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A Comparison of Flexi-bar and General Lumbar Stabilizing Exercise Effects on Muscle Activity and Fatigue

Jung-Hee Kim, PT, MSc[1)], Ki-Hyun So, PT[2)], Yu-Ri Bae, PT[2)], Byoung-Hee Lee, PT, PhD[1)*]

[1)] *Department of Physical Therapy, Graduate School of Physical Therapy, Sahmyook University: 815 Hwarang-ro, Nowon-gu, Seoul 139-742, Republic of Korea*
[2)] *Department of Adult Physical Therapy, Seoul Rehabilitation Hospital, Republic of Korea*

Abstract. [Purpose] The objective of this study was to compare the effects of flexi-bar training and general lumbar stabilization training on muscle activity and fatigue. [Methods] Twenty normal persons participated in this study. After warm up and a Maximum Voluntary Isomeric Contraction (MVIC) test, participants performed bridging exercise, quadruped lumbar stabilization exercise on quadruped and curl-up, with and without the flexi-bar training, each exercise lasting for 30 seconds. Electromyography was used for the assessment of the muscle activity and fatigue of the rectus abdominis, erector spinae, external oblique and internal oblique muscles. [Results] The bridging and quadruped exercises with the flexi-bar elicited significant increases in the muscle activates of the muscle groups. The curl-up exercise with the flexi-bar showed significant differences in external oblique and internal oblique muscle activities compared to the exercise without the flexi-bar. Muscle fatigue showed different results depending on the exercise. [Conclusion] Generally, flexi-bar exercise induced greater muscle activation and fatigue. However, because there were differences of effect dependent on the posture, we should prescribe the appropriate exercise for the target muscles.
Key Words: Flexi-bar, Trunk stability, Vibration training

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INTRODUCTION

Trunk stability is an essential element in the prevention of low back pain, because it prevents a compensatory movement in the lumbar region and reduces load on to the lower back[1, 2)]. In particular, the ability to control the trunk muscles is highly important for the protection of facet joints or intervertebral disks from repetitive damage[3)].

The aims of trunk stability exercises are to improve the coordination of synergist and antagonist muscles, which are involved in stabilization of the spine, and to minimize unnecessary movement in the lumbopelvic region, in order to protect the trunk from the repeatedly occurring micro-trauma, pain, and degenerative changes[4)].

A number of effective exercise methods for trunk stabilization have been proposed: for example, curl-up exercise, side-bridging, birddog exercises, and bridging, as well as exercises using a Swiss ball or on unstable surfaces[5–8)]. Recently, studies of exercise with vibration stimulation have been reported[9, 10)]. Among the methods providing vibration stimulation, the flexi-bar is a training instrument which provides vibration stimulation. It consists of weighty rubbers at the end of an elastic bar of around 152 cm in length, and it is known to generate vibration at a frequency of 5 Hz when it is actively moved[10)]. Vibration stimulation of the human body at frequencies below 50 Hz is known to be more effective than to be delivered into a body[11)]. Shaking the flexi-bar creates not only vibration stimulation at a low frequency of 5 Hz, but also delivers this vibration to the body thereby facilitating muscle activation of the limbs and trunk. Thus, it has been widely used in fitness centers and rehabilitation treatment for improving muscle strength and improvement of coordination, and balance ability[10)]. Previous studies of exercise with a flexi-bar have mainly focused on the activation of muscles for stabilizing of the trunk, in particular, the rectus abdominis, transverses abdomonis muscle, latissimus dorsi muscle, and erector spinae muscles. However, they have only reported muscle activation according to the use of the flexi-bar and an inelastic bar[10)]. Thus, none of these studies reported a comparison of trunk muscle activation between general exercise of the lumbar region and exercise using the flexi-bar.

Accordingly, the aim of this study were to compare the muscle activation of the trunk muscles between flexi-bar and trunk stabilization exercises in order to evaluate whether the flexi-bar exercise is more effective at improving trunk stability.

*Corresponding author. Byoung-Hee Lee (E-mail: 3679@syu.ac.kr)

SUBJECTS AND METHODS

Twenty healthy adult subjects (12 males and 8 females) working at S Hospital in Seoul, Korea were recruited for this study. The general characteristics of the subjects were as follows: a mean age of 27.5 years, a mean height of 170.2 cm, a mean weight of 62.0 kg, and a mean body mass index of 21.2. None of the participants had a history of injury or movement disorder of the extremities in the last five years, and all had normal muscle strength, balance, and cardiopulmonary, visual, and auditory functions. All the participants were fully informed about the study, and they gave their prior consent to participation in this study. All the procedures conducted in this study were given prior approval by the Research Ethics Committee of Seoul Rehabilitation Hospital (SRH2012R-02).

