvature.

In the present study, thoracic flexibility was measured by expansion in two directions, namely the transverse and longitudinal diameters. In previous studies, thorax flexibility was studied by measuring thorax circumference using a tape measure [7,8]. Nevertheless, the previous measurement method does not allow us to determine in which direction the thorax flexibility is limited. The method used in this study can reveal the direction of thorax dilation restriction. This is expected to lead to the consideration of intervention methods in the direction of the problem.

METHODS

Participants: The 24 study participants comprised healthy men (Table 1). The inclusion criteria were as follows: (1) patients with no history of back pain within the past month and (2) no history of surgery for orthopedic diseases. Exclusion criteria were as follows: (1) patients with marked idiopathic scoliosis or thoracic deformities, (2) obesity, and (3) self-reported persistent extremity pain during measurement.

All relevant ethical considerations were adhered to. Oral and written informed consent was obtained from the participants before they participated in the study. The study was conducted in accordance with all the guidelines of the Declaration of Helsinki. This study was approved by the Ethics Committee of Kyoto Tachibana University (approval No. 17-01).

Procedures: The following items were measured: 1) thoracic flexibility; 2) spinal curvature angle; and 3) physical functions. All measurements were performed on the same day.

Thoracic flexibility: Thoracic flexibility was measured using a thorax dilatometer (GLAB Co., Ltd.) (Figure 1) [9]. This device measures the anteroposterior and lateral sides of the thorax and can measure the longitudinal and lateral diameters of the thorax. The height of the thorax was measured at the following two points: the sternal xiphoid process (upper thorax) and the 10th rib (lower thorax).

The measurements were taken under the following conditions: 1) during inspiration and expiration in the upright position and 2) during expiration in the trunk extension position. The lateral and longitudinal diameters of the thorax were measured to the nearest 1 mm. The longitudinal and lateral thoracic expansion differences were calculated from the measurements obtained in the upright and trunk extension positions. Three measurements were obtained at each limb position and site, and the mean value was used as the representative value.

Spinal curvature angle: The spinal curvature angle was measured using the Spinal Mouse (Index Co., Ltd.) to measure the thoracic, lumbar, and sacral tilt angles. The examiner placed the tracking wheel of the spinal mouse on the spinous processes from the seventh cervical vertebra (C7) to the first sacral vertebra (S1) and moved the wheel from head to coccyx to obtain measurements. After sufficient practice, the measurements were performed thrice by a physiotherapist.

The measurements were taken under the following conditions: (1) in the resting standing position, followed by (2) maximum extension of the trunk in the standing position.

In the resting standing position, the participant was barefoot with their feet shoulder-width apart and the hip and knee joints extended. Participants were instructed to gaze at a marker attached to a wall 3 m in front of them. They also held their hands behind their heads. For the trunk extension position, the participants extended their trunks from a standing position with the neck in a neutral position. The patients were careful not to bend the knee joint during the procedure.

The curvature angles for the thoracic (Th1/2 to Th12/L1), superior thoracic (Th1/2 to Th6/7), inferior thoracic (Th7/8 to Th12/L1), and lumbar spines (L1/2 to L5/S1) were calculated. To understand the influence of trunk extension, the extent of change from the standing position to the trunk extension position was calculated. The resting standing position was used as the neutral position. The directions of curvature for extension and flexion were positive and negative, respectively.

Physical functions: We measured the upper body deflection height and hip extension range of motion (ROM); these were considered the physical functions.

The upper body deflection height was measured using an analog upper-body deflectometer (TKK5004, Takei Instruments Co., Ltd.). The distance from the floor to the lower edge of the chin was measured when the trunk was stretched with maximum effort in the supine position. Hip extension ROM was measured passively using the method described by the Japanese Society of Rehabilitation Medicine [10]. Measurements were performed once on each side using a goniometer. The mean values of the left and right sides were used as the representative values.

Data analysis: The changes in lateral and longitudinal diameters while in the upright position at rest and trunk extension were compared using two-way analysis of variance with two factors. The factors were the direction of thoracic expansion (lateral and longitudinal diameters) and the measurement site (upper and lower).

Correlation coefficients between the curvature angle of each spine region (superior thoracic, inferior thoracic, and lumbar spine) and various body functions, including thoracic extension difference, were determined. In addition, partial correlation coefficients adjusted for age, height, and weight were used

upright position

trunk extension position

Fig. 1: Example measurement using the thorax dilatometer.
The lateral and longitudinal diameter were measured in upright position (left) and trunk extension position (right)

to determine the relationship between regional curvature, thoracic dilation difference, and physical functions.

