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ASSESSMENT OF PARAVERTEBRAL MUSCLES'S BEHAVIOR FOLLOWING CORE TRAINING – A TOOL IN THERAPY OF LUMBAR SPINE PATHOLOGIES

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Abstract: *Complex and heterogeneous disorders of lumbar spine are frequently encountered. This study presents in three active adults the muscular behaviour after a CORE training on lumbar spine (tracking the immediate effect) using Myon surface EMG tool associated to VICON system capture of motion. Results suggest that Core training improve muscle function, potentially benefits for physiotherapy practice both the prophylactic and the therapeutic intervention for lumbar spine pathologies. This type of training is worthy to be integrated and applied in the current physiotherapeutic practice, to target the muscles responsible for trunk and spine stability and mobility.*

Key words: *CORE training, therapy of lumbar spine pathologies, surface EMG*

1. Introduction

Low back pain (LBP) is considered among the pathologies that occur in almost every age, caused by different activity or the lack of activity. In the case of LBP the muscles changes in structure and dimensions. In the case of recurrent or acute nonspecific pain, atrophy of the multifidus and paraspinalis occurs, with fat infiltration in subjects with chronic pain [3] [4], the multifidus muscles being smaller with significant fat infiltration [13]. Ranger et al. [11] indicates that cross-sectional area of multifidus may be a predictor of LBP [2]. Atrophy of this muscle accompanied by an increased fat infiltration has been associated with LBP and lumbar radiculopathy [9] or chronicity of the condition [7]. Although imagistic methods are accurate, in clinical practice, the quantification of these indices does

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not provide answers in the case of young subjects with lumbar pain and no other symptoms of LBP.

1.1. Core training

Approximately 90% of LBP are nonspecific and with unknown cause, subjects having muscular weakness in hip adductors, Core muscles and back extensors; therefore, hip muscle stretching and CORE stretching exercise (CSE) are effective for improving trunk stability in subjects with non-specific LBP [6]. Core training is mainly used as a training method in commercial fitness; the application of this type of training not being applied in clinics by physiotherapists for LBP subjects.

According to Zemková [14] a better understanding of power-force-velocity profiles during core-intensive exercises has implications for the design of sports training and rehabilitation programs to improve athlete performance and/or reduce the risk of LBP. Balance and CORE stabilization exercises have often been associated with improved athlete performance and decreased injury incidence [15].

Analysing the effectiveness of different exercise models, Pilates did not improve functionality or relieve pain in LBP compared to CSE [10], Searle et al. [12] showed that Core strength training is superior to other therapeutic exercise programs, with a beneficial effect on pain relief and decreased disability.

Despite the multitude of research on LBP, some researchers underline the lack of clinical studies regarding of intervention superiority, an aspect often attributed to the fact that the design of most clinical trials includes the delivery of a single intervention to a heterogeneous group of subjects with LBP [1]. Choosing the most effective types of exercises for LBP remains controversial and a topic that requires further research [8].

2. Study Objectives

The premise from which study started is to clarify the role that CORE training plays in stabilizing the lumbar spine and how muscle behaviour is influenced during a common functional activity such as walking. The evaluation wants to capture what happens at the muscle level, actively, dynamically the muscle activation process and its symmetry with implications for the prophylaxis and combating the occurrence of LBP conditions.

The objective of the study was to assess the behaviour of the lumbar paravertebral muscles on 3 healthy subjects via EMG before and after performing a Core training, tracking the immediate effect in view of the subsequent application of such a program. Thus, we compared right-left symmetry indices and recorded myoelectric activity during gait.

The hypotheses from which this pilot study started were that: implementing a Core training program influences paravertebral muscle balance in daily activities; is there different paravertebral muscle behaviour depending on the phases of gait?

3. Material and Methods

The measurements were performed in the Laboratory of Innovative Techniques and Processes in Bioengineering, at the Research Infrastructure in Applied Sciences (INCESA www.incesa.ro).

The EMG results were analysed descriptively, correlations of the evolution of the paraspinal symmetry index with the phases of gait were made, with their graphic representation.

