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THE RELATION SETTLED BETWEEN PARAVERTEBRAL AND WHOLE BODY BALANCE THROUGH THERAPEUTIC EXERCISE IN CHRONIC LOW BACK PAIN PATIENT

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Abstract: *Considering the low back pain's complexity, its assessment and diagnosis can become difficult. Not a lot of studies have correlated the whole-body balance of the patient diagnosed with LBP with the functional balance of the paravertebral muscles.* ***Materials and Methods****: The research aims to assess lumbar muscle behavior and plantar pressure in accordance to a specific therapeutical protocol followed for 12 months by 20 subjects diagnosed with chronic lumbar pain. Assessment of patients diagnosed with LBP will involve the paravertebral muscles using surface electromyography (sEMG). The baropodometric analysis of the subjects offers information regarding the whole-body balance and was carried out using the RSscan pressure platform.* ***Results*** *were based on the impact of the proposed and applied kinetic program regarding rebalancing and load redistribution at the plantar level as well as a general redistribution of the body weight, at the anterior-posterior and left/right level. After 12 months a good left/right rebalancing is observed. As well results of the left/right muscle symmetry resulting from the EMG-measurements have been analyzed. After 12 months EMG recordings show a symmetrical ratio with a favorable evolution.* ***Conclusion*** *a well-structured therapeutical protocol can induce both paravertebral and whole-body balance.*

Key words: *low back pain, electromyography, plantar pressure.*

1. Introduction

According to the specialized literature, in 1990, the prevalence of lumbar disorders was reported to be 8.2% of the total global population, showing a decreasing trend to 7.5% in 2017. However, in absolute figures, the population affected by low back pain was 377.5 million people in 1990 and rising to 577 million people in 2017 [22]. Musculoskeletal disorders affect between 13.5% and 47% of the total world population; pain is acting as a limiting factor and, in extreme cases, is leading to disability [6], [16]. 39% of musculoskeletal disorders affect the lumbar region, according to a report published in 2021 by

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Work-Related Musculoskeletal Disorders Statistics. However, low back pain is a complex condition and refers to a broad etiological spectrum, including increased body weight, improper movements, heavy lifting, or conditions such as osteoarthritis, osteoporosis, vertebral body fractures, inflammatory diseases like rheumatoid arthritis, infectious diseases, malignant conditions, or congenital disorders [8], [21]. Lumbar disorders can encompass a wide range of symptoms that may have a sudden onset or, conversely, develop slowly and gradually, potentially leading to disability in extreme cases [3].

The predominant symptom is localized pain in the lower back, with its intensity often influenced by posture. Posture can affect the pain in various ways, sometimes alleviating it during walking or by supine posture.

The pain may be accompanied by muscle tension or spasms, and it can be either localized or radiated to the distal extremities, most commonly following the path of the sciatic nerve [15].

For understanding postural disorders induced by low back pain, it is necessary to quantify deviations from reference values [17]. The symmetry of forces applied by the lower limbs can be used as a tool for assessing the severity of the condition or the effectiveness of treatment in patients diagnosed with chronic lower back pain [14].

Early detection of lower back pain can lead to an appropriate therapeutic approach, thereby minimizing the negative effects that may arise in the absence of an accurate diagnosis. In this regard, assessment relies on adapted techniques and methods, as well as specific evaluation scales and tests.

Altered back muscle activity has been considered a contributing factor to lower back pain. Several muscles, such as the erector spinae, multifidus, latissimus dorsi, and gluteus maximus, play a decisive role in stabilizing and dynamically controlling the lumbar region [1].

Numerous studies report changes in back muscle functionality in patients with both chronic [12], [20].

Electromyography (EMG) is a diagnostic method that provides information about changes occurring at the muscular level or within nerve fibers. There are three parameters that characterize the EMG curve: amplitude, frequency, and waveform over time [13], [18].

Plantar pressure asymmetry and uneven loading of the lower limbs can serve as a control parameter for lumbar disorders. Specialized studies provide detailed descriptions of the interdependent relationship between plantar pressure and spinal deviations or postural deviations in chronic conditions [2], [4].

Together with technological advancement, plantar pressure measurement systems are increasingly employed in both research and clinical settings. These systems can differentiate between normal and pathological patterns and can be addressed to a wide range of conditions. Nowadays the RSscan system offers high data reliability and has proven its utility in clinical trials [23].

2. Objectives

Based on patients diagnosed with chronic lower back pain, the present study aimed to verify the hypothesis that, for the patients included in the study who underwent a kinetic rehabilitation program, there is a connection between the paravertebral muscle balance, assessed through surface EMG, and global posture, evaluated through plantar pressure indices using the RSscan platform.

3. Material and Methods

3.1. Study Design

The study is designed on a group of 20 patients, aged between 37-50, diagnosed with low back pain, who underwent for 12 months a therapeutic protocol based on specific physical exercise.

3.1.1. *Inclusion criteria*

All subjects included had previously been diagnosed with non-specific chronic low back pain; subjects were within the age range of 30-50 years; subjects were cooperative and willing to follow a therapeutic protocol; subjects had not shown imaging changes that describe specific bone marrow conflict.

3.1.2. Exclusion criteria

From the study had been excluded: Subjects diagnosed with chronic lower back pain, but in an acute phase; subjects who underwent surgery for the treatment of lumbar disorders; subjects with post-traumatic sequelae which contraindicate exercise protocol; subjects with conditions where physical exertion is restricted.

3.2. Method

Patient assessment had been organized before and after completion of the therapeutical protocol (after 12 month).

The modular and portable BIOFEEDBACK 2000 x-pert system was used for the electromyