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Original Article

A Study on EMG Activation Changes of Spinal Stability Muscles during Forced Respiratory Maneuvers

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Purpose: The purpose of this study was to investigate whether changes in electromyography (EMG) activations of spinal stability muscles with respiratory demand change were due to changes in respiratory demand or in postural demand.

Methods: Forty healthy subjects (19male, 21female, 20.8±1.9years old) performed quiet breathing and four different forced respiratory maneuvers (FRM) (Pulsed Lip Breathing, Diaphragmatic Breathing, Combination breathing, and respiratory muscle endurance training breathing) while in sitting and standing positions. EMG data for four muscles (TrA/IO, EO, RA, and ES) were collected and filtered using a band pass filter (20~200Hz) and a notch filter (60, 120, 180Hz).

Results: There were no significant differences on percentage of change on %MVIC between QB and FRM (PLB, CB, DB, and RMET) between positions (all p>0.05).

Conclusion: Change of EMG activations during FRM to QB was induced by the change of respiratory demand not by changed postural demand.

Keywords: Spinal Stability, EMG, Respiration

Ⅰ. Introduction

Spinal stability and respiration are related to each other as a matter of muscles in use. Generally, spinal stability muscles are divided into two subgroups based on anatomical attachment; global muscle group and local muscle group.[1] The spinal stability muscles used in respiratory tasks include transversus abdominis (TrA), internal oblique muscle (IO) from local muscle group as well as external oblique muscle (EO) and rectus abdominis (RA) in global muscle.[2, 3] During quiet breathing, the recruitment of other muscles like TrA, IO, EO, or RA to respiration rarely happens, since a healthy diaphragm and lung elasticity seem sufficient for proper respiration.[4] However, during challenged breathing, when the diaphragm contraction draws air for inspiration, those muscles are often activated to meet the changed respiratory demand by performing active expiration.[5, 6]

The balanced activations of muscles are controlled by the central nervous system during performance of both spinal stability and respiratory tasks.[3, 7] The mechanism of spinal stability in these muscles is co-contraction of muscles which increasing intra-abdominal pressure.[8] It has been found that spinal stability muscles function as respiratory muscles by increasing electromyography (EMG) activation when respiratory demand is increased.[2-4, 7, 9-11] However, it was not clear whether changed EMG activations of spinal stability muscles were due to respiratory demand change or

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postural demand change. Some studies found increased postural sway with standing compared with sitting[12] while other studies said postural sway in sitting was larger than in standing.[13, 14] So, EMG activation changes can be due to either respiratory demand change or postural demand change. One of reasons for controversial findings was the comparisons were performed postural sway of between sitting and standing under one respiratory pattern. To study spinal stability muscle activations with respiratory demand change, it is required to see the spinal stability muscle activation changes among different respiratory demands in one position which needs the minimum spinal stability muscle activations for postural control like sitting.[12] So, the changed spinal stability muscle activations could be said due to respiratory demand variations. In addition, it is the percentage of change not the level of spinal stability muscle activations when the comparisons are performed between different positions. For example, if the differences in spinal stability muscle activations between sitting and standing were due to respiratory demand changes, the percentage of change with respiratory demand change from natural breathing in sitting should be consistent even in standing. Otherwise, the differences in spinal stability muscle activations between sitting and standing are caused mainly by postural control demand change.

Therefore, the purposes of this study were to investigate EMG activation changes of spinal stability muscles among different respiratory demands in sitting and to perform the comparisons with the percentage of changes between sitting and standing under the same respiratory demand. The final goal of this study was to see the EMG activation changes of spinal stability muscles were due to changes in respiratory demand or in postural demand.

In this study, four different breathing patterns were used to change respiratory demands which were diaphragmatic breathing (DB), combination breathing (CB), pulsed lip breathing (PLB) and respiratory muscle endurance training breathing (RMET). Those breathing patterns are grouped as forced respiratory maneuver (FRM). It was hypothesized that changes in EMG activation of spinal stability muscles during FRM with postural change were due to respiratory demand change.

II. Materials and Methods

1) Subjects

Forty healthy volunteers (19male, 21female) participated in this study. Subjects were 20.8 ± 1.9years old, 1.7 ± 0.1m tall, weight 61.0 ± 9.6Kg, and BMI 21.7 ± 2.4Kg/m2. Patients with a history of low back pain within the last six months, experiencing low back pain at present, musculoskeletal impairment of lower limbs, or neurological or respiratory pathology were excluded. Prior to participation, all participants were required to read and sign an informed consent, in accordance with the ethical standards of the Declaration of Helsinki. The protocol for this study was approved by the university's ethics committee.

