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Electromyographic activity and cocontraction of trunk muscles during exercises performed with an oscillatory pole: an analysis of the effect of different postures

Atividade eletromiográfica e cocontração dos músculos do tronco durante exercícios realizados com haste oscilatória: uma análise do efeito de diferentes posturas

Actividad electromiográfica y co-contracción de los músculos del tronco durante ejercicios con barra oscilante: análisis del efecto de diferentes posturas

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ABSTRACT | This study aimed at analyzing the electromyographic activity (EMG) and cocontraction of torso muscles during exercises with a flexi bar, in two different postures (neutral pelvis and posterior pelvic tilt). 20 young women with no lower back pain took part in the study (ages between 18 and 28 years) and they were recruited from a university population. In order to collect the data, an exercise was performed with a flexi bar being held with both hands. It was perpendicular to the ground and it was oscillating in the sagittal plane. That exercise was conducted in two different pelvis postures (neutral and posterior tilted). The EMG signals were collected bilaterally on the following muscles: internal oblique (IO), rectus abdominals (RA), iliocostalis lumborum (IL) and multifidus (MU). The analysis of variance (ANOVA) of repeated measurements was found to display an interaction between muscles and postures (F=5.18; p=0.003). The activation of IL muscle in the neutral posture was 7.93% higher than in the posteriorly tilted posture (p=0.005), and the activation of IO muscle was 13.62% higher in the posteriorly tilted posture than during the exercise in the neutral posture (p=0.002). According to our results, the performance of the exercise with a posteriorly tilted pelvis increased the activation of IO muscle, whereas IL muscle was found to have a higher activation when the exercise was performed in a neutral posture. Future studies need to be conducted in order to understand the neuromuscular adaptations that are generated by exercises with flexi bars, and their relevance to the prevention and treatment of nonspecific lower back pain.

Keywords | Electromyography; Physical Therapy Modality; Applied Kinesiology; Lower Back Pain.

RESUMO | O objetivo deste estudo foi analisar a atividade eletromiográfica (EMG) e cocontração dos músculos do tronco durante a realização de exercícios com haste oscilatória em duas diferentes posturas (pelve neutra e pelve em retroversão).Participaram do estudo 20 mulheres jovens (idades entre 18 e 28 anos),sem dor lombar, recrutadas em uma população universitária. Para a coleta de dados foi realizado um exercício com haste oscilatória posicionada verticalmente ao solo, sendo segurada com ambas as mãos e oscilando no plano sagital. Este exercício foi realizado em duas diferentes posturas da pelve (neutra e retrovertida). Os sinais EMG foram coletados bilateralmente, sobre os músculos: oblíquo interno (OI), reto abdominal (RA), iliocostal lombar (IL) e multífidos (MU). A análise de variância (ANOVA) de medidas repetidas demonstrou

A study developed in the Musculoskeletal Evaluation Laboratory of the Philosophy and Science School of Universidade Estadual Paulista (UNESP) – Marília (SP), Brazil.

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interação entre músculos e posturas (F=5,18; p=0,003), sendo que a ativação do músculo IL na postura neutra foi 7,93% maior do que a postura retrovertida (p=0,055), e a ativação do músculo OI foi 13,62% maior na postura retrovertida do que durante o exercício em postura neutra (p=0,002). De acordo com os nossos resultados, a realização do exercício em postura com retroversão da pelve aumentou a ativação do músculo OI, enquanto o músculo IL apresentou maior ativação durante a realização do exercício em postura neutra. Futuros estudos são necessários para o entendimento das adaptações neuromusculares geradas pelo treino com exercícios com haste oscilatória e sua relevância para a prevenção e tratamento da dor lombar inespecífica.
Descritores | Eletromiografia; Modalidade de Fisioterapia; Cinesiologia Aplicada; Dor Lombar.