None of the participants had a professional athletic background, and all of them were right hand dominant. The participants conducted a warm-up exercise consisting of mild walking and stretching for about five minutes before the main experiment. Then, in order to normalize individual differences in skin resistance and muscle strength, we measured the maximum voluntary isometric contraction (MVIC) of the target muscles(rectus abdominis, externus obliquus, internus obliquus, erector spinae). The MVIC measurement was conducted with maximum isometric contraction for five seconds in the required posture, and the middle three seconds of measurement, excluding the first and last one seconds, were used in the analysis.

The flexi-bar (Flexi-Sports, Bisley, Stroud, UK) used in this experiment is an exercise tool having weights at the both ends of a glass fiber elastic bar of 719 g in weight and 1,520 mm in length. At the center part, a grip of 17.9 cm was placed so that a user could grip this part and shake the bar for the exercise. We did not accurately measure the flexi-bar's vibration frequency, but it is known that when the flexi-bar is used, it generates a vibration stimulus of approximately 5 Hz[10].

In this experiment, three types of general trunk stability exercise and the same exercises combined with the flexi-bar exercise were used to compare muscle activation and muscle fatigue. The three trunk stability exercises were bridging, quadruped, and curl-up. In order to minimize the interference effect due to performance order of the flexi-bar exercise and the general trunk stability exercise, participants were randomly divided into two groups, A and B, and the A group performed the flexi-bar combined exercises first followed by the general trunk stability exercise, while the B group performed the general trunk stability exercise followed by the flexi-bar exercise. Each group performed its exercise for 30 seconds and rested for 90 seconds after each trial. The performance of the middle 20 seconds, excluding first and last five seconds of performance, was used in the analysis.

To measure muscle activation and muscle fatigue due to the intervention, a surface electromyograph (MWX8 DataLOG, Biometrics Ltd, UK) was used. The electrodes used were SX230 EMG sensors manufactured by Biometrics Ltd., and they were attached to 8 regions in total: the right and left sides of rectus abdominis, erector spinae, externus obliquus, and internus obliquus. The EMG signals were sampled at 1,000 Hz and full-wave rectified, then band-pass filtered between 20 to 250 Hz, and notch-filtered at 60 Hz to remove artifacts. To minimize artifacts, all peripheral devices except for the laptop PC and sEMG required for the experiment were turned off, and care was taken to avoid twisting of the cables of the electrodes.

Statistical analysis was performed using SPSS ver. 18.0. The mean and standard deviation of age, weight, and height, general characteristics of the subjects were calculated. Differences in muscle activation and fatigue between the conditions were compared using the paired t test. Values of $p<0.05$ were considered significant.

RESULTS

The results of the muscle activation in the bridging exercise and quadruped combined with the flexi-bar show that all the muscles' activations increased more significantly in the bridging exercise combined with the flexi-bar than in the bridging only exercise ($p<0.05$). No significant difference in muscle activation was found for the rectus abdominis and erector spinae between the curl-up only exercise and the flexi-bar combined exercise; the flexi-bar combined exercise showed higher muscle activation only in the external oblique and internal oblique muscles ($p<0.05$) (Table 1).

The measurement of muscle fatigue in the bridging only and the flexi-bar combined exercises showed that the flexi-bar combined exercise elicited higher muscle fatigue in the erector spinae ($p<0.05$). The comparison of the quadruped and flexi-bar combined exercises showed that the flexi-bar combined exercise elicited higher muscle fatigue in the erector spinae, left external oblique, and left internal oblique muscles ($p<0.05$). The comparison of muscle fatigue between the curl-up and the flexi-bar combined exercises found that the flexi-bar combined exercise elicited higher muscle fatigue in the rectus abdominis and internal oblique ($p<0.05$) (Table 2).