Electromyographic analysis method with a Wireless EMG recording was performed with the Myon equipment connected to the VICON motion analysis system, which allows for simultaneous EMG signal collection. Four surface electrodes with superior adhesion and large contact surface, to ensure an accurate recording of the EMG signal, were placed on the lumbar paraspinal muscles, two on each side of the spine, in the region corresponding to the L5 vertebra. For the L3-L4-L5 muscles, electrodes were positioned parallel to the spine. Myon wireless sensors were attached to the back with adhesive tapes, ensuring they were charged.

Besides this assessment of the muscular behaviour with EMG, during gait, we also performed a collection of kinematic data during walking using the VICON motion analysis system. Thus, an analysis of EMG data corresponding to the gait cycles was obtained. For this purpose, specific VICON markers were attached to the analysed subjects, which correspond to the plug-in gait model for the lower limb, thus performing a kinematic analysis of walking, which allows defining the phases of walking simultaneously with the EMG recording at the level of the lumbar paraspinal muscles.

The purpose of EMG recordings was to estimate left-right muscle imbalance by assessing the muscle strength (mV) of the spinal extensor muscles. EMG recordings were performed before and after the training program, analysing muscle behaviour in correlation with the phases of gait, EMG signals were collected during 3-5 gait cycles.

Core training program was based on the principles of physical training characterized by 3 parameters: *intensity, duration and frequency*, but in this study only reference was made to intensity and duration. The program was applied in a single session, and was preceded and followed by EMG recordings, before and after the program, during gait (Table 1).

General objectives for this training consist in Core muscular force development, increasing and maintaining flexibility for the trunk and lumbar spine. The chosen physical exercise program respected the principle of the 3 periods - warm-up, the actual strength CSE exercises program and cool-down, proposing as component elements of each period various types of stretching and complex postures.

Fig. 1. *Positioning of VICON plug in gait system markers and lumbar EMG electrodes recording during gait*

The applied Core training program Table 1

Program	*Warm-up* For each Ex: hold position for 10-15 seconds Sets: 2, 20-second breaks between sets	*Ex CSE type* Each ex 10 repetitions Sets: 3, 10-second breaks between sets	*Cool-down* 5-10 minutes
Specific objectives of those exercises	Improvement of flexibility, mobility by improving muscular blood flow and connective tissue extensibility.	Improvement or control of muscle contractures, posture deficits, static posture, flexibility and mobility of the spine. Correct muscle strength imbalance and asymmetries, improving static / dynamic balance / motor control, posture re-education, improving coordination / control of the back muscles.	Relaxation, return to normal after physical exertion, with the normalization of physiological parameters such as pulse, blood pressure, breathing
Exercises	*Stretching* for a correct posture, in supine stabilizing of core thru elongations (C stretch, W-exercises) in siting (for lower and anterior torso), lunges, round back squat from upright *Flexibility stretching* for back muscles, hips+ lower limbs combined with circular movements (ex. Cobbler stretch, advancing frogs)	*Trunk extensions* from prone position for trapezius, erector spinae, latissimus dorsi *Arm - opposite leg extensions* from prone position for back and thigh muscles *Arm - opposite leg extensions* from quadruped in 3 times for back and thigh muscles.	Stretching for the calfs, hamstrings, quadriceps, hip flexors, iliotibial band, shoulders, neck.

4. Results and Discussions

Analysis and interpretation of results included a descriptive analysis of the data recorded by EMG, but also an analysis of the behaviour of the paraspinal muscles corresponding to the phases of gait. The presentation of the results is carried out through case studies, adopting the procedure of conducting a pilot study to verify the effect of a Core training on the lumbar paraspinal muscles, by interpreting the left/right symmetry index in gait.

Results of the recordings (EMG). ***EMG values in gait***. The recordings were made during 3-5 gait cycles, variable, because the average gait speed was 1.24-1.34m/s, the recording frequency was 1000Hz.

The obtained values of the left/right symmetry index [mV], measured with EMG (mV), for gait activity, in the 5 phases of gait and the average values are presented in tables 2,3.

