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Change in onset times of the abdominal muscles following functional task in lumbar spinal stenosis

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The purpose of this study was to investigate the difference in the onset times of the abdominal muscle following a rapid arm task in lumbar spinal stenosis (LSS). In total, 32 patients with LSS were recruited from W oriental hospital. Muscle activity onset of the internal oblique (IO) and external oblique (EO) muscles was measured by electromyography (EMG) activity with a rapid arm movement and during the performance of a walking task. The LSS group demonstrated a significantly later onset of the IO, EO, and rectus abdominal (RA) muscles than the normal group. The deltoid reaction time of the normal group demonstrated significantly earlier activations of IO and EO, while the deltoid reaction time of the LSS group demonstrated significantly delayed activations of IO and RA. The EMG measurements of the IO, EO, and RA muscles while standing and walking were reliable and they offer empirical information about the trunk muscle activation of LSS patients.

Keyword: Electromyography, Lumbar spinal stenosis, Onset time

INTRODUCTION

Lumbar spinal stenosis (LSS) is one of the most commonly diagnosed spinal disorders in older adults. Although the pathophysiology of the clinical syndrome is not well understood, a narrow central canal or intervertebral foramen is an essential or defining feature (Battie et al., 2014) The disease often takes the form of a degenerative arthritic disease of the spine, which is often associated with significant functional limitations in walking, as well as disabilities (Winter et al., 2010). Although LSS is not life threatening and there is no established cause, LSS has been associated with neurogenic disorders of the paraspinal muscles, as measured by stretch reflex responses (Arbit and Pannullo, 2001). Numerous studies have demonstrated alterations in trunk muscle constitution or structure, function, and control at the concave side of the thoracic curve. Biopsy studies have shown abnormalities in the paraspinal muscles of LSS subjects concerning their architectures (Sihvonen et al., 1993).

Using a biomechanical model of the trunk, Schultz et al. demonstrated that the recruitment of muscles from the convex side of the lumbar curve could have a beneficial effect on back pain by reducing its amplitude (McAfee et al., 2007). Asymmetries in EMG recordings have been reported (Hodges et al., 1999; Park and Yu, 2013) to change in the reflex responses of paravertebral muscles (Colloca et al., 2003; Egli et al., 2007). An etiologic concept linking an axial impaired motor control system to the structural deformity of LSS is proposed. Postural studies reveal that during a quiet stance, adaptation is indicated by conditions associated with visual control of sway, particularly of lateral sway; during imposed perturbations of the body, destabilized postural reactions are pronounced in tests requiring visual-vestibular coupling (Malmivaara et al., 2007).

However, little is known about the strategies used by the central nervous system to control the motors of LSS. The contemporary study focuses on a feedback mechanism, namely the reflex contraction of back muscles in response to forward trunk displacement. Delayed trunk muscle reflex latencies have been shown in subjects with LSS in response to sudden unexpected perturbations. We hypothesized that we would find differences between LSS patients and the controls regarding delayed feed-forward activation of the trunk muscle during arm movement and changes in muscle acti-

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vation during walking.

The aim of this study was tantamount to investigating abdominal muscle activation patterns of the differences in trunk muscle onset timing between subgroups of LSS patients and asymptomatic controls.

MATERIALS AND METHODS

Subjects

In total, 32 subjects (12 males, 20 females) with a mean (SD) age, height, weight, duration, and visual analogue scale (VAS) of 55.5 (7.2) years, 162.2 (4.9) m, 55.8 (3.2) kg, 87.2 (8.4) months, and 4.8 (3.7), respectively, participated in the study. LSS patients had previously been screened and diagnosed by an orthopedic surgeon. No patient was under active treatment, none had surgery before, and no patient presented any neurological signs of pathological importance to the clinical examination. Subjects were eligible if they were at least 50 years old; had LSS syndrome defined as anatomical signs of spinal canal narrowing, as viewed by magnetic resonance imaging; were fluent in English; had associated clinical symptoms of current pain in the back and/or one or both legs diagnosed as neurogenic claudicating or chronic nerve root compression; and had symptoms for at least 6 months with an insidious onset.

