

# Effects of Changing the Resistance Direction Using an Elastic Tubing Band on Abdominal Muscle Activities during Isometric Upper Limb Exercises

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**Abstract.** [Purpose] We investigated the effects of changing the resistance direction using an elastic tubing band on abdominal muscle activities during isometric upper limb exercises in a seated position. [Subjects] Twenty able-bodied volunteers (10 males, 10 females) were recruited for the study. [Methods] All subjects performed isometric upper limb exercises with an elastic tubing band involving three different shoulder movements (extension, flexion, and horizontal abduction). Surface electromyography (EMG) signals were recorded from the rectus abdominis (RA), external oblique (EO), and internal oblique (IO) bilaterally during isometric upper limb exercises. [Results] There were significant differences in EMG activity of the bilateral RA during shoulder extension, shoulder horizontal abduction, and shoulder flexion. The EMG activities of the bilateral EO and IO were significantly higher in shoulder extension and horizontal abduction than in shoulder flexion when the subjects performed the arm exercise in the seated position. There was no significant difference between shoulder extension and horizontal abduction. [Conclusions] We suggest that upper limb extension and horizontal abduction using an elastic tubing band could be effective at improving abdominal muscle activities without trunk movement during isometric upper limb exercises.

**Key words:** Abdominal muscle, Elastic tubing band, Resistance direction

(This article was submitted Feb 14, 2012, and was accepted Mar. 8, 2012)

## INTRODUCTION

Low back pain (LBP) is one of the most common musculoskeletal problems worldwide, and carries a significant economic and social burden<sup>1)</sup>. Diverse methods have been proposed for the treatment of LBP, such as advice and education, cognitive behavioral therapy, electrotherapy, general exercise, motor control exercise, and spinal manipulative therapy<sup>2)</sup>. Among these, evidence suggests that motor control training or exercise are effective in the treatment of LBP<sup>3)</sup>. In particular, strengthening exercises for the abdominal muscles is a common strategy for improving functional activity and decreasing pain in patients with LBP<sup>4)</sup>.

One of the most important roles of the abdominal muscles is to stabilize the lumbar spine, which is accomplished by their ability to maintain low-level isometric contraction to support the trunk in various positions<sup>5)</sup>. Weakness of the superficial trunk and abdominal muscles are risk factors for LBP<sup>6)</sup>. LBP patients present with weak trunk extensor and flexor muscles<sup>7)</sup> and lower levels of maximal voluntary isometric contractions (MVIC)<sup>8)</sup>. However, it is difficult to strengthen trunk muscles in these patients, because of the development of pain and their fear of trunk movement during therapeutic exercises<sup>9)</sup>.

The fear-avoidance model presupposes negative thoughts regarding pain as a potential cause for pain-related fear, resulting in avoidance<sup>10)</sup>. People with chronic low back pain who have high levels of pain-related fear avoid submaximal performance in a variety of physical exercises<sup>11)</sup>. Indeed, patients with pain-related fear modify the manner in which they move in an effort to avoid pain or harm<sup>12)</sup>.

Elastic tubing bands are suitable exercise equipment for changing the resistance direction. Specifically, they have been shown to be a useful clinical tool for enhancing strength training. An advantage of an elastic band is that it allows variable resistance exercises in a variety of planes, such as the sagittal, frontal, and transverse, or a combination of these. Additionally, elastic bands are easy to use, economical, and safe.

Many researchers have focused on trunk muscle activation during anticipatory postural adjustments associated with arm movement. In earlier studies, Arokoski et al.<sup>13)</sup> and Behm et al.<sup>14)</sup> reported the effects on trunk muscle activity during the performance of upper-limb exercises. According to Arokoski et al.<sup>13)</sup>, resisted upper limb extension resulted in high abdominal muscle activity, while resisted upper limb flexion led to high back muscle activity. Resisted upper limb abduction produced high muscle activity in both the back and abdominal muscles in the standing position. Tarnanen

et al.<sup>15)</sup> also reported that isometric shoulder extension, performed bilaterally, induced the greatest levels of rectus abdominis (RA) and external oblique (EO) muscle activation in the standing position.

Although several researchers have examined trunk muscle activity during the performance of upper-limb exercises, the picture is incomplete, because most of these studies were performed in the standing position only. Moreover, no study has shown that the use of an elastic band in upper limb resistance affects trunk muscle activity in the seated position.

Thus, the aim of this study was to assess the effects of changing the resistance direction using an elastic tubing band on abdominal muscle activity during isometric upper limb exercises in the seated position. We hypothesized that EMG activities of the abdominal muscles would be increased in shoulder extension exercises using an elastic tubing band.

## SUBJECTS AND METHODS

Twenty healthy participants (10 males, 10 females) were recruited for the study (Table 1). Participants were excluded if they had past or present neurological or musculoskeletal pain, cardiopulmonary problems, or limited range of shoulder motion during upper limb resistance exercises. All subjects read and signed an informed consent form approved by the Inje University Ethics Committee for Human Investigations prior to participation.