RESUMEN | Este estudio tuvo por objetivo analizar la actividad electromiográfica (EMG) y la co-contracción de los músculos del tronco durante el ejercicio con barra oscilante en dos posturas distintas, la pelvis neutral y la en retroversión. Participaron veinte mujeres entre los 18 hasta los 28 años de edad, sin dolor lumbar, reclutadas en una universidad. La recolección de datos se realizó por un ejercicio con barra oscilante, que colocada verticalmente al suelo, podría ser agarrada por ambas manos de las participantes y, así, oscilar en el plan sagital. Las señales EMG se recogieron de forma bilateral en los músculos oblicuo interno (OI), recto abdominal (RA), iliocostal lumbar (IL) y multifidus (MU). El análisis de la varianza (ANOVA) de las medidas repetidas mostró interacción entre músculos y posturas (F=5,18, p=0,003), siendo que la activación del músculo IL en la postura neutral fue un 7,93% mayor que en la postura en retroversión (p=0,055) y la activación del músculo OI fue un 13,62% mayor en la postura en retroversión que durante el ejercicio en la postural neutral (p=0,002). Con respecto a los resultados, el ejercicio realizado con la postura en retroversión de la pelvis aumentó la activación del músculo OI, mientras que el realizado con la postura neutral aumentó la activación del músculo IL. Es necesario que se hagan futuros estudios para comprender mejor las adaptaciones neuromusculares generadas por el entrenamiento con ejercicios con barra oscilante y su importancia para la prevención y el tratamiento del dolor lumbar inespecífico.
Palabras clave | Electromiografía; Modalidad de Fisioterapia; Quinesiología Aplicada; Dolor Lumbar.

INTRODUCTION

Nonspecific lower back pain is characterized as one of the musculoskeletal dysfunctions which affect adult people the most, which leads to a high cost for health care and social security systems[1,2]. Among the probable causes which are the most mentioned for the onset of nonspecific lower back pain is the reduced stability in the lumbar area[3].

Lumbar spine stability is maintained through the interconnected actions of three sub-systems: the active, the passive, and the neural feedback system[4,5]. The active sub-system is the first mechanism which is triggered to stabilize spine segments when external disturbances occur[4,5]. This sub-system, which is composed of the torso muscles, bay be subdivided, according to its anatomical and functional characteristics, in local muscles, such as the multifidus, the transverse abdominal muscle (TrA), and the internal oblique (IO), which are inserted in the lumbar vertebrae and stabilize the vertebral segments; and global muscles, such as the rectus abdominis (RA), the external oblique (EO), and the iliocostalis lumborum (IL), which are inserted in different anatomical points in the vertebrae, and are capable of generating very long movements[8].

Previous studies indicated exercises which promote the activation of torso-stabilizing muscles, such as the IO and the MU, in order to treat and prevent nonspecific lower back pain[9]. Among the several physical exercise techniques that have been recently proposed to promote the cocontraction and training of the lower back-stabilizing muscles are the exercises with flexi bars[10]. In that kind of exercise, unlike the exercises that are performed on vibrating platforms, the vibration of the rod is produced through the contraction of the muscles in the upper segment, and it is transmitted to the whole body of the person performing ht exercise[11]. Thus, the oscillation of the rod promotes disturbances on the core of the person performing the exercise. In order to maintain both core and lumbar stability, such person resorts to posture adjustments, such as contracting the deep muscles of the abdomen, such as the TrA and the OI[10,12,13].

Besides the possible mechanism to recruit the torso-stabilizing muscles, the current literature also has important findings on factors which must be observed in order that exercises with flexi bars be prescribed[10,12-15]. According to the study by Gonçalves et al.[15], the activation of the torso-stabilizing muscles

(IO and MU) is increased with the use of a flexi bar, as compared to the performance of the same exercise through the use of a rigid bar. The rod oscillation plane results in changes in the pattern through which muscles are recruited, and it may or may not favor the activation of the deep muscles of the trunk[10,12-15]. Besides that, performing exercises with a flexi bar in the standing position favors the activation of IO and MU muscles, in relation to a sitting position[10,13,15].

In that sense, considering that the exercise with a flexi bar may be an important clinical tool for physical therapists in the prevention and treatment of nonspecific lower back pain, understanding the factors that interfere in its prescription, such as the posture in which it must be performed, is extremely relevant. Considering that, as far as the authors know, no previous study has mentioned the effect of pelvic posture in the muscle recruitment pattern during exercises with flexi bars, this study aimed at analyzing the electromyographic activity (EMG) and cocontraction of torso muscles during exercises with a flexi bar, in two different postures (neutral pelvis and posterior pelvic tilt). The initial hypothesis of this study is that performing the exercise in the neutral pelvic position may promote a higher activity in the stabilizing muscles, once that during rest (no exercises being performed), in the neutral position, those muscles were found to be more activated[8].

