MUSCULAR SYNERGISM DURING CORE STABILITY EXERCISES

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The aim of this study was to compare the myoelectric activity and synergism of Core region muscles among exercises commonly prescribed for Core training. The myoelectric activity of seven men was collected and the activation ratio among lumbar erector spinae (LES), lumbar multifidus (MT), external oblique (EO) and rectus abdominis (RA) were compared among eight exercises. The results suggest that EO has higher activation during frontal bridge, side bridge and “bird dog” exercises, RA has higher activation during frontal and side bridge, while LES and MT demonstrated higher activation during “bird dog” and double leg and single leg back bridge. We concluded that to train all muscles groups in a synergic way, in different postures, it should be prescribed at least one variation of the exercises that presents the flexor, lateral flexor and extensor pattern.

KEYWORDS: Biomechanics, Motor Behavior, EMG, Muscular Synergism, Core Training.

INTRODUCTION: The Core region functions as a “muscle belt” that stabilizes the lumbo-pelvic region, with or without the presence of upper and/or lower limbs movements (Kavcic et al., 2004). Besides being responsible for the lumbar and thoracic spine stabilization, it allows mobility and more efficacious upper and lower limbs force production and transfer (Akuthota & Nadler, 2004). It also acts as the center of the biokinematic chain in most daily and sport activities. The training of this region has been adopted by the community in order to increase athletic performance, as well as for clinical purposes in order to prevent and rehabilitate orthopedic injuries (Nadler et al., 2002, Tse et al., 2005, McGill & Karpowicz, 2009).
The term "stabilization exercise" has been used to denote any form of exercise that challenges stability of the spine, while muscle recruitment patterns, static and dynamic postures are trained (Akuthota & Nadler, 2004). The active stability is provided mainly through co-contraction of muscles present in this region to alleviate the overload on the trunk (McGill, 2007). Despite the importance in understanding the strategies of trunk stabilization provided by these muscles, Kavcic et al. (2004) reported that few studies have assessed the activation and muscle co-contraction during different core stability exercises. Thus, the purpose of this study was to compare the myoelectric activity and synergism of Core region muscles among exercises commonly prescribed for strengthening and stabilizing core region.

METHODS: Seven men experienced in strength and core training (body mass: 78.8 ± 10.5kg, height: 180.3 ± 7.8cm, age: 27 ± 6 years) participated in the study. The myoelectric activity of Lumbar Erector Spinae (LES), Multifidus (MT), External Oblique (EO) and Rectus Abdominis (RA) was collected (BIOPAC Systems Inc., California) during the execution of eight core stability exercises commonly prescribed (Table 1). Each exercise was performed in randomized order for 30 seconds with 5 minutes rest among them. The signals were filtered by a fourth order Butterworth filter, with cutoff frequencies of 20Hz and 400Hz. RMS values were obtained, at each 5ms signal, for 10 seconds (range 5 to 15 seconds) and normalized by the greatest RMS value obtained during two maximal voluntary isometric contractions (MVIC), in positions of flexion, for RA, extension to the LES and MT, and lateral flexion of the trunk, for the EO. The muscle synergism between couples of muscles was calculated by dividing the value of normalized myoelectric activation in the following conditions: EO/RA, EO/LES, EO/MT, RA/LES, RA/MT, LES/MT. The values of synergism and values of each individual muscle were compared among exercises through the Friedman's non parametric test of analysis of variance with repeated measures and Dunn's post-hoc tests. The level of significance was set at 5%.

Table 1. Name, legend and figure of the exercises used in this study.