Surface EMG data were recorded using a Trigno wireless EMG system (Delsys Inc., Boston, MA, USA) with surface electrodes fixed at an inter-electrode distance of 10 mm. EMG data were collected from the RA, EO, and IO bilaterally. The electrode placements for the abdominal muscles were as follows: RA, 2 cm lateral to the umbilicus; EO, the inferior edge of the eighth rib superolateral to the costal margin; and IO, 2 cm medial to the anterior superior iliac spine in the horizontal plane<sup>16)</sup>. The electrode sites were shaved and cleaned by rubbing with alcohol to reduce skin impedance.

Data analysis was performed using the EMG works software (ver. 4.0; Delsys). The sampling rate was 1000 Hz and data were band-pass filtered between 20–450 Hz. Raw data for each muscle were processed into root mean square (RMS) data. To normalize the data, the mean RMS of the maximal voluntary isometric contraction (MVIC) was calculated for each muscle at the manual muscle testing positions described by Kendall et al.<sup>17)</sup> All EMG data are expressed as a percentage of the MVIC (%MVIC).

Before testing, all subjects were informed of the methods and practiced the procedures to familiarize themselves with them. Subjects were instructed to sit with an upright trunk on a wooden stool so that their feet were flat on the floor. The subject's knees and ankle joints were flexed at 90° and their feet were hip-width apart. A pole was placed directly in front of the trunk at a distance of 1 m, and the subject's shoulder height was measured to determine the fixed axis to set the elastic band to. A blue elastic tubing band (Thera-Band, Hygenic Corporation, USA) was used to regulate resistance of the upper limbs because it has a medium level of elasticity. All subjects grasped 80 cm from the fixed axis

**Table 1.** Subject characteristics

Parameters	All (n=20)	Men (n=10)	Women (n=10)
Age (years)	24.2 ± 3.2	24.2 ± 2.7	24.2 ± 3.7
Weight (kg)	61.3 ± 12.2	71.0 ± 8.0	51.6 ± 6.1
Height (cm)	169.8 ± 9.4	177.1 ± 4.4	162.5 ± 6.8

Mean ± SD

of the elastic band, so that regular resistance was applied to the upper limb. A goniometer was used to determine when the shoulder was at 40° of extension and flexion. A target bar was placed at the elbow to provide feedback to the subject. Each subject was instructed to extend or flex his or her shoulders bilaterally with full extension of the elbow joint until the elbow touched the bar and to hold the position for 5 s. Horizontal abduction started at 90° flexion of the shoulder, and the subject was then asked to perform horizontal abduction with full extension of the elbow joint until the upper limbs were bilaterally to parallel to the torso, and to hold the position for 5 s. The EMG data for the six muscles were collected during this 5-s holding time. The three tasks (extension, flexion, and horizontal abduction) were performed in a random order.

Each trial was performed three times, with a 30-s rest between trials. The mean value of these three measurements was used for the data analysis. For the data analysis, we used 3 s of the 5 s of EMG data for the six muscles, excluding the initial and final 1 s.

Data were analyzed using the SPSS software (ver. 18.0; Chicago, IL, USA), and results were considered significant at values of  $p < 0.05$ . Significant differences between the three conditions were examined using one-way repeated measures analysis of variance (ANOVA), and post hoc analyses were performed using Bonferroni's correction.

## RESULTS

EMG activities (% MVIC) of all abdominal muscles during shoulder extension and horizontal abduction were significantly increased versus shoulder flexion when subjects performed arm exercises in the seated position ( $p < 0.05$ ) (Table 2). There were significant main effects of condition (shoulder extension, shoulder horizontal abduction, and shoulder flexion) in the right RA ( $F_{1,20} = 31.57$ ,  $P = 0.001$ ), left RA ( $F_{1,20} = 54.96$ ,  $P = 0.001$ ), right EO ( $F_{1,20} = 16.18$ ,  $P = 0.001$ ), left EO ( $F_{1,20} = 16.69$ ,  $P = 0.001$ ), right IO ( $F_{1,20} = 9.75$ ,  $P = 0.001$ ), and left IO ( $F_{1,20} = 12.86$ ,  $P = 0.001$ ). There were significant differences in EMG activity in the bilateral RA among shoulder extension, shoulder horizontal abduction, and shoulder flexion ( $p < 0.05$ ). EMG activities of the bilateral EO and IO were significantly higher in shoulder extension and horizontal abduction than in shoulder flexion when the subjects performed arm exercises in the sitting position ( $p < 0.05$ ). There was no significant difference between shoulder extension and horizontal abduction.