Average values of the left/right symmetry index [mV]

Table 2

Gait phase	**SUBJECT 1**				**SUBJECT 2**				**SUBJECT 3**			
	Before exercise		**After exercise**		**Before exercise**		**After exercise**		**Before exercise**		**After exercise**	
	Right Side	**Left Side**	**Right Side**	**Left Side**	**Right Side**	**Left Side**	**Right Side**	**Left Side**	**Right Side**	**Left Side**	**Right Side**	**Left Side**
1	0.0001350	0.0001330	0.0001708	0.0001673	0.0001000	0.0001010	0.0000944	0.0000988	0.0001160	0.0001140	0.0000991	0.00001260
2	0.0001290	0.0001240	0.0001673	0.0001702	0.0000964	0.0000919	0.0001150	0.0000878	0.0001050	0.0001050	0.0001370	0.0001030
3	0.0001550	0.0001400	0.0001671	0.0001637	0.0000984	0.0001140	0.0001130	0.0001030	0.0000996	0.0000927	0.0001020	0.0001080
4	0.0001310	0.0001210	0.0001655	0.0001628	0.0000983	0.0001023	0.0001075	0.0000965	0.0001041	0.0000897	0.0001170	0.0001100
5	0.0001210	0.0001310	0.0001641	0.0001638	0.0001000	0.0001010	0.0000944	0.0000988	0.0001065	0.0001220	0.0001100	0.0001180
Me-diate {mV]	**0.0001342**	**0.0001298**	**0.0001670**	**0.0001656**	**0.0000964**	**0.0000919**	**0.0001150**	**0.0000878**	**0.0001042**	**0.0001047**	**0.0001130**	**0.0001144**
Sym-metry left/ right	**0.96**		**0.99**		**1.04**		**0.898**		**1.004**		**1.012**	

Table 3. Values of symmetry indices during gait phases

Symmetry indices report before / after exercises	**SUBJECT 1**	**SUBJECT 2**	**SUBJECT 3**
Right side	0.80	0.91	0.922
Left side	0.78	1.05	0.914

In Subject 1 we observed an increase of the average values of the maximum amplitude and an increase of the average value of the symmetry index (we considered that the value 1 corresponds to a left/right symmetry), from 0.96 to 0.99, which signifies a favorable response, although in this case the value below 1 indicates the existence of a greater force on the right side, which correlates with the evolution of the average value of the maximum amplitude, which shows the existence of a lower force before performing the program, on the right side. It can be observed that on the left side the ratio is lower compared to the right side, with a decrease in force, but which improves after performing the Core program.

In subject 2, we found that the average amplitude value is increased post-workout, at the level of the right side, while it decreases at the level of the left side. The left/right symmetry has a value above 1, before the Core program being 1.04, which signifies an imbalance in the sense of the existence of a greater force on the left side, while after performing the program the symmetry index decreases, reaching 0.898, therefore there is a balancing tendency based on the increase in force at the level of the left side. Analyzing the unilateral ratio before and after applying the Core program, it is seen that at the level of the right-sided muscles there is a better evolution, with a value close to 1, while at the level of the left-sided muscles a decrease in force is observed.

In the case of subject 3, the evolution is also specific, the average values of the maximum amplitude have increased values after applying the Core program, the left/right symmetry indices have values above 1 both before and after the Core program, which signifies the existence and preservation of a left/right imbalance in favor of the left side, from 1.004 to 1.012.

Variations in the symmetry index and the phases of gait

Since walking is a daily activity, it was considered useful to create a graphic and value representation of the evolution of the symmetry index in relation to the phases of gait, considering as phases of gait, the double support phase (with three subphases - double support 1, unipodal support, bipodal support 2) which represents 60% of the duration of a gait cycle, and the balance phase which represents 40% of the duration of a gait cycle (Figure 8).

Variations of the left/right symmetry index, measured with EMG (mV), during gait phases, for the three subjects are presented below, regarding the evolution of the symmetry index during a gait cycle, for the three subjects, before and after applying the Core program. *Subject 1*-Figures 2 and 3, *Subject 2* -Figures 4 and 5, and *Subject 3* -Figures 6 and 7.