DISCUSSION

There have been studies of the effect of whole body vibration on muscle activation which provided vibration stimulus passively while standing on a vibration plate[9]. However, passive vibration stimulus is hard to store the energy successfully when it is applied for a long time[12]. On the other hand, active input of vibration stimulus can affect the neuromuscular system immediately, and it is maintained in the long-term[13]. In particular, vibration delivered to the muscle belly or tendon can induce the tonic vibration reflex (TVR). The TVR is known to facilitate muscle contraction by increasing the recruitment of the alpha motor neurons through the activation of muscle spindles and the polysynaptic pathway[14, 15]. We consider that the higher muscle activations generated in the flexi-bar combined exercises were also the result of the TVR being induced by the vibration stimulus.

Shaking the flexi-bar while lifting the hip can induce continuous vibration thereby making the support base more

Table 1. Comparion of muscle activities between exercises with and without the flexi-bar

Exercise	Muscle	Flexi-bar + Bridging		Bridging	
		Left	Right	Left	Right
Bridge	RA	5.7 (1.6)**	5.5 (1.8)**	2.9 (1.1)	3.1 (1.3)
	ES	44.2 (5.1)**	44.2 (6.3)*	38.9 (5.1)	39.3 (5.9)
	EO	21.7 (7.5)**	21.1 (6.4)**	16.3 (5.8)	16.4 (5.7)
	IO	21.0 (6.9)**	21.3 (7.6)**	15.3 (3.6)	15.3 (3.0)
		Flexi-bar + Quadruped		Quadruped	
		Left	Right	Left	Right
Quadruped	RA	12.3 (2.7)**	12.2 (2.7)**	5.9 (1.3)	5.9 (1.2)
	ES	21.6 (5.3)**	16.1 (2.7)**	13.9 (2.7)	11.8 (2.5)
	EO	47.0 (10.2)**	30.0 (6.4)**	36.5 (8.9)	18.8 (4.2)
	IO	17.7 (2.1)**	32.6 (5.6)**	11.5 (2.5)	26.9 (4.6)
		Flexi-bar + Curl up		Curl up	
		Left	Right	Left	Right
Curl up	RA	52.5 (6.9)	52.8 (7.5)	49.8 (3.7)	49.9 (3.8)
	ES	8.9 (1.6)	8.8 (1.6)	8.2 (2.7)	8.1 (2.6)
	EO	52.8 (5.2)*	54.2 (5.2)**	49.1 (4.6)	49.8 (5.0)
	IO	54.7 (4.3)**	54.2 (4.5)**	50.6 (4.4)	50.7 (3.7)

Numbers in parentheses represent standard deviation. RA; rectus abdominis, ES; erector spinae, EO; external oblique, IO; internal oblique, *p<0.05, **p<0.01 between the condition of flexi-bar and general trunk stabilizing exercises

Table 2. Comparion of muscle fatigue between exercises with and without the flexi-bar

Exercise	Muscle	Flexi-bar + Bridging		Bridging	
		Left	Right	Left	Right
Bridge	RA	14.3 (0.8)	14.7 (1.1)	14.3 (1.1)	14.7 (1.5)
	ES	14.7 (0.5)**	14.9 (0.5)**	15.5 (0.8)	15.8 (0.8)
	EO	15.5 (3.7)	14.9 (1.2)	15.7 (4.5)	14.9 (1.3)
	IO	14.9 (1.5)	14.7 (1.0)	15.8 (3.4)	15.5 (3.3)
		Flexi-bar + Quadruped		Quadruped	
		Left	Right	Left	Right
Quadruped	RA	14.7 (0.7)	14.79 (0.8)	14.4 (0.8)	14.6 (1.2)
	ES	14.7 (0.8)**	14.7 (0.7)**	16.2 (1.9)	16.1 (1.2)
	EO	14.9 (0.9)	14.7 (0.7)	15.5 (0.9)	15.2 (1.1)
	IO	14.7 (1.1)*	14.7 (0.7)*	16.3 (3.5)	15.0 (0.9)
		Flexi-bar + Curl up		Curl up	
		Left	Right	Left	Right
Curl up	RA	15.0 (0.6)**	15.1 (0.7)*	15.8 (1.2)	15.5 (1.1)
	ES	15.4 (1.5)	15.7 (1.5)	15.7 (1.6)	16.0 (2.0)
	EO	15.2 (0.8)	15.0 (0.6)	15.6 (1.1)	15.3 (1.1)
	IO	14.7 (0.8)*	14.6 (0.7)*	15.1 (1.0)	15.2 (1.1)

Numbers in parentheses epresent standard deviation, RA; rectus abdominis, ES; erector spinae, EO; external oblique, IO; internal oblique, *p<0.05, **p<0.01 between the condition of flexi-bar and general trunk stabilizing exercises

unstable. Thus, activation of not only muscles near the spine but also muscles in the abdominal region increased due to the muscle activation increase in the trunk, which was required to maintain posture. This result is consistent with the results of a previous study, in which exercise performed on unstable surface increased muscle activation, due to an increase in the muscle activity needed to stabilize the spine as well as the surrounding joints to maintain the posture on the unstable surface[8)].