METHODOLOGY

Subjects

20 women, aged 18 to 21 years, with body masses of 56.9±5.1kg, who were 1.68±0.07m tall, and who had body mass indices of 24.9±1.3kg·m^{-2} took part in the study. They had no lower back pain, and had not taken part in physical training for the previous three months. The volunteers who mentioned muscular, tendon, articulatory, or ligamentous injury in the torso or upper limbs in the three previous months were not included in the study.

Equipment

The following equipment was used in the study:

- Flexi bar (Sanny®, São Bernardo do Campo, Brazil), with the following dimensions: 1.50m long, 9.70mm in diameter, and weighing 800g, made of fiberglass and rubber;
- Biological signal acquisition module (Myosystem-Br1P84, Data Hominis®, Uberlândia, Brazil), with a sample rate adjusted to 2000Hz, and total gain of 2000 times (20 times in the sensor and another 100 times in the device).

Procedure

The procedures for the collection of data were conducted in a single day. Initially, the volunteers familiarized themselves with the exercise by using the flexi bar with its oscillation set to 5Hz, through acoustic stimuli from a metronome[10,12,13,15].

After familiarized, volunteers started being prepared for the EMG signal acquisition. Before the electrodes were placed, their skin was shaved, sanded with a fine-grit sandpaper, and cleaned with alcohol, as a way to prevent possible interferences in the electromyographic signal[16]. The electrodes were placed bilaterally on the internal oblique (IO), rectus abdominis (RA), iliocostalis lumborum (IL) and multifidus (MU) muscles[10,16].

The exercises with flexi bars were conducted with volunteers standing, with their shoulders flexed by approximately 90 degrees, holding the bar with both hands in the vertical position and performing the oscillations in the sagittal plane, in two distinct postures (Figure 1): (a) straightened lumbar spine, with posteriorly tilted pelvis and semi-flexed knees; (b) lumbar spine in neutral pelvic position and completely extended knees[8,17].

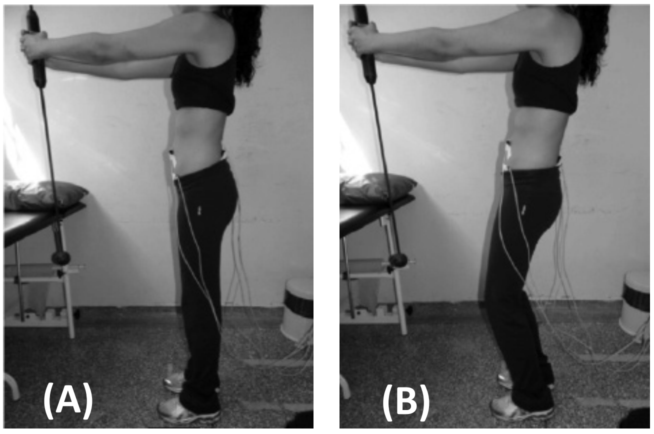

Figure 1. (A). Exercise performed in a neutral posture, (B). Exercise performed in a posteriorly tilted posture, (B)

The order in which the exercises were performed, with the lumbar spine straightened or not, was randomly selected through a simple raffle. The exercises were vperformed in 3 series of 15 seconds, with 1-minute intervals between each series and each exercise.

ANALYSIS OF DATA

The EMG signal was analyzed in specific routines that were developed in a Matlab (Mathworks®) environment. The data were processed through the use of a 20-500Hz band-pass filter. Following that, the signal was rectified with the use of the full-wave rectification method. In order to create the linear envelope, a fourth-order low-pass filter with a 6Hz cutoff frequency, in order to smooth the signal. The EMG signals between the fifth and the tenth seconds of the third series of the exercise were analyzed (Figure 2).

The activation of each muscle was calculated through the average activation during the five seconds that were considered for analysis. The EMG signal was normalized through the peak activation value of the exercise in neutral posture.

Besides that, the linear envelope of EMG signals was used to calculate the antagonist cocontraction between IO/RA and MU/IL muscles, through the use of the following equation[18,19]:

$$\text{Cocontraction index} = 2\ x\ \frac{\text{Common A\&B area}}{\text{A area + B area}}\ x\ 100$$

where the common A&B area represents the common activation area between two muscles, and A and B areas represent the area of each of those muscles.

