Journal of Modern Rehabilitation

Research Article

Evaluation of Trunk Muscle Activation during the Two Directions of Flexi-Bar Exercise in People with and without Low Back Pain

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Citation Herasi M, Kahrizi S, Hoviattalab M. Evaluation of Trunk Muscle Activation during the Two Directions of Flexi-Bar Exercise in People with and without Low Back Pain. Journal of Modern Rehabilitation. 2022; 16(4):304-311. https://doi.org/10.18502/jmr.v16i4.10757

https://doi.org/10.18502/jmr.v16i4.10757

Article info:
Received: 01 Apr 2021
Accepted: 20 Jul 2021
Available Online: 01 Oct 2022

Keywords:

Non-specific chronic low back pain; Flexi-bar; Trunk muscle activation; Electromyography

ABSTRACT

Introduction: The flexible-bar with a small amplitude of 5 Hz, which transmits vibrations to the trunk, enables the activation of the core muscles that can be used to rehabilitate subjects with low back pain. Two types of exercise direction that can affect trunk muscles of low back pain subjects similar control group are not known. This study aimed to evaluate and compare exercises with two directions of the oscillating flexible poles in people with and without low back pain (LBP).

Materials and Methods: Twelve women with Mean±SD age of 28.75±2.92 years, and body mass index (BMI) of 22.31±2.10 kg/m^2 and a history of low back pain, and 12 healthy subjects with Mean±SD age of 28.75±2.49 years and BMI of 21.59±1.50 kg/m^2 voluntarily participated in this study. The electromyography (EMG) signals of trunk muscles were measured during two handheld oscillating flexible bars in two directions. The root means square (RMS) of signals for each muscle is normalized by the maximum RMS.

Results: The results of comparing two types of exercise in two groups showed significant differences for left external oblique (P=0.017), right external internal oblique (0.002), and left internal oblique (0.008). Also, the difference in the interaction between group×exercise was significant only for left internal oblique (P=0.026).

Conclusion: Muscle activity in the low back pain group appears different while performing exercises with a flexible-bar compared to the control group. This confirms motor control impairment in these populations and having different strategies for trunk co-activation during exercise.

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1. Introduction

Low back pain (LBP) is a widespread disease but mainly under self-limiting conditions. In developed countries, the lifetime incidence of non-specific low-back pain is about 60% to 70%, resulting in enormous costs for the health care system and reduced productivity [1]. This type of chronic low back pain (CLBP) disorder has no identified diagnosis, making it challenging to manage and treat [1, 2]. People with low back pain have two common disorders, such as decreased endurance of back extensors [3] and delayed feed-forward postural responses in the deep abdominal muscles [4]. Chronic underuse of respective muscles may reduce endurance of back extensors due to a lack of appropriate physical activity. High rate loading is included in the spinal segmental stabilization program [3] since it involves a two-step preparation phase such as voluntary and then involuntary muscle movement [4]; however, the evidence on muscle effects is still scarce. Therapeutic approaches are still needed to activate the target muscles and are resilient to external factors. The forward and backward vibration caused by the flexible bar can activate the stimulus muscles to maintain equilibrium [5]. Flexible bar activities are the physical response to vibration required for trunk stability without specialized training [6]. It works based on vibration training by superimposing a low-frequency (5 Hz) vibration-like stimulus to the muscles during movement. The flex-bar is effectively marked to target and stabilize the deep muscle of the body. Data from various experiments confirm that the back muscle activation, unlike abdominal muscles, is subject to the oscillation plane. These data can be used to diagnose impaired trunk muscle coordination and monitor the functional regeneration of certain patients with back pain during exercise interventions [4]. It has been reported that muscle activation via flexi-bar is not affected by the subject's posture. The bar's orientation and material are essential since the leading muscles recruited during the exercise are defined. Goncalves et al. concluded that exercises with a flexible bar compared to a rigid bar indicated that flexi-bar imposes a stronger stimulus on the trunk muscle activity and increases their activation. However, the effect was only significant for the internal oblique muscle [7].