Legend for the pictures
- Bipodal support 1 - Unipodal suport
- Bipodal support 2 - Balance

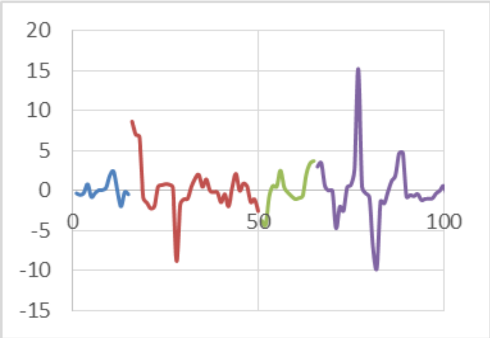

Fig. 2. *Subject 1 - Variations in the left/right symmetry index, measured with EMG (mV), during gait phases before the kinetic program*

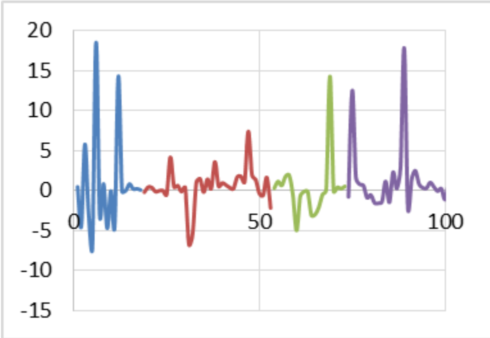

Fig. 3. *Subject 1 - Variations in the left/right symmetry index, measured with EMG (mV), during gait phases after the kinetic program*

In the case of subject S1, an increase in the symmetry index is observed for almost all phases of gait after applying the Core program, a more significant increase in the double support phase 1 and 2, but also in the balance phase. In the single-leg support phase, the symmetry index remains quasi-constant.

For subject S2, the left/right symmetry index shows higher values in the single-leg support, double-leg support 2 and swing phases of gait.

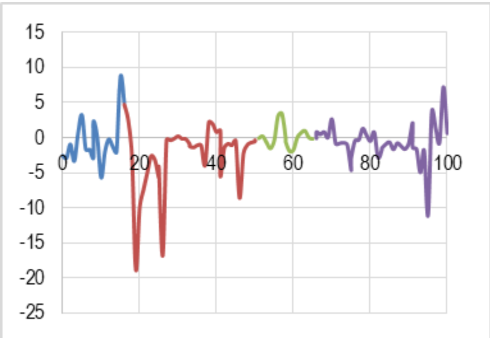

Fig. 4. *Subject 2 - Variations in the left/right symmetry index, measured with EMG (mV), during gait phases before the kinetic program*

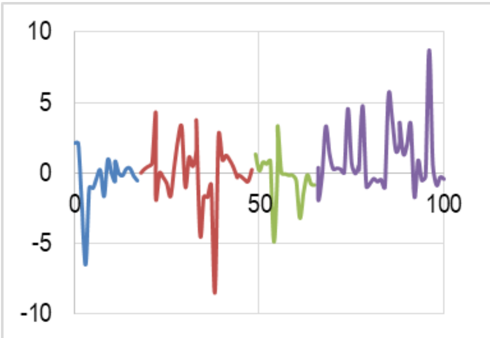

Fig. 5. *Subject 2 - Variations in the left/right symmetry index, measured with EMG (mV), during gait phases after the kinetic program*

Regarding subject S3, a decrease in the symmetry index is graphically observed in the bipedal support phase 2 and in the swing phase. Therefore, the graphs above, which represent the left/right symmetry index correlated with the phases of gait, show a trend of an increase in the symmetry index in the swing phase, which translates into an improvement in trunk control in these phases, as a result of performing the Core program.

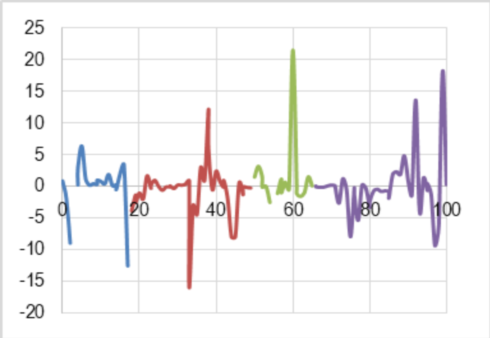

Fig. 6. *Subject 3 - Variations in the left/right symmetry index, measured with EMG (mV), during gait phases before the kinetic program*