The statistical package PASW 18.0 (SPSS inc.) was used to conduct the statistical analysis. Shapiro-Wilk test was used for testing the normality of data. Analysis of Variance (ANOVA) was used for repeated measurements, considering muscles, sides, and postures as dependent variables, and the electromyographic activation as the independent variable. Bonferroni's post hoc analysis was used when factors were found to interact with one another. The significance level was adjusted to $p<0.05$.

RESULTS

Significant differences were found in the interaction among muscles and postures (F=5.18 and p=0.003). p=0.002Thus, the activation of IL (Average±SD) was 7.93% higher in the neutral posture as compared to the posteriorly tilted posture (p=0.055), and the activation of IO (Average±SD) was 13.62% higher in the posteriorly tilted posture as compared to the neutral posture (p=0.002, Figure 2). No main posture effects were found for the cocontraction analyses (F=0.896 and p=0.404).

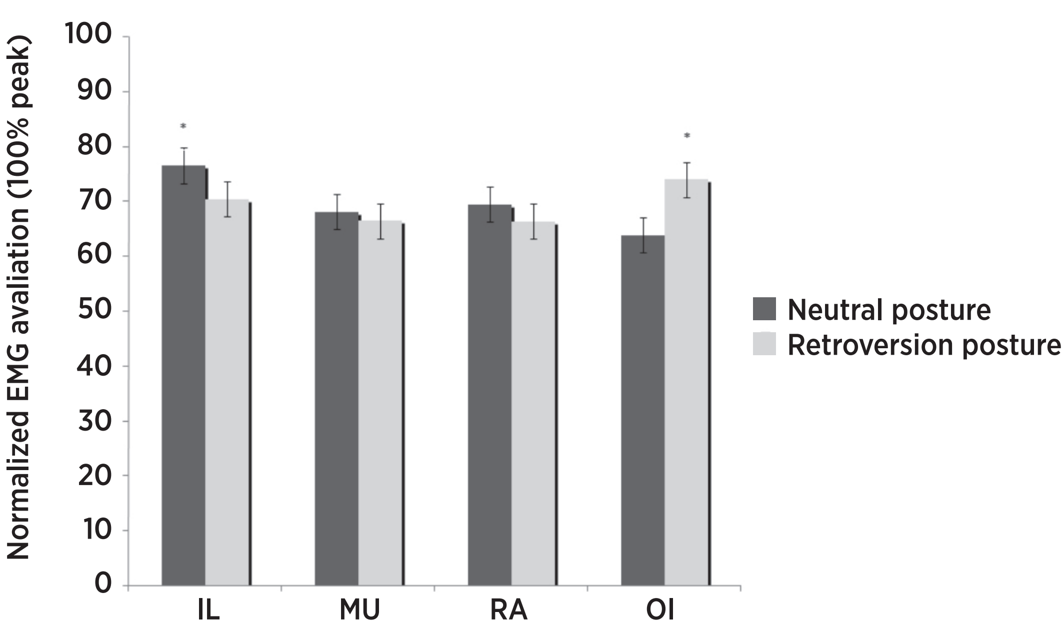

Figure 2. Average and standard deviation of the activation of torso muscles during the exercises. IL = iliocostalis lumborum; MU = multifidus; RA = rectus abdominis; and IO = internal oblique. (*) Significant difference

DISCUSSION

This study aimed at analyzing the EMG activity and the contraction of torso muscles during exercises with a flexi bar, in two different postures (neutral pelvis and posterior pelvic tilt). The most relevant result in this study was the fact that IO muscle was 13.62% more recruited during the exercise in the posteriorly tilted position as compared to the exercise that was performed in the neutral posture. On the other hand, the IL muscle was found to have an EMG activation that was 7.93% higher during the exercise in the neutral posture. In that sense, our results refute the initial hypothesis of this study, as, unlike what was expected, there was increased Io activation during the exercise that was performed with a posteriorly tilted pelvis, and increased IL muscle activation during the exercise with a neutral position.

Previous studies provided two different ways to understand the effects of exercises with flexi bars in the lumbar spine stability. According to Anders et al.[12], a single muscle group (OI, MU, and TrA), has the exclusive function of promoting stability, whereas another muscle group – called global (RA and IL) is uniquely responsible for generating torque and torso movements[12]. Marques et al.[10], Moreside et al.[14], and Gonçalves et al.[15] indicated that the (standing or sitting) posture in which the exercise is performed, and the oscillation plane of the bar modify muscle recruitment and cocontraction. Thus, lumbar spine stability is not only provided through the action of local muscles, but rather by the joint action of all torso muscles. Our results corroborate the ones from Marques et al.[10], Moreside et al.[14], and Gonçalves et al.[15], once the activation for both the local muscle (IO) and the global muscle (IL) was modified according to the alterations in pelvis positioning.