Exercise	Frontal Bridge	Right Side Bridge	Left Side Bridge	"Bird Dog"*	"Bird Dog"**	Right Single Leg Back Bridge	Left Single Leg Back Bridge	Double Leg Back Brigde
Legend	FB	RSB	LSB	BDRA	BDLA	RBB	LBB	DBB

* Performed with right arm and left leg lifted;
** Performed with left arm and right leg lifted;

RESULTS: The statistical test detected differences in the EO/RA synergism (p = 0.0002) and post-hoc test showed that these differences occurred between LSB and BDLA, RBB and BDLA, DBB and BDLA. For the EO/LES synergism statistical test also detected significant differences among exercises (p <0.0001), and the post hoc test showed differences between FB and RSB, FB and DBB, RSB and DBB. The analysis of variance detected differences in EO/MT synergism (p <0.0001) and post hoc test revealed that these differences were present between the exercises FB and RBB, FB and LBB, FB and DBB, RSB and DBB, LSB and DBB, BDLA and DBB. In relation to the synergism of RA with LES (RA/LES) and MT (RA/MT) significant differences were identified (p <0.0001). The post hoc test identified that the significant differences between the exercises were similar in both situations (FB and LBB, FB and DBB, RSB and DBB, LSB and DBB) with the exception of the condition FB and BDLA, which were not identified differences in the RA/MT synergism. For the LES/MT synergism were not found statistically significant differences (p = 0.3704). Analyzing the individual muscles, all of them showed statistical significant differences. For the EO the Dunn's test detected differences between the situations RSB and FB, DBB and FB, RBB and RSB, RSB and DBB, BDLA and DBB (p <0.0001). For the RA (p <0.0001) post hoc test showed differences in the situations FB and LBB, FB and DBB, RSB and LSB, RSB and DBB. For LES (p = 0.0002), the post hoc test identified differences between the situations FB and RSB, FB and RBB, FB and BDLA, LSB and RBB. MT (p <0.0001) showed differences between the situations FB and RSB, FB and BDLA, FB and LBB, RSB and LSB (Table 2).

Table 2. Values, described as mean (standard error), of the synergism in the six situations and individual myoelectric activity of the four muscles in each exercise. In the right column the p values are presented. Similar symbols below each row represent significant differences between two exercises.

	FB	RSB	LSB	BDRA	BDLA	RBB	LBB	DBB	P value
EO (%)	65.5 (16) * &	52.5 (11.5) * % ^	9.5 (2.6)	9.6 (3.3)	36.6 (6.9) #	6.0 (1.6) %	10.5 (2.7)	2.6 (0.6) & ^ #	<0.0001
RA (%)	33.5 (7.8) * &	40.0 (13.5) # ^	10.8 (2.8) #	5.5 (1.2)	6.0 (1.7)	8.1 (3.2)	5.7 (2.0) *	3.5 (1.1) & ^	<0.0001
LES (%)	5.0 (1.3) * & #	37.2 (5.5) *	7.5 (1.3) ^	31.1 (6.5)	38.6 (6.2) #	42.1 (7.9) & ^	34.7 (2.3)	33.1 (4.1)	0.0003
MT (%)	4.2 (0.6) * & #	37.8 (7.5) * %	6.5 (0.7) %	19.5 (4.1)	35.9 (7.5) &	24.7 (3.5)	30.9 (4.5) #	25.4 (2.9)	<0.0001
EO/RA	2.3	2.9	1.3	2.3	7.9	1.1	2.4	1.1	0.0003

	(0.7)	(1.5)	(0.7) *	(1.1)	(2.3) * & %	(0.3) &	(0.8)	(0.5) %	
EO/LES	12.7 (6.5) * &	1.4 (0.3) * %	1.0 (0.3)	0.3 (0.1)	1.0 (0.2)	0.1 (0.0)	0.3 (0.1)	0.1 (0.0) & %	<0.0001
EO/MT	15.6 (2.4) * & %	1.4 (0.1) #	1.3 (0.3) $	0.5 (0.1)	1.1 (0.2) ^	0.2 (0.1) *	0.3 (0.1) &	0.1 (0.0) ^% #$	<0.0001
RA/LES	7.5 (3) * & %	1.6 (0.7) #	1.6 (0.3)	0.2 (0.1)	0.2 (0.1) %	0.2 (0.1)	0.2 (0.1) *^	0.1 (0.0) & # ^	<0.0001
RA/MT	8.7 (1.7) * &	1.1 (0.3) #	1.6 (0.4)	0.3 (0.1)	0.2 (0.0)	0.3 (0.1)	0.2 (0.0) * ^	0.1 (0.0) & # ^	<0.0001
LES/MT	1.8 (0.4)	1.1 (0.2)	1.2 (0.2)	1.6 (0.2)	1.2 (0.2)	1.7 (0.3)	1.2 (0.2)	1.3 (0.2)	0.3704

