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Original Article

Relationship between asymmetric trunk flexion movement and elector spinae muscle activity

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Abstract. [Purpose] To clarify the relationship between asymmetric trunk flexion movement and erector spinae (ES) muscle activity using a three-dimensional motion analysis system and surface electromyography. [Subjects and Methods] The subjects comprised 14 healthy individuals. Angles of trunk flexion, rotation, and side bending were measured using a three-dimensional motion analysis system attached to the trunk and pelvic segment. Activities of the ES muscle on both sides at the L1 and L4 levels were measured using surface electromyography. [Results] In healthy individuals, the ES was more markedly activated in the trunk extension phase than in the trunk flexion phase. There was no significant difference in terms of the extent of trunk rotation and trunk side bending during these tasks. [Conclusion] This study did not clarify the relationship between asymmetric movement during trunk flexion and ES activity.

Key words: Flexion relaxation phenomenon, Three dimensional motion analysis system, Surface electromyography

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INTRODUCTION

In modern society, a large number of individuals have low back pain (LBP), which negatively influences their activities of daily living. In particular, non-specific LBP with no imaging findings is the most common diagnosis in patients with LBP. LBP is considered the result of accumulation of microscopic damage to robustness of the lumbar spine like joint capsules or muscles[1]. Both prevention of non-specific LBP and guidance on appropriate movements while performing activities of daily living are needed. It is also necessary for physical therapists to be able to use non-invasive methods to identify causative factors of the pain.

The flexion-relaxation phenomenon (FRP) is the myoelectric silencing of a muscle during full flexion movement[2]. The FRP of the ES muscles was reported to show silencing during full flexion lumbar movement in asymptomatic subjects; this phenomenon involves the transfer of the role of the extension moment producer to the deep back muscles to achieve spinal stability[3]. On the other hand, in patients with LBP, there is a laxity of structures and altered neuromuscular activation pattern that is often found in the back muscles, in which the FRP of the ES muscles is not present. Therefore, the FRP of the ES muscles has been used to evaluate LBP and monitor intervention-related factors after treatment[4] and it is especially useful to evaluate for non-specific LBP.

In previous studies, it was reported that FRP occurred with full lumbar flexion in the sagittal plane. However, lumbar flexion is thought to be an asymmetric movement combined with lateral bending and axial rotation, and there is very much a possibility that healthy individuals with no LBP would have right and left asymmetry in the FRP of the ES muscles due to repetitive movements and poor posture in their daily work environment or while performing activities of daily living. Jin[4] reported that asymmetric lumbar flexion elicits a loss of FRP in the ipsilateral muscle in symptomatic subjects. Although 90%

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of non-LBP subjects show FRP, many of them would be at risk of LBP due to asymmetry in the FRP of the ES muscles[3, 6].

The aim of this study was to clarify the relationship between asymmetric trunk flexion movement and ES muscle activity using a three-dimensional motion analysis system and surface electromyography.

SUBJECTS AND METHODS

Subjects were 14 healthy individuals (seven males and seven females; mean age ± standard deviation: 24.5 ± 0.8 years). The subjects had no history of injury or physical functional impairment that could have rendered stoop lifting difficult, and they had no current LBP. All subjects provided informed consent before participating in the experiment. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later revision. And also, this study has been approved by research ethics committee of Takasaki University of health and welfare (Permission number: 2819).

Subjects performed trunk-forward bending movements with their elbows and knees extended. They stood with their feet width 10% of their total height. Phase definition for trunk flexion in the standing position decide by kinematic data measured in below task. For dynamic capture, subjects were required to stand in a neutral position for 2 s and then flex forward with their arms dangling freely for 4 s (flexion phase). They were instructed to hold the fully flexed position for 4 s and were then instructed to return to the neutral standing position for 4 s (extension phase). During all tasks, the movement rhythm was set at 60 bpm using a metronome. After sufficient practice time, subjects performed the exercise three times, and the mean values of the three trials were used for data analysis. A three-dimensional motion analysis system (VICON, Oxford Metrics Ltd., Oxford, The United Kingdom) was used to record kinematic data in whole phases. Kinematic data were collected using 6 motion capture cameras that sampling frame is at 60 Hz. A total of nine infrared reflective markers placed at acromion, the edge of the iliac crest, both sides of the greater trochanters, the outside cleft of the knee (both sides), and C7 spinous projection[9]. Data collected were used to calculate trunk flexion angle, trunk and pelvis rotation angle, and the extent of lateral displacement of the acromion and pelvis. Surface electromyograms (EMG) were also recorded in whole phases using a multi-channel telemetry system (WEB-7000, Nihon Kohden Corp., Tokyo, Japan), an EMG transmitter (ZB-150H, Nihon Kohden Corp., Tokyo, Japan), and a receiver (ZR-700H, Nihon Kohden Corp., Tokyo, Japan). The raw signal was amplified and the band-pass was filtered (15–500 Hz), digitized at 1,000 Hz, and stored for offline analysis on the laboratory computer. After cleaning the subjects' skin with alcohol, electrodes were placed over the ES muscles at L1 and L4 levels on both sides and laterally 2 cm apart from the center of the gluteal fold[2]. Before the task, maximal strength of the ES muscles was assessed using manual muscle testing methods, and the data were used to calculate FRP. Muscle maximum voluntary contraction (MVC) was measured at the same time. The volume of muscle activity during the task was divided by the MVC, and the calculated data were represented in the analysis as %MVC. A threshold level of 10% of MVC was used to initially determine the beginning (EMG-ON) and the end (EMG-OFF) of the myoelectric activity. After that, sampling data are analyzed in two way, subjects divided into two groups according to their trunk position in maximum trunk flexion phase.: subjects rotate to the left side when they flex their trunk (Rot to L group) and subjects rotate to right side when they flex their trunk (Rot to R group). Another one way is that subjects divided into two groups: subjects bending to the left side when they flex their trunk (Bend to L group) and subjects bending to the right side when they flex their trunk (Bend to R group).