2) Experimental methods

(1) Breathing patterns

Breathing patterns included following maneuvers: QB (Quiet Breathing): the breathing pattern normally observed during resting. Participants were asked to breathe naturally ; PLB (Pulsed Lip Breathing) : Inhalation through the nose with the mouth closed and exhalation slowly through pursed lips held in a whistling or kissing position[15] ; DB (Diaphragmatic Breathing) : inhalation through the nose with outward abdominal motion while reducing upper rib cage motion and exhalation through the nose with abdominal muscle contraction[15] ; CB (Combination Breathing : DB+PLB) : inhalation through the nose with outward abdominal motion while reducing upper rib cage motion and exhalation slowly through pursed lips with abdominal contraction[15] ; RMET (Respiratory Muscle Endurance Training) : the breathing technique using a Spirotiger (Idiag, Spiro Tiger, Switzerland), a partial rebreathing device that ensures normocapnia.[16] The Spirotiger was set at 70% of maximal voluntary ventilation in one minute (MVV) with 50% of vital capacity (VC). MVV and VC were measured using a Spirometer (Bionet, Cardiotouch-3000, USA). Respiration ratio of inhalation to exhalation was 1:2. FRM was taught by the examiner prior to testing, and adequate practice was allowed for adequate learning of FRM

(2) EMG measurement

Prior to data collection using EMG system (LAXTHA, LXM 5308), each subject was prepared as follows. The skin was cleaned with alcohol to reduce impedance.[17-20] Pairs of Ag/AgCl electrodes (3M Red Dot) with a surface diameter of 2cm and center to center distance of 3cm were arranged parallel to the fibers over the right side of the following muscles : Transversus abdominis/internal oblique (TrA/IO) approximately 2cm medial and inferior to the anterior superior iliac spine (ASIS)[21] ; External oblique (EO) placed above the IO electrode site, approximately 15cm from the umbilicus laterally[21] ; Rectus abdominis (RA) 3cm superior to the umbilicus and 2cm lateral to the mid-line[21] ; Erector spine (ES) the intersection of the line corresponding to the muscle fiber orientation and horizontal lines through the spinous process of L2.[22] A ground electrode was placed on the right ASIS.

(3) MVIC measurement

Maximal voluntary isometric contractions (MVICs) were measured prior to data collection and %MVIC was calculated for normalization of the EMG data.[17, 23] MVIC of each muscle was the mean of two trials, with a two-minute rest between trials.[24] Subjects performed isometric contractions against exertion of manual resistance by the tester.

3) Data collection and statistical analysis

Each participant performed five different breathing patterns in sitting and standing positions randomly. In order to investigate and compare the problem that forced respiratory maneuvers (FRM) in standing position could change the postural sway, we needed to add sitting position.[12]

When in upright positions, participants were encouraged to maintain a lumbar lordosis. Breathing patterns were supervised by a physical therapist that was proficient in the approach. EMG data were collected for 30 seconds during performance of each breathing pattern, followed by a 1-min rest period. The mean of two trials was used for data analysis. The raw EMG signal was processed using TeleScanTM ver. 3.03. Raw data were filtered using a band pass filter (20~200Hz) and a notch filter (60, 120, 180Hz) was included in the hardware program. EMG data were rectified and smoothed using a Root Mean Square (RMS) algorithm with a neighboring point of 100. Sampling ratewas 1,024Hz with a pre-amplifier gain of 1,250 ㎶. Prior to statistic analysis, %MVIC of spinal stability muscles were converted to the percentage of changes from QB using the equation 〈[(%MVICFRM-%MVICQB) / %MVICQB] * 100〉.[25]

The Statistical Package for Social Sciences (SPSS ver. 18) was used for data analysis. Descriptive statistics was used to evaluate muscle activations for each muscle during QB and FRM. Independent t-test was used to compare the percentage of change on relative muscle activation between QB and FRM for each muscle in each position. Statistical significance for all tests was accepted at $p < 0.05$.

III. Results

The result of percentage of change on %MVIC between QB and FRM (PLB, CB, DB, and RMET) for each muscle in sitting and standing positions showed that there were no significant differences between positions (all $p > 0.05$) (Table 1).

Figure 1. showed that %MVIC of for each muscle during QB and FRM.

Ⅳ. Discussion

The results of this study showed the differences of spinal stability muscle activation between sitting and standing were due to respiratory demand change not postural demand change. Claeys et al. (2011)'s study found COP displacement in sitting was reduced by one-half compared to standing.[12] Therefore, the percentage of change in spinal stability muscles with standing should be different from sitting if the differences of spinal stability muscle activation between sitting and standing were due to postural demand change. However, this study showed the percentage of change in spinal stability muscles in standing was not different from sitting. So, the differences of spinal stability muscle activation with respiratory demand changes like FRM were caused not by postural demand change.

The changes of spinal stability muscle activations caused by respiratory demand change can be found in healthy young group with motor abundance of the postural chain which plays an important role in the flexible compensation