Stevens (2006) found that when bridging was performed on an unstable surface, contraction of the external trunk muscles occurred in order to maintain the trunk stability, blocking displacement of the spine and pelvics[7)]. This prevented significant increase of muscle activation in the multifidus and erector spinae, which are relatively deep muscles[7]. In this study, the flexi-bar combined bridging exercise induced greater activation in the erector spinae than the bridging only exercise. This means that the unstable support base and continuous vibration stimulus provides by the flexi-bar induced contraction not only in the superficial muscle group, but also in the deep muscle group.

Raising the arms and legs while adopting the quadruped position induces greater trunk muscle activation[16], in particular, the abdominal oblique muscles are known to be involved in maintaining stability by preventing spine rotation[17]. In this study, comparison of muscle activation between when the right hand was raised in the quadruped position and when the right hand shook the flexi-bar was performed. The results show that the flexi-bar combined exercise elicited greater muscle activation in all muscle groups. In particular, the activity of the left external oblique and right internal oblique showed a higher activation than the muscles on the opposite sides. This result can be explained by the equilibrium reaction to the continuous vibration stimulus and instability.

Vera-Garcia reported that the rectus abdominis and external oblique were activated more by the curl-up exercise on an unstable surface than on a stable surface[8]. In the flexi-bar combined exercise of the present study, muscle activation of the rectus abdominis and external oblique was greater than in the exercises without the flexi-bar, but no significant differences were found. In general, the rectus abdominis and external oblique are known to produce a torque between the thorax and the pelvis, performing the role of distributing loading[18]. It is important to minimize the activation ratio between the internal oblique and the rectus abdominis, in particular, the activation of rectus abdominis in order to secure the stability of the lumbopelvic region[5], because the curl-up position can induce large contraction in these two muscles due to the excessive loading, which was generated by the effect of body mass and gravity. Compared to other exercises performed in this study, excessive activation of rectus abdominis can be induced in the curl-up exercise so it would be difficult to recommend the flexi-bar combined curl-up exercise for effective trunk stability over the the curl-up only exercise.

In this study, muscle fatigue of the conditions was measured by extracting the central frequency component using frequency spectrum analysis. The result show that the bridging and flexi-bar combined exercise elicited significantly greater muscle fatigue in the erector spinae, while the quadruped and flexi-bar combined exercise elicited significantly greater muscle fatigue in the erector spinae, and the curl-up and flexi-bar combined exercise elicited significantly greater muscle fatigue in the rectus abdominis and internal oblique.

The median frequency of the EMG signal is a typical index of muscle fatigue, which is generated by a reduction in the activity frequency of the motor unit due to continuous muscle activation, reduction of myofacial conduction velocity, reduction of myofacial excitatory, and changes in ion balance[19, 20]. That is, as the number of repetitions of exercise increases, muscle fatigue also increases. Muscle fatigue increase means muscle activity increases, therefore it can be understood as a process of muscle strength increase. The flexi-bar guide catalogue proposes that ideally exercise should be performed in one position for 30 to 60 seconds with at most 10 minutes of exercise in total. This study followed this guideline and participants maintained each position for 30 seconds. However, we considered a single exercise of around 10 minutes, would generate excessive muscle fatigues if the flexi-bar swing was performed for more than 30 seconds in one single position. Therefore, an effective trunk stability exercise using the flexi-bar would be one position maintained for less than 30 seconds at most, with sufficient rest provided between the positions during flexi-bar exercise.

The participants of this study were 20 in total. Therefore, it is difficult to generalize our study results due to the small number of participants. Furthermore, even if we conducted prior education on the use of flexi-bar before the experiment, differences in the flexi-bar amplitude can occur during the measurement because of the differences in the individuals' exercise ability. Because of this, it is also difficult to assert that the muscle response was consistent. Since this study examined only three types of trunk stability, the result in this study cannot be applied to all trunk stability exercise. The effect of flexi-bar exercises will be established if more studies of flexi-bar exercises in various positions are published.

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