Exercise intervention effectively reduces pain and improves function in managing chronic low back pain [8]. Exercise can be prescribed for patients with CLBP with some distinct goals. The main aim is to enhance flexibility and strength in back muscles and increase the performance of endurance activities that are performed for most of these patients. The second aim is to decrease the severity of back pain. The average decrease in back pain severity, ranging from 10% to 50% after exercise treatment, has been reported in most exercise studies. The third aim is to reduce the impairment associated with back pain by desensitizing fears and worries, altering pain behaviors and values, and improving the efficacy of that process. Some studies have exposed the mechanisms by which exercise can access this purpose [9]. Exercising with the flexi-bar disturbs the person's equilibrium. Then, to maintain stability, the person resorts to posture adjustments, such as contracting the trunk muscles to enhance stability [4, 10]. The tool allows the patient to produce oscillatory movements of the upper limb. The trunk is braced at the same time to give the upper limb a strong base. Using a flexi-bar, in particular, has gained popularity as a method in physical medicine clinics. However, there is little knowledge to guide its usage, especially in subjects with an LBP history. Therefore, this study was conducted to evaluate the trunk muscle activation during the two directions of flexi-bar exercise in people with and without LBP.

2. Materials and Methods

Subjects

Twenty-four young university women (12 subjects with CLBP and 12 healthy subjects) were physically fit, right-handed, and voluntaries in this pretest-posttest study. Table 1 presents the general characteristics of the participants in both groups. Subjects were included according to the inclusion and exclusion criteria and clinical examination of the physician collaborator and as Standards of National Institutes of Health (NIH) guidelines for research on chronic low back pain [11]. They did not have a more specific medical diagnosis and had to experience non-specific LBP for more than six months and experience at least three self-reported recurrent episodes of LBP [12]. The volunteers in the control group experienced no LBP for more than three days and no LBP in the last year. The participants were blinded to the aims of this study and the efficacy of the flexi-bar exercise. Before participating, the subjects received a description and procedures of this study and signed informed consent. The Institutional Review Board of the University of Medical Sciences approved our study with Ethical Number D52/6710, Tehran City, Iran.

Protocol

The volunteer was familiar with the experimental procedures on the first day. On the second day, with a minimum of 24 hours and a maximum of 72 hours, the exercises were conducted randomly allocated order in two directions.

In this study, a lightweight and flexible fiberglass bar with a length of 153 cm, a weight of 710 g, and a thickness of 9.5 mm were used. A rubber handle about 20 cm in the middle of the rod made it possible to hold with one or two hands.

The experimental sessions began with a 5-minute warm-up, consisting of light jogging and muscle stretching. Then the subjects scored their pain on a 10 cm visual analog scale (VAS). The pain ratings lower than 3/10 on the day of testing were one of the inclusion criteria. Two exercises were performed by holding flexible-bar such as the one-handed vertical orientation of the flexi-bar (antro-posterior oscillations) and with 90°C flexion in the shoulder (exercise 1), the two-handed horizontal orientation of the flexi-bar (up-down oscillation) with 90°C flexion in the shoulder (exercise 2) (Figure 1). A scaled mirror was positioned in front of the volunteers for visual feedback to help the volunteers maintain their shoulder and arm positions during the exercises.

All subjects performed the exercises with flexi-bar while standing with their open eyes. Each exercise was performed randomly for 15 s and 60 s of rest after each exercise. A metronome set at 300 beats per minute (bpm) was used to monitor the pole movements). By the elbow flexion-extension, the pole's movement was primarily achieved [13]. The elbow joint and lumbar spine angles were recorded continuously and simultaneously with electromyography (EMG) data during the experiments by two electro-goniometers (Biometrics Ltd, United Kingdom (Table 2), to ensure that muscle contraction was not due to vigorous movements of the trunk or elbow.

Electromyography (EMG)

In a bipolar configuration, an eight-channel EMG system (Data Link DLK900, Biometrics Co, UK) with silver-silver chloride (Ag/Ag-Cl) surface electrodes with an active area of 1 cm2 and an inter-electrode distance of 2 cm were used. The electrodes were located bilaterally on the left and right parts of the muscles, rectus abdominis (RA) 1 cm above the umbilicus and 2 cm lateral to the midline, external oblique (EO) between the lower part of the rib cage and the upper part of the iliac spine, internal oblique (IO) 2 cm medial and lower part of the anterior superior iliac spine and on the erector spine (ES) at the level of the L3 spinous process, 3 cm lateral to the midline [14]. The reference electrode was placed on the right lateral malleolus. Before placing the electrodes, the skin was shaved, abraded, and cleaned with alcohol.