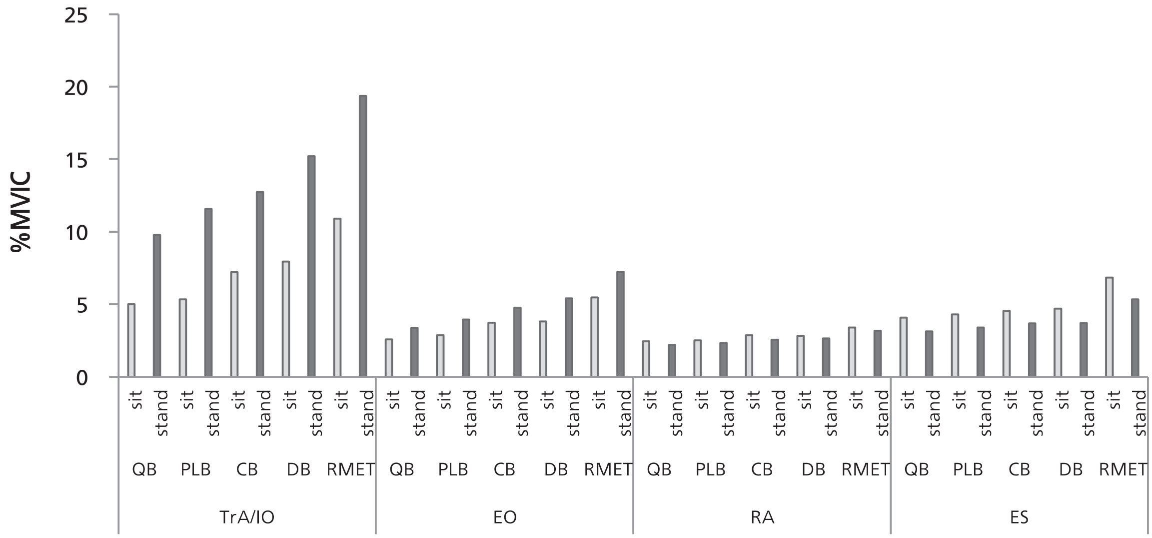

Figure 1. %MVIC of each muscle during QB and FRM in sitting and standing positions.

%MVIC=%Maximal voluntary isometric contraction; QB=Quiet Breathing; PLB=Pulsed Lip Breathing; CB=Combination Breathing; DB=Diaphragmatic Breathing; RMET=Respiratory Muscle Endurance Training; TrA/IO= Internal oblique abdominis; EO=External oblique abdominis; RA=Rectus abdominis; ES=Erector spinae.

Table 1. Percentage of %MVIC change in FRM (PLB, CB, DB, and RMET) to QB for each muscle in both sitting and standing positions.

	FRM (to QB)	sit (Mean ± SD)	stand (Mean ± SD)	p-value
TrA/IO	PLB	26.24 ± 68.77	34.66 ± 80.73	0.62
	CB	63.74 ± 86.37	60.69 ± 138.19	0.91
	DB	80.00 ± 103.73	93.92 ± 149.66	0.63
	RMET	177.99 ± 232.08	158.99 ± 208.75	0.70
EO	PLB	13.52 ± 25.38	17.95 ± 26.59	0.45
	CB	46.67 ± 48.02	43.69 ± 47.71	0.78
	DB	50.87 ± 49.70	63.24 ± 64.50	0.34
	RMET	117.29 ± 117.51	122.45 ± 127.35	0.85
RA	PLB	4.20 ± 8.79	8.00 ± 11.29	0.10
	CB	18.80 ± 16.72	16.38 ± 13.21	0.47
	DB	17.84 ± 15.02	22.34 ± 20.43	0.26
	RMET	49.03 ± 79.67	61.00 ± 136.49	0.63
ES	PLB	5.05 ± 16.41	7.22 ± 13.22	0.52
	CB	13.13 ± 25.37	19.85 ± 16.40	0.16
	DB	14.99 ± 23.33	18.21 ± 15.09	0.47
	RMET	75.03 ± 60.52	77.48 ± 52.45	0.85

%MVIC=%Maximal voluntary isometric contraction; TrA/IO= Transversus abdominis/Internal oblique abdominis; EO=External oblique abdominis; RA=Rectus abdominis; ES=Erector spinae; QB=Quiet Breathing; PLB=Pulsed Lip Breathing; CB=Combination Breathing; DB=Diaphragmatic Breathing; RMET=Respiratory Muscle Endurance Training.

for breathing during quiet stance.[26] Differently from healthy young group, for the patient group like subjects with low back pain, respiratory demand change perturbs postural stability more. So, central nervous system uses spinal stability muscles to meet the postural demand than respiratory demand.[27] Therefore, the percentage of change in spinal stability muscles in standing can be different from in sitting or the subjects with lower back pain fail to meet either postural demand or respiratory demand. So, the subjects with chronic low back pain demonstrated impaired body balance.[28] Lumbar extensor fatigue[29] and inspiratory muscle fatigue[30] could also elicit a change in postural strategy in response to a perturbation.

Interestingly, %MVIC of RA and ES in sitting was higher than standing in this study. The possible explanation for this finding was the decreased number of segments in sitting like hips and knees which assist postural control in standing. So, increased activations of muscles were needed to take over the hips and knees roles.[13, 14]

The limitation of this study was the use of surface EMG instead of needle EMG. However, the placement of electrode was selected with great caution with intensive literature review, and skin was prepared carefully in order to reduce impedance[17, 31] and surface EMG provides a simple, non-invasive, cost-effective alternative for clinical application as compared to intra-muscular investigations.[21]

The conclusion of this study is that change of EMG activations during FRM was induced by the change of respiratory demand not by changed postural demand.

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