DISCUSSION: In this study we compared the myoelectric activity and muscle synergism among various abdominal and trunk extensors exercises and our findings are comparable and similar to the study of Kavcic et al. (2004) with respect to the main exercises that activate trunk flexors and extensors. The exercises FB, RSB, LSB demonstrated a flexor pattern, while the exercises BDRA, BDLA, RBB, LBB and DBB showed an extensor pattern (Kavcic et al., 2004).

During the BDLA it was verified that the EO has a significant activation (36.6%), which demonstrates the importance of this muscle during asymmetric activities. We postulate that these results are related to the oblique pennation angle of the fibers of this muscle, which was ratified by the small actions of RA, which has a more longitudinal angle of pennation (Oatis, 2008). The differences between the EO/RA synergism occurred in the exercises that there are a predominance of the extensors muscles, which was expected since the RA is an antagonistic to these muscles and EO is not. Only in the LBB and BDRA, characterized by an extensor pattern, we did not find differences due to the low recruitment of EO.

The RSB was that exercise that required high muscle activity of both flexors and extensors of the right side, however, LSB did not demand high activity of these muscles. This suggests that these exercises have an unilateral dominance of muscle recruitment that could be an important ally in the correction of asymmetries of strength and power between the right and left sides (McGill et al. 1999).

Although the analysis of muscle synergy is essential for the initial understanding of the strategies of lumbar stabilization, the study of the activity of individual muscles is also significant because the lumbar stability is achieved with low percentages of activation, about 20% to 40% of maximum (McGill, 2007).

The RSB and FB were the exercises that required greater activation of the abdominal muscles, reaching percentages from 50% to 65% for EO and 30% to 40% for RA. Thus, we believe that training these exercises should be recommended only for experienced individuals, since the high muscle activation can modify the stability of lumbar spine leading to premature fatigue. The recommendation would be that for untrained individuals such exercises are initiated with the knee on the ground, to decrease the lever arm. The training of the muscle EO, should be preceded by bird dog exercise prior to such exercises (RSB and FB), since all the active muscles remained within the recommended levels (around 30% of maximum) for training the lumbo-pelvic stability (McGill, 2007).

In the exercises RBB and LBB the muscle activity of MT and LES remained within the recommended range, but the participants reported a high rate of subjective effort, especially in the gluteus and back thigh regions. Therefore, it would be advisable to prescribe bilateral exercises (DBB) initially, since the activity of lumbar muscles is similar regardless the

number of mechanical constraints. The exercises BDRA and BDLA were active within the recommended range.
Future studies with the inclusion of exercises on unstable surfaces and in other populations, as untrained beginners, could be very valuable to complement the data obtained in this study.

CONCLUSION: We conclude that in order to train all muscle groups synergistically in different postures at least one variation of exercises that show a flexor pattern (FB, RSB), a variation of exercises that presents a lateral flexor pattern (FB, RSB and BALA) and exercises that have an extensor pattern (RBB, LBB and DBB) should be performed. Among the possible variations, it could be included a decrease of the lever arm of the exercises, for example, with the knee on the ground during frontal and lateral bridge. The aim of these changes is to develop a pedagogical progression, which allows the inclusion of exercises with greater ease in the early stages of training. This would allow adaptation to training stimuli in a less harmful manner to the lumbar spine.

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