After electrode placement, a maximal voluntary contraction (MVC) was obtained for each muscle to be used for signal normalization, as specified by Kendall for specific manual muscle testing [15]. Each MVC test was performed three times for each muscle, and the root means square (RMS) was extracted from them, and then the highest value of 3 trials was considered as the max value. The minimum contraction RMS was extracted from the EMG recorded of all muscles when subjects were in the lie-down position as a min value to be employed in the following normalizing equation:

The EMG signal was filtered at a sample rate of 1000 samples/s, band-pass between 10-500Hz. Then it is converted from analog to digital using a 13-bit resolution. The EMG data of five s of exercise between the 5th and 10th seconds of the 15s of exercise were considered for analysis since this period was the highest stability of the frequency oscillation of the pole [16]. All the signals of exercise data, MVC, and min value were processed in the time domain by calculating RMS amplitude over sliding windows of 150ms by Data Link software. The mean EMG signals of three trials of RMS were used for data analysis. Then, these mean RMS values were normalized to MVC amplitude for each subject [17].

Statistical analysis

The assumption of normality was examined using the Kolmogorov-Smirnov test. Comparisons were made between the groups and exercises. The repeated-measures analysis of variance (ANOVA) was used with the between-subject factor of group (asymptomatic and CLBP) and within-subject/repeated factor of exercises (one-handed vertical orientation, two-handed horizontal orientation). The statistical significance level has been set as $P<0.05$. The SPSS software, v. 25 has been used to conduct all analyses.

3. Results

No significant differences were observed in age, weight, and height means between the two groups. (P>0.05); therefore, they could be considered match groups (Table 1). Comparing the two types of exercise in both groups (Table 3) indicated differences in the percentage of MVC muscles of left EO (P=0.017), right EO (0.002), and left IO (0.008). By completing the test, it was revealed that for these muscles, activation of exercise type 1 was higher than activation of exercise type 2 only for people without LBP (Figure 2). In exercise type 2, both groups has equally responded. A significant difference existed in the interaction between the group and exercise only for left IO (P=0.026). The activation of left IO as the percentage of MVC was 28% lower in subjects with LBP in exercise type 1 compared to subjects without LBP.

The LBP subjects activated all these muscles, unlike asymptomatic subjects with a similar pattern in the two exercises. Figure 3 shows trunk muscle activation for two different positions tested.

By t-test, the analyses showed a difference between two types of exercises only for the asymptomatic group in 3 muscles, such as left external oblique (LEO), right external oblique (REO), and left internal oblique (LIO). One-handed exercise of the flexi-bar (exercise 1) in this group led the EO muscle to have 38.97% and 23% MVC for the left and right sides, respectively. The left IO muscle showed the highest activation level (46.04% MVC). While the two-handed use of a flexi-bar (exercise 2) resulted in the left EO muscle having 23.98% MVC, right EO muscle 17.59% MVC, and left IO muscle 28.63% MVC (Figure 2). All muscles on both sides of LBP sub-

Table 1. Demographic information of participants (n=12)

Characteristic	Mean±SD		P
	LBP	Healthy	
Age (y)	28.75±2.92	28.75±2.49	0.55
Height (cm)	166.91 ± 3.08	163.83±6.45	0.19
Weight (kg)	62 ± 6.03	57.83±4.56	0.30
BMI (kg/m²)	22.31 ± 2.10	21.59±1.50	0.32

LBP: Low Back Pain; BMI: Body Mass Index

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Table 2. The angular displacement (degree) of trunk and elbow during shaking with the flexible pole

Variables	Groups	Mean±SD		P
		Asymptomatic Subjects	Low Back Pain Subjects	
Trunk	Exercise 1	4.23±1.10	3.60±1.47	0.248
	Exercise 2	4.05±1.39	3.40±0.98	0.201
Elbow	Exercise 1	18.42±2.50	17.17±2.09	0.200
	Exercise 2	18.72±3.89	17.74±2.73	0.480

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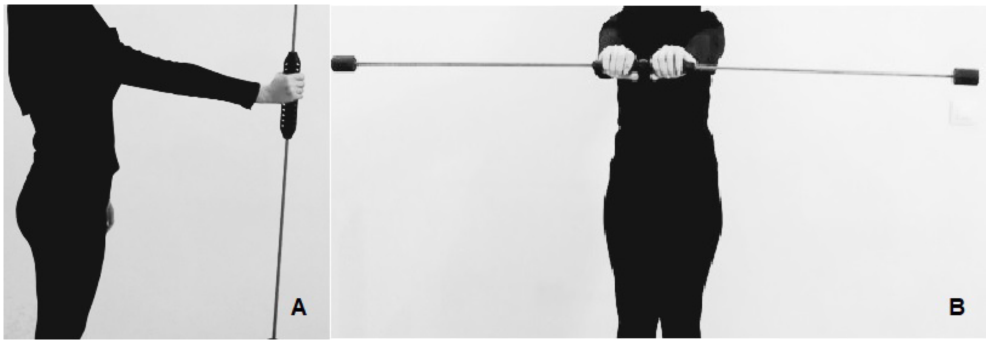