Electromyography measurement

The electromyography (EMG) activity of the trunk and arm muscles was recorded utilizing intramuscular fine-wire and surface electrodes. Pairs of surface electrodes (10 mm diameter Ag/AgCl discs, inter-electrode distance of 20 mm, Grass Telefactor, USA) were placed over the oblique internus (OI) abdominal, the oblique external (OE) abdominal, and the rectus abdominal (RA) muscles, respectively, and over the muscle bellies of the right anterior muscles (Hall et al., 2009). The skin was prepared, and the electrodes were aligned parallel to the muscle fibers and placed in accordance with previous studies demonstrating that these placements maximize the signal-to-noise ratio related to the levels of cross-talk. EMG data were pre-amplified 1,000 times, further amplified two times, and band pass filtered at 60 Hz.

Rapid arm movement

Subjects performed rapid arm movements, and self-paced walking tasks were carried out after two practice trials to allow for adjustments in the direction and speed of the arm movements and walking. Because of reported differences in onset times and patterns between slow and fast movements, all tasks were performed on a verbal command in a randomized order.

Five right arm repetitions were collected and averaged to provide the latency data for each movement direction of each subject. Any right arm movements to a left arm verbal command were not used, as these could not be considered a random response.

In response to an auditory signal, subjects stood in a relaxed standing position and rapidly flexed their arms unilaterally at the shoulders to 60° as fast as possible while standing. Distinct tones indicated movement direction, and the order and timing of the auditory tones were randomized to limit the predictability of the task. Ten repetitions of the flexion were completed, as this number of trials has been demonstrated to optimize repeatability of the data (Marshall and Murphy, 2003).

Ten-meter walking task

Participants walked across a 10-m walkway at their preferred walking velocity four times before and after each fatigue session. Consistency at the beginning of the walking period was ensured, as each individual initiated a walking gait with his or her same foot in each trial. Participants performed all trials barefoot to control for footwear influences. Abdominal muscle EMG was recorded during self-paced walking. This task was repeated four times (Saunders et al., 2004).

Data analysis

Onset of EMG activity was identified visually without reference to the identity of the muscle, direction of the movement, or the time of the test, as well as to whether the data were from trials. Visual identification has been shown to be reliable and is preferred to computer-based methods, as it is less affected by factors such as amplitude of background EMG or the rate of increasing activity. The onset of trunk muscle EMG was calculated relative to that of the deltoid (Cowan et al., 2001). The task involved a rapid arm raise on a visual trigger before and after a back-extension fatiguing task.

Statistical analysis

Means (SD) were determined and used to derive the coefficient of variation (CV) for the baseline amplitude data. The deltoid onset time (time from the auditory stimulus to anterior deltoid onset) during rapid arm movement and the mean (SD) during walking were compared utilizing an analysis of variance (ANOVA). Between-group characteristics were compared using the Mann–Whitney U-test. SPSS software (SPSS for Windows, version 12.0,

Table 1. Pattern of Trunk Muscle Activation and comparisons for group difference in trunk muscle onset latency (m/s)

	Deltoid	IO*	EO*	RA*
Normal	305 ± 5.3	325 ± 15.1	320 ± 20.6	395 ± 20.5
LSS	316 ± 20.6	394 ± 18.4	346 ± 27.5	424 ± 23.4

All values mean ± SD. LSS, lumbar spinal stenosis; IO, internal obliques; EO, external obliques; RA, rectus abdominals. Statistical difference at $P < 0.05$, *P value for difference between groups.

Table 2. Control group post hoc pair wise comparisons for muscle onset latency pattern

		Mean Difference	*P*	95% CI for Mean Difference	
				Upper Bound	Lower Bound
Deltoid	IO	-14.2	0.05	-32.7	0.4
	EO	-18.4	0.34*	-25.2	9.7
	RA	-54.9	0.02*	-90.3	-63.3
IO	Deltoid	14.2	0.05	-0.9	33.5
	EO	3.4	0.74	-12.4	27.2
	RA	-32.4	0.02*	-80.2	-45.9
EO	Deltoid	18.4	0.02*	-7.5	34.7
	IO	-3.4	0.34*	-24.2	10.2
	RA	-64.2	0.74	-85.4	-44.9
RA	Deltoid	54.9	0.02*	63.7	99.2
	IO	32.4	0.02*	40.7	80.4
	EO	64.2	0.02*	32.2	75.4

IO, internal oblique's; EO, external oblique's; RA, rectus abdominals. LES, Statistical difference at $P < 0.05$, *P value for difference between groups.