To investigate the factors that affect each part of the spine curvature, a multiple regression analysis was performed with the spinal curvature angle of each part as the dependent variable. The other spinal curvatures, thoracic extension differences, and other measurements were the independent variables. In accordance with previous studies, the variable selection was conducted in advance using univariate analysis. Only independent variables with a significance level of <0.20 were entered into the multiple regression model for analysis. Statistical analysis was performed using the statistical software package SPSS for Windows (IBM SPSS Statistics ver24). The statistical significance level was set at 5%.

RESULTS

The values for thoracic circumference are presented in Table 2. During inspiration in the upright position, the circumferential diameters of the upper and lower thorax tended to be greater in the lateral diameter than in the longitudinal diameter (p=0.001).

The circumferences of the upper and lower thorax in the upright and trunk extension positions during expiration also showed a similar phenomenon (p=0.001).

The data for thorax dilation differences are presented in Table 3. No significant changes were observed in the longitudinal or lateral diameters of the upper and lower thorax in the upright position. In contrast, in the trunk extension position during expiration, the lower thorax expanded more than the upper thorax. Notably, the lateral diameter of the lower thorax tended to expand significantly (p=0.009).

The data for spinal curvature angle are presented in Table 4. In the upright posture, the superior and inferior thoracic spines were curved backward and the lumbar spine forward. During trunk extension in the standing position, the backward curvature angle of the superior thoracic spine remained unchanged. The backward curvature of the inferior thoracic spine and forward curvature of the lumbar spine increased with trunk extension.

The data on the correlation analysis between the thorax flexibility and spinal curvature angle

Table 1: Characteristics of participants.

	Mean (SD)	Range
Age (years)	20.5 (1.1)	18—21
Height (cm)	172.7 (4.8)	163.5—181.7
Weight (kg)	63.3 (5.7)	51.4—73.7
BMI (kg/m²)	21.2 (1.8)	18.5—24.9
Hip Ext ROM (°)	21.7 (5.4)	15.0—30.0
Flexibility of trunk extension (cm)	41.8 (10.9)	23.0—66.5

SD, standard deviation
ROM, range of motion

Table 2: Measured values of thorax circumference.

Position	Condition	(Region) Upper thorax (direction) Lateral diameter (cm)	Upper thorax Longitudinal diameter (cm)	Lower thorax (direction) Lateral diameter (cm)	Lower thorax Longitudinal diameter (cm)
Upright	Max-Insp[a)]	32.9 (2.1)	20.4 (1.8)	26.9 (1.5)	19.2 (1.9)
	Max-Exp[b)]	31.8 (2.0)	18.9 (1.8)	25.8 (1.5)	18.0 (1.7)
Trunk extension	Max-Exp[c)]	31.8 (1.8)	18.5 (1.8)	26.8 (1.5)	18.2 (1.8)

Max-Insp, Maximum inspiration; Max-Exp, Maximum expiratory; Mean (SD); n=24
a) Interaction: p<0.01, F=40.3. Main effects (region): p<0.01, F=91.1
Main effects (direction): p<0.01, F=729.9
b) Interaction: p<0.01, F=48.5. Main effects (region): p<0.01, F=89.6
Main effects (direction): p<0.01, F=843.8
c) Interaction: p<0.01, F=42.5. Main effects (region): p<0.01, F=57.6
Main effects (direction): p<0.01, F=965.70000

Table 3: Difference in thoracic circumference during upright and trunk extension positions.

Position	Condition	(Region) Upper thorax (Direction) Lateral diameter (cm)	Upper thorax Longitudinal diameter (cm)	Lower thorax (Direction) Lateral diameter (cm)	Lower thorax Longitudinal diameter (cm)
Upright d)	**Insp-Exp**	1.11 (0.46)	1.51(0.60)	1.05 (0.50)	1.21 (0.49)
Trunk extension e)	**Max-Exp**	0.01 (0.77)	-0.33 (0.59)	1.00 (0.70)	0.19 (0.78)

Mean (SD)
d) Interaction: p=0.28, F=1.20
Main effects (region): p=0.08, F=3.10 Main effects (direction): p=0.09, F=7.22
e) Interaction: p=0.11, F=2.61
Main effects (region): p<0.001, F=27.0 Main effects (direction): p<0.001, F=15.6

Table 4: Spinal curvature angle in the standing position.

		(Position) Upright	Trunk extension	Difference
(Level)	**Superior thoracic (°)**	12.4 (6.8)	11.9 (8.2)	-0.5(6.2)
	Inferior thoracic (°)	14.1 (4.3) *	19.8 (6.1)	5.3(6.2)
	Lumbar (°)	-15.6(6.3) *	- 28.3(9.6)	-12.7 (8.1)

Mean (SD), n=24000
Interaction: p<0.001, F=20.7
Main effects (level): p=0.046, F=20.7 Main effects (position): p=0.69, F=0.22
* p<0.05; Upright vs Trunk extension

Table 5: Correlation between the change in the thorax and curvature angle of spine during trunk extension.