Figure 1. Pictures of two exercises holding the flexi-bar in the middle, with either one-handed (A) or both hands (B) JMR

Table 3. Analysis of variance results for the group, exercise, and group× exercise effect

Variables		Group			Exercise			Group×Exercise		
		P	F	Power	P	F	Power	P	F	Power
EO	Left	0.889	0.00	0.05	0.017*	7.94	0.72	0.268	1.36	0.18
	Right	0.354	0.93	0.14	0.002*	15.27	0.94	0.530	0.42	0.09
IO	Left	0.474	0.54	0.10	0.008*	10.43	0.83	0.026*	6.64	0.65
	Right	0.685	0.17	0.06	0.052	4.74	0.51	0.415	0.71	0.12
ES	Left	0.291	1.22	0.17	0.719	0.136	0.06	0.321	1.08	0.15
	Right	0.145	2.45	0.29	0.584	0.31	0.08	0.297	1.20	0.17
RA	Left	0.384	0.82	0.13	0.148	2.42	0.29	0.152	2.35	0.28
	Right	0.149	2.40	0.29	0.475	0.54	0.10	0.235	1.58	0.21

RA: Rectus Abdominis; ES: Erector Spine; IO: Internal Oblique; EO: External Oblique; Rt: Right side; Lt: Left side

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* Significance value with P<0.05.

jects were activated similarly in both exercises (Figure 3). In this group, no significant differences were observed between muscle activation of exercises 1 and 2.

4. Discussion

This study shows that the pattern of the deep trunk muscle is different in the two groups of healthy and chronic low back pain when using a flexible- bar. Changing the flexible-bar oscillating plate can change the pattern of muscle contractions in healthy people. Nevertheless, the deep muscles in both directions were equally active in people with chronic low back pain. Oscillating movements of the flexi-bar transmit low-frequency vibration to the body, which leads to cyclic disturbances in the upper limbs and trunk, followed by activation of the trunk muscles. Different exercises can be designed for different muscle patterns by changing the direction and oscillation plane of the flexi-bar.

During the exercises, the amplitude of the angular displacement of flexion and extension of the trunk and the elbow was examined by a digital electro-goniometer to ensure that the angular changes did not differ significantly between the two healthy and low back pain groups. The results showed that the value of angular changes was constant and negligible (Table 2). Therefore, the differences in trunk muscle activity between the two groups can not be attributed to the lumbar kinematic changes during exercise.

When trunk stability increases, the forces damaging the spine are reduced [18]. Flexi-bar as an external load disturbing the body's balance system can accelerate trunk muscle activity to keep trunk stability. When vibration is applied by shacking the flexi-bar to muscles, it produces proprioceptive stimulation, which significantly affects muscle contraction [6]. Moreover, it enhances muscular strength and endurance [19]. This study's findings re-

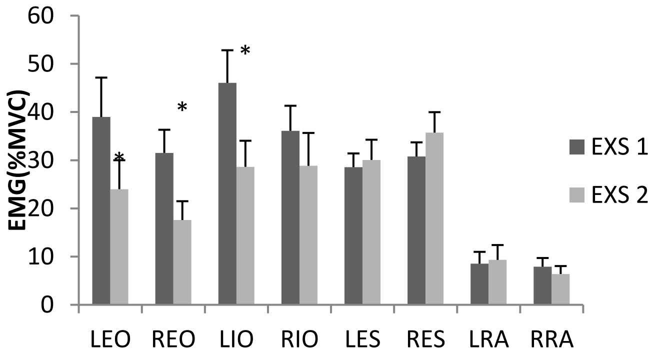

Figure 2. Trunk muscles activity in people without Low Back Pain (LBP) (Exercises 1 and 2)

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*P<0.05

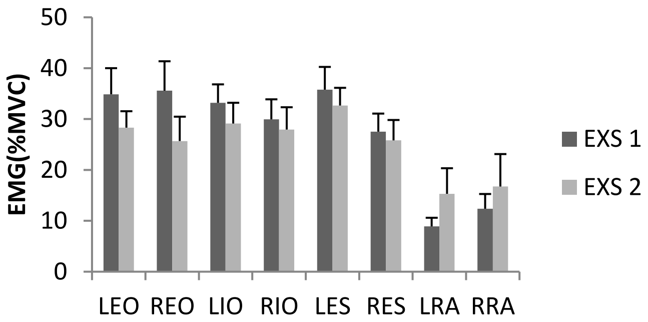

Figure 3. Trunk muscle activation in people with Low Back Pain (LBP) (exercises 1 and 2)

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vealed that the prescribing of flexi-bar exercises for both healthy and LBP individuals is essential.