**Table 2.** Abdominal muscle activity (%MVIC) during bilateral upper limb exercises in the seated position

Muscle		Mean $\pm$ SD		
		EXT	FLEX	H-ABD
RA	Rt.	13.22 $\pm$ 5.13	6.19 $\pm$ 4.08	8.74 $\pm$ 5.51
	Lt.	14.57 $\pm$ 6.48	6.64 $\pm$ 5.14	9.13 $\pm$ 5.19
EO	Rt.	32.77 $\pm$ 21.00	11.99 $\pm$ 6.66	25.95 $\pm$ 19.03
	Lt.	29.59 $\pm$ 17.25	12.59 $\pm$ 7.03	24.23 $\pm$ 15.20
IO	Rt.	26.76 $\pm$ 22.95	9.45 $\pm$ 7.73	21.26 $\pm$ 18.78
	Lt.	28.57 $\pm$ 18.96	10.05 $\pm$ 7.21	26.83 $\pm$ 17.90

(n=20) Abbreviations: EXT, extension; FLEX, flexion; H-ABD, horizontal abduction; RA, rectus abdominal; EO, external oblique; IO, internal oblique

## DISCUSSION

In this study, we investigated the effects of changing the resistance direction using an elastic tubing band on abdominal muscle activities during isometric upper limb exercises in the sitting position. The results indicate that the direction of resistance on the upper limb appeared to affect the activation patterns of the abdominal muscles. The EMG activities of the abdominal muscles were significantly higher in shoulder extension and horizontal abduction than in shoulder flexion when the subjects performed arm exercises in the seated position ( $p < 0.05$ ). These results support our hypotheses that EMG activities of the abdominal muscles would increase in shoulder extension exercises using an elastic tubing band.

When a limb is moved, the body reacts with forces that are equal in magnitude, but in the opposite direction to the limb movement<sup>18</sup>). Tarnanen et al.<sup>15</sup>) reported that the greatest muscle activities of RA and EO were elicited during bilateral shoulder extension. During bilateral shoulder extension, a long lever arm and the upper-body muscles are able to produce sufficient torque to load the trunk muscles. Thus, we found that changes in upper limb movement may activate of the abdominal muscles.

In this study, we found that applying resistance during shoulder extension while sitting significantly increased abdominal muscle activity compared to shoulder flexion. Earlier studies have reported that the abdominal muscles are activated quickly during arm extension to adjust extension moments at the torso<sup>19, 20</sup>). Arokoski et al.<sup>13</sup>) showed that the RA and EO muscles had high activity during resisted upper limb extension in the standing position. This was similar to our results in the seated position. The present study confirmed that abdominal muscle activities increased, especially those of the EO and IO, with continuous extension moments. Thus, external force directed at the rear trunk can increase abdominal muscle activity, which helps to maintain posture.

We also found that resisted shoulder horizontal abduction in the seated position significantly increased abdominal muscle activity compared to shoulder flexion. Tarnanen et al.<sup>21</sup>) reported that the multifidus and EO muscles had high activities during shoulder horizontal abduction in the standing position. The abdominal oblique muscles play a role

in stabilizing the trunk and pelvis in control of the neutral spine position<sup>22</sup>). The results of the present study suggest that the abdominal oblique muscles are more affected by the direction of movement. As the upper limb extends, external force is applied to the rear trunk. Therefore, these results appear to be similar to those observed during extension.

Upright postures may help reduce LBP, and this is commonly recommended in LBP management<sup>23</sup>). Although we did not measure kinematic data (trunk rotation, flexion, and extension angle), we did instruct subjects to maintain an upright posture during the upper limb exercise.

Patients with LBP who have high levels of pain-related fear avoid submaximal performance in a variety of physical exercises<sup>11</sup>). Thomas et al.<sup>24</sup>) reported that patients with high pain-related fear avoid lumbar spine motion when performing a common reaching movement. It is important to consider the safety of the exercises included in rehabilitation programs for LBP patients. The benefits of changing the direction of resistance using a tubing band include increased abdominal muscle activity without torso motion, such as flexion, extension, and rotation. It can be assumed that this type of resistance can be recommended for LBP patients who cannot perform trunk stabilization exercises directly. Additionally, the resisted direction can be taken into account when planning exercise programs for the conservative treatment of LBP.

This study had several limitations. First, the sample size was small. The 20 healthy subjects of this study were recruited to investigate changes in the EMG activities of abdominal muscles. Second, this study used surface EMG to determine muscle activity, and ignored the possibility of cross-talk from adjacent muscles. Third, we did not measure arm muscles that act directly on the movement, such as the deltoid, pectoralis major, and latissimus dorsi. Further studies are needed to measure the strength of the arm muscles by an objective method and to investigate whether these results have implications for the rehabilitation of patients with trunk muscle deficits, such as LBP and stroke patients.

## ACKNOWLEDGEMENTS

This work was supported by the 2012 Inje University research grant.

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