Table 3. LSS group post hoc pairwise comparisons for muscle onset latency pattern

		Mean Difference	*P*	95% CI for Mean Difference	
				Upper Bound	Lower Bound
Deltoid	IO	-54.2	0.04*	-76.5	-41.8
	EO	-21.4	0.23*	-41.3	7.0
	RA	-97.2	0.02*	-122.8	-70.2
IO	Deltoid	54.2	0.04*	42.3	87.1
	EO	46.5	0.00*	12.7	74.6
	RA	-28.4	0.16*	-65.2	6.2
EO	Deltoid	21.4	0.23*	-5.1	63.5
	IO	-46.5	0.00*	-82.1	-10.5
	RA	-67.2	0.10*	-88.4	-40.7
RA	Deltoid	97.2	0.02*	70.4	117.7
	IO	28.4	0.75	-5.2	56.4
	EO	67.2	0.10*	49.2	114.9

LSS, lumbar spinal stenosis; IO, internal oblique's; EO, external oblique's; RA, rectus abdominals. Statistical difference at $P < 0.05$, *P value for difference between groups.

USA) was used for all analyses, and a P-value of 0.05 was set for significance.

RESULTS

Deltoid reaction times were not different between the two groups. The normal group's reaction time was 305 ± 5.3 and the LSS group's was 316 ± 20.6 milliseconds (Table 1). In a comparison between the control an d the LSS groups, the latter demonstrated a significantly later onset of the IO ($P < 0.05$), EO ($P < 0.05$), and RA ($P < 0.00$) muscles than the normal group. The deltoid reaction time of the control group demonstrated significantly earlier activations of IO ($P < 0.05$) and EO ($P < 0.05$) (Table 2). The deltoid reaction time of the LSS group demonstrated significantly delayed activations of IO ($P < 0.05$) and RA ($P < 0.05$) (Table 3).

DISCUSSION

In this study of 32 middle-aged males and females with LSS, the deltoid onset time during rapid arm movement was compared to the trunk muscle latency. The latency of EMG was assessed utilizing the arm raise while walking method for the onset times of IO, EO, and RA in a standing position. This was conducted through a comparison of the onset times of IO, EO, and RA, which were used as a base for lumbar feed-forward.

Many previous studies have conducted investigations of Tra, IO, EO, and RA muscle feed-forward onset. However, this study used a surface EMG measurement, as it is impossible to exclude Tra. Using a unilateral upper arm flexion perturbation, we found that in the control group, the Tra, IO, and EO muscles were activated significantly earlier than the other trunk muscles. Several studies of chronic back pain reported an inconsistent demonstration of Tra feed-forward onset (Hodges and Bui, 1996). Silfies et al. (2009) reported that the trunk muscle onset time of normal subjects was activated early for the EO, LM, and ES muscles in a cross-sectional study.

The LSS group demonstrated a predominantly reactive strategy with increased variability in the activation latency of the trunk muscles. We also found significantly delayed onsets of IO, EO, and RA in the LSS group. Our LSS group demonstrated significantly delayed trunk flexor and extensor muscle activations. This result is consistent with a status of low back pain in extensor (Leinonen et al., 2003).

The results of this study are compared to the analogous parts of low back pain. In addition, the measure did not include the Tra limitations. In future studies, including the study of Tra may be necessary.

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In this study, even though the factors mentioned above were not completely controlled, the EMG measurements of the IO, EO, and RA muscles while standing and during walking were reliable, and they offer empirical information about the trunk muscle activation of LSS patients.

CONFLICT OF INTEREST

There are no potential conflicts of interest relevant to this article.

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