Position	Level	Upper thorax Lateral diameter	Upper thorax Longitudinal diameter	Lower thorax Lateral diameter	Lower thorax Longitudinal diameter
Upright	**Superior thoracic (°)**	0.039	0.26	0.496*	0.286
	Inferior thoracic (°)	0.086	0.095	-0.219	0.017
	Lumbar (°)	-0.016	0.223	-0.063	0.001
Trunk extension	**Superior thoracic (°)**	-0.01	0.125	0.453*	-0.045
	Inferior thoracic (°)	0.239	0.293	0.142	0.135
	Lumbar (°)	0.193	0.172	0.093	0.17

∗p<0.05; Lateral diameter vs Longitudinal diameter

are presented in Table 5. In the lower thorax lateral diameter, the thoracic extension difference in the upright position and amount of change in the thorax during trunk extension were positively correlated with the superior thoracic curvature angle.

DISCUSSION

This study aimed to determine the relationship between thoracic flexibility and spinal curvature angle during trunk extension movements. Twenty-four healthy participants participated in this study. Thoracic flexibility was investigated by measuring the longitudinal and lateral diameters of the upper and lower thorax. The spinal curvature angle was measured during resting standing and trunk extension. The results showed that the difference in the lateral diameter of the lower thoracic extension was greater than that of the longitudinal diameter during trunk extension. Furthermore, the difference in the lateral diameter of the lower thoracic dilation was found to be a compensatory movement of the superior thoracic curvature in the resting standing and trunk extension positions. These results indicate that thorax flexibility should be considered when evaluating spinal curvature. Limited lower thorax dilation may be involved in the onset of extensional lower back pain.

Differences in the direction of thorax dilation during trunk extension: The lower thorax expanded more than the upper thorax during trunk extension during expiration. In particular, the lateral diameter of the lower thorax increased. Notably, the lower thorax is structurally attached to the sternum via costal cartilages and is more flexible than the upper thorax [11]. In addition, the ribs expanded outward and upward in the lower thorax. Thus, the lower thorax was more likely to expand in the lateral diameter than the longitudinal diameter. Therefore, thorax dilatation was considered to significantly increase the lateral diameter compared with the longitudinal diameter.

Furthermore, Ichinose et al. [12] reported that a greater lateral diameter of the lower thorax during extension exercises results in a greater trunk extension ROM. We suggest that improving the flexibility of the lower thorax in the lateral direction during trunk extension may be an important factor in facilitating trunk extension movements. Particularly, participants with extension-type lower back pain may have reduced flexibility of the lateral diameter of the lower thorax, and this may be an indicator that should be evaluated.

Spinal curvature angle: The results of this study showed an increase, not a decrease, in the inferior thoracic curvature during trunk extension. Several studies have reported that lumbar spine curvature is increased, and thoracic spine curvature is decreased, by the kinetic chain when the trunk is extended [13,14], which is inconsistent with the results of the present study. One of the reasons for this is the difference in measurement methods. Narimani and Arjmand [15] reported that they measured the spinal curvature by placing the upper extremities in a free position during trunk extension from the upright position. On the other hand, in the present study, the upper limbs were raised with both hands crossed at the back of the head and the cervical vertebrae in the mid-position, which made thoracic extension unlikely to occur. This may have resulted in a lack of extension of the inferior thoracic spine.

Relationship between thoracic extension difference and spine curvature angle: The lateral diameter of lower thoracic dilation was correlated with the superior thoracic curvature in the upright and trunk extension positions. Lee [11] reported that the lower thoracic cage extended upward during trunk extension. Lower thoracic flexibility may have compensated for thoracic spinal motion as lower thoracic lateral diameter expansion did not decrease the superior thoracic curvature angle.

Limitations: This study had some limitations. First, the participants were healthy, male adults. Hence, future research is needed to include participants from different age and sex groups and those with lower back pain. Second, there were methodological limitations. The participants performed trunk extension movements with their hands folded behind their heads while using the thorax dilatometer. This may have affected the differences in the superior thoracic curvature and upper thoracic dilation.

CONCLUSION

In this study, we found that the lower thorax dilated during trunk extension and the amount of change in the thoracic dilation difference during trunk extension is positively correlated with the superior thoracic curvature angle. In the present study, the lower thorax extended laterally during trunk extension in normal subjects. This phenomenon may be involved in extension-type lower back pain. Future studies are necessary to examine the relevance of the mechanism of onset of extension-type lower back pain.

ABBREVIATIONS

LPR - lumbar-pelvic rhythm

NLBP - non-specific low back pain

Conflicts of interest: The authors declare that they have no competing interests.

Author Contributions:

Yokoyama and Nejishima were involved in study design and data interpretation.

Higuchi and Ishino were involved in the data analysis.

All authors critically revised the report, commented on drafts of the manuscript, and approved the final report.

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