The IL muscle is inferiorly inserted into the dorsal sacrum side, and the IO muscle is inferiorly inserted into the region of the iliac crest and the anterior superior iliac spine[20]. Therefore, the pelvic position may alter the length of those muscles, thus contributing to or hindering the muscle contraction efficiency. The higher activation of IL muscle during the exercise that was performed in a neutral posture is possibly related to the fact that, in that position, the muscle is in an optimal length-tension relationship in order to generate torque, and, therefore, its activation may promote increased stability to the spine in the sagittal plane.

For the IO muscle, we suggest that the performance of exercises with flexi bars in the posture with a straight lower back puts the pelvis into a more unstable position. That takes place because some lumbo-pelvic stabilizing muscles, such as the iliopsoas and the IL muscles are stretched, which reduces the contraction efficiency of those muscles to generate force. In that sense, the higher IO muscle recruitment during the performance of exercises in the posteriorly tilted pelvic posture occurred in order to offset the reduced stabilizing efficiency of other muscles in the lumbo-pelvic region. Besides that, in the posteriorly tilted pelvic position, the center of mass is displaced from its position of balance, thus adding an increased challenge for torso stability[20].

The relationship between the pelvic positioning and the EMG activation of torso muscles was previously studied during rest, in standing, and sitting positions, by O'Sullivan et al.[8,17]. According to those authors, in both postures, the neutral pelvic position was the one to favor the most the recruitment of torso-stabilizing muscles (IO an MU) as compared to the position with a posteriorly or anteriorly tilted pelvis. That took place as, in the neutral pelvic position, there is decreased action of passive tissues (fasciae, ligaments, etc.) for spine stabilization. Thus, the results in this study are not in agreement with the results found by O'Sullivan et al.[8,17].

Despite that, as far as the authors know, no previous studies have evaluated EMG activation during exercises with flexi bars in different pelvic positions, Marques et al.[10], Anders et al.[13], and Gonçalves et al.[15] demonstrated that IO activation in the standing posture was higher than the one in the sitting posture during the performance of exercises with flexi bars. According to those authors, there was higher IO activation, as in the standing position, the pelvis is more unstable, which implies in a higher muscular action in order to maintain stability[10,13,15]. Thus, the possible explanation for our results not to corroborate the studies by O'Sullivan et al.[8] and O'Sullivan et al.[17] is that, besides the instability that is caused by the standing posture, the posteriorly tilted pelvic position and the oscillation of the bar added challenges to spine stability, thus altering the muscular recruitment responses.

This study is an initial investigation on the effect of pelvic position on the recruitment of torso muscles during the performance of exercises with flexi bars. Thus, based on our results, it is possible to state that the positioning of the pelvis may later the muscular recruitment pattern. However, it is not possible to determine which pelvic position - neutral or posteriorly tilted - is the one that is the most indicated for the prevention and treatment of lower back pain, nor whether the adoption of the posteriorly tilted pelvic position during the performance of exercises with flexi bars may result in any kind of overload to the lumbar spine. Therefore, further investigation is necessary in order to contribute to the understanding of the most adequate pelvic positioning to the performance of exercises with flexi bars and their possible effects in the prevention and treatment of lower back pain.

Constraints

The results of this study refer to the muscular activation responses from young and healthy people with no lower back pain, which limits the use of our results with other populations. Besides that, only one kind of exercise was tested, which suggests the need for further studies which investigate the effect of exercises with flexi bars, as performed in different pelvic positions and with bars oscillating in different planes of movement in the muscular recruitment of the torso.

CONCLUSION

According to our results, the performance of exercises with flexi bars in a posteriorly tilted pelvic position increased the activation of the muscle IO, whereas the performance of exercises with flexi bars in a neutral pelvic position increased the activation of IL. In that sense, this study demonstrated that the positioning of the pelvis may alter the muscular recruitment pattern of the torso. Therefore, further investigation is necessary in order to contribute to the understanding of the most adequate pelvic positioning for the performance of exercises with flexi bars and their possible effects in the prevention and treatment of lower back pain.

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