The significant increase in EO and IO activation of the asymptomatic or healthy group in both exercises was consistent with other studies [6, 7, 16]. Since the IO muscle maintains the stability of the lumbar spine through attachment to the thoracic, and lumbar fascia, increased contralateral muscle activity during exercise 1 also was expected. However, the interesting point was that this increase was not significant in people with LPB compared to asymptomatic subjects; thus, interaction exercise × group was significant. The vertical use of the flexi-bar appeared to result in a relatively high activation level of the oblique abdominal muscles (task-related adaptive changes), however in the LBP group, the vertical and horizontal direction of the flexible pole resulted in similar amounts of contraction. It means that, unlike the healthy group, the activity of the left IOmuscle had no relation to the direction of the bar and the amount of activity was not significant in both types of exercises. Ultimately, as other authors have stated, the change in the oscillation plane was able to invoke various activation features [4, 20]. Logically, the vertical and horizontal orientation of the bar produces twisting and sagittal torque, respectively, therefore an increase in oblique muscle activity likely responds to the need to control the twisting effect of the vertical pole oscillation.

The results of this study are according to Moreside et al. [21]; Sanchez-Zuriaga et al. [22], Anders et al. [4], and Goncalves et al.' [7] studies found that in healthy subjects, higher activity in IO using the 1-holding blade may be to control more stability challenges in this exercise. Table 3 presents that the main effect of the exercises was significant for both sides of EO besides the left side of IO, meaning that exercise type 1 or one-handed exercise (oscillation in the sagittal plane) caused higher activation than exercise 2. That is why this exercise is recommended for training the spine stabilizing muscles.

People with low back pain always have a co-contraction in their muscles, due to impaired movement control, especially in a challenging situation where stability is at risk. As a threat to stability, perturbations induced by flexi-pole cause the activation of abdomen muscles independent of the oscillation plane [4]. By comparing the means of two exercises in both groups, the difference between subjects with and without low back pain has been evident in choosing different strategies. An alteration in the motor strategies of these subjects has been confirmed to avoid pain provocation. Hence, the LPB subjects prefer to choose the same strategy to neutralize the swaying movement of the trunk in two exercises instead of responding specifically to the demand of each exercise as healthy subjects. Co-contraction in LBP subjects reduces the probability of noxious tissue stresses, such as ligaments, joints, muscles, and fascia by limiting the range of motion and "over-activation strategy". Although adaptation to pain has a short-term benefit, it may have consequences resulting in further problems in the long term, such as earlier fatigue or increased load on the lumbopelvic region [23]. Therefore, specialized training is needed to correct this problem. More research on this device can clarify this hypothesis.

5. Conclusion

It seems that, unlike healthy people, people with LBP do not activate specific muscles based on the demands of the direction of the Flexi-bar to neutralize the twisting or sagittal torques in two directions of vertical and horizontal, respectively. Since the results of this study are consistent with previous studies, flexi-bar training in these subjects is clinically beneficial due to the higher muscle co-contraction in subjects with LBP. This may put them at risk for compressive force and increased muscle fatigue during exercise, therefore the prescription should be done with more caution.

Future research is needed to investigate the trunk muscle activation and relationship with postural stability in various directions of the flexi-bar in Long-term training. Also, evaluating the new training with this device to improve low back pain is essential from the clinical point of view.

Limitations exist in the current study; First of all, the results of this study refer to the immediate effect of the flexi-bar exercise, therefore the implementation of the long-term effect on the trunk muscle pattern of LBP people is unclear. Second, it is difficult to generalize the obtained results due to the small number of participants.

Fatigued, MVC is more critical in people affected by motivational effects, such as fear, encouragement, and psychological problems, in patients with LPB who are being evaluated and maybe not show the actual MVC.

Ethical Considerations

Compliance with ethical guidelines

This study was consistent with the principles of the Declaration of Helsinki, and the Ethical Board of the Medical Sciences, Faculty of Tarbiat Modares University approved the study (Code: D52/6710).

Funding

This work was supported by the research vice-chancellor of Tarbiat Modares University, Tehran, Iran (Grant Number: Med13999).

Authors' contributions

Study concept and design: Mona Herasi, Sedighe Kahriziand Maryam Hoviattalab; Analysis and interpretation of data and writing-original draft preparation: Mona Herasi and Sedighe Kahrizi; All authors read and approved the final manuscript.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

This study was supported by the Tarbiat Modares University, Tehran, Iran.

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