Statistical analyses were performed using IBM SPSS Statistics (Version 22) for Windows. Values of the %MVC of the ES muscles on the right and left sides were compared. Subjects were then divided into two groups according to the direction of trunk rotation and lateral displacement during the trunk flexion task. In these groups, correlation between the angle of trunk rotation or the extent of lateral displacement and the %MVC of the ES muscles was evaluated using Spearman's rank correlation coefficient.

RESULTS

FRP was observed in ES muscles at L1 and L4 levels in 85.7% of the subjects and no FRP was observed at either level in the others. These no FRP subjects were excluded from subsequent analysis. There were no significant gender differences in the range of trunk flexion at EMG-off or EMG-on (EMG-off: male 53–62°, female 85–89°; EMG-on: male 92–96°, female 85–89°). In males, there was a larger volume of muscle activity in the extension phase than in the flexion phase at both sides L4. However, in terms of muscle activity at L1 level, there was no significant difference. In females, there was a larger volume of muscle activity in the extension phase than in the flexion phase at L1 level. On the other results, there was no significant difference, but there were trend that larger extension phase than flexion phase (Table 1).

There was no significant difference, when they divided two groups (Rot to L group and Rot to R group), (Table 2). In the Rot to R group, there was a correlation between the extension phase's movement of rotation and the activity of the ES muscle (r=0.963, $p<0.05$).

Subjects divided another two groups (Bend to L group and Bend to R group), but Bend to R group comprised only two subjects and we cannot analyze statistically, so only Bend to L group was considered (Table 3). At EMG-off, there was no correlation, but at EMG-on, there was a correlation between the activity of the ES muscles and the range of trunk side bend-

Table 1. Volume of muscle activities with each position (%MVC)

			Measurement position		
			Flexion phase	Extension phase	
Males	L1	Left	30.22 (6.31)	37.50 (8.09)	
		Right	27.48 (5.01)	36.19 (12.14)	
	L4	Left	30.07 (12.08)	54.38 (18.18)	**
		Right	24.18 (10.09)	45.87 (15.06)	**
Females	L1	Left	19.66 (2.07)	43.45 (11.16)	**
		Right	33.01 (18.39)	50.80 (15.06)	
	L4	Left	38.43 (10.71)	58.19 (6.01)	*
		Right	32.23 (9.22)	56.56 (16.88)	*

Mean (Standard Deviation), **$p<0.01$, *$p<0.05$.

Table 2. Relationship between the movement of rotation and the activities of the ES muscles

		Integral values of %MVC	
		Flexion phase	Extension phase
Rot to L group (n=7)	L1 left	0.325	−0.406
	L1 right	−0.190	−0.666
	L4 left	0.515	0.115
	L4 right	0.602	−0.457
Rot to R group (n=5)	L1 left	0.337	0.963*
	L1 right	0.842	0.410
	L4 left	−0.669	0.211
	L4 right	−0.798	0.195

R-value, *$p<0.05$.

Table 3. Relationship between trunk side bending and activities of the ES muscles

	Angle of trunk flexion defined by ES muscle activities	
	EMG-off	EMG-on
L1 left	0.465	0.685*
L1 right	0.332	0.727*
L4 left	−0.395	0.766*
L4 right	−0.189	0.682*

R-value, *$p<0.05$.

ing. These are positive correlations, the greater the lateral bending, the earlier the muscular activities of ES muscles start in trunk extension phase.

DISCUSSION

This study measured FRP with the movement of trunk flexion, and the FRP was observed in ES muscles at L1 and L4 levels in 85.7% of the subjects and no FRP was observed at either level in the others. In previous studies, the incidence of FRP in healthy subjects were 95–100% in ES muscles at L1 level[5], 83–100% at L3 level[6], and 83–100% at L5 level[5]. The incidence of FRP in this study was consistent with that of previous studies. There were no significant gender differences in the range of trunk flexion at EMG-off or EMG-on (EMG-off: male 53–62°, female 85–89°; EMG-on: male 92–96°, female 85–89°). During the trunk flexion task, the ES muscles work to coordinate the velocity of the movement of trunk flexion and stabilization of the spinal column[7, 8]. With regard to the present results, the activity of the ES muscles disappears at 40–60° of trunk flexion, which angle is load by the gravity, so it has influenced from the robustness of stabilization a lot. In the extension phase, there was a positive correlation between the movement of side bending and the range of trunk flexion. There was no correlation between the integral values of %MVC and the movement of side bending. It can be said that the greater the movement of side bending, the earlier the activity of the ES muscles begins. The most functional disorders of the spine are caused by the poor alignment of the vertebral column, instability, or poor patterns of movement[10]. Patients with LBP have sustained contraction of the ES muscles because their movements are always asymmetric. In this study, I included no subjects with LBP, but non-FRP (14.3%) subjects had sustained contraction of the ES muscles. Thus, it would seem that asymmetric movements cause sustained contraction of the ES muscles.

One method to measure trunk flexion movement was to mix range of trunk flexion and hip flexion, so it may be affected by the activity of the other muscles. Thus, in the next study, we will measure each and consider the effect of the movement of the hip on FRR of the ES muscles.

Conflict of interest

The authors have no financial or personal conflicts of interest to declare.

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