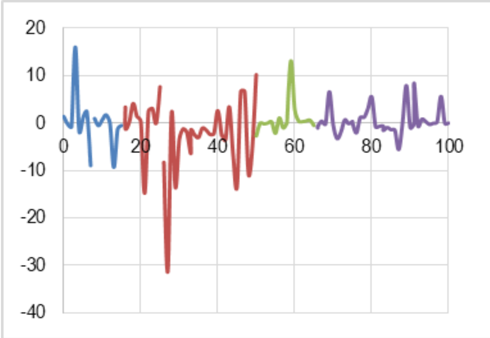

Fig. 7. *Subject 3 - Variations in the left/right symmetry index, measured with EMG (mV), during gait phases after the kinetic program*

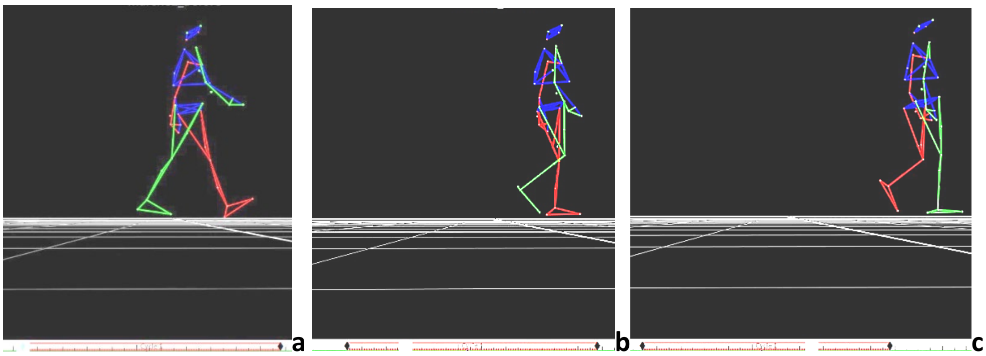

Fig. 8. *Support phase (left upper limb) and swing phase (left upper limb) a. Bipodal support 1 (left heel strike) b. Unipodal support (left leg) c. swing phase (left upper limb)*

4.1. Discussions

The results obtained can be analysed in relation to other studies that have highlighted the fact that biomechanical factors have a great influence on the development of LBP and many of them emphasize the role of the link between muscle structure, muscle behaviour and the onset of LBP. [5] This aspect was also observed in our study, taking into account the great variability of the way in which muscle activation is performed through Core exercises. EMG proved that exist a great variability of the muscle activation patterns, as observed in the diversity of the results obtained in the 3 subjects. Referring to the stability of the spine, altered in LBP conditions, it can be said that no muscle group is more important than another, therefore the Core training approach in therapeutic management represents a solution in achieving improvement in stability of the spine. The amplitude - muscle strength relationship is controversial, since there are situations in which muscle strength is deficient, although the amplitude is high. The correlation is rather associated with the energy available to the muscle. The problems that arise are related to the possibility of identifying the deficient muscle group, at which level intervention should be performed, therefore EMG monitoring, during several types of activities, is desirable to be introduced into therapeutic intervention programs that are necessary for therapeutic management.

Such evaluations ***performed in dynamic*** offer valuable data which cannot be obtained in static assessments such as MRI/X-Ray; therefore they have the advantage of capturing the functional movement of structures involved in movement.

5. Conclusions

The results indicate that the CORE training common to fitness environment, represents a useful approach worthy to be applied in the current physiotherapeutic practice, to target the muscles responsible for trunk and spine stability and mobility, for a better management of both prophylactic and therapeutic intervention for lumbar spine pathologies.

Muscular strength imbalances can be improved after CORE exercises; the muscle symmetry can regain functionality. The correspondence with the phases of gait shows an increase in muscle symmetry after training. The Core concept allows symmetrical training of muscle strength and leads to the improvement of static and dynamic balance and motor control and implicitly the control of spinal movements. The values of the symmetry index during gait have an evolution towards the value 1, which signifies the installation of muscular symmetry; the tendency of an increase in the symmetry index in the swing phase, which translates into an improvement in trunk control in these phases, because of performing the Core program. These observations confirm the hypothesis of the study.

The assessment of electromyographic behaviour correlated with the phases of gait showed us that, although there is stabilization of the spine in both phases of gait, we are still talking about differences in paravertebral muscle activation that require more in-depth analysis, but which partially confirms the hypothesis of this pilot study - there is different paravertebral muscle behaviour depending on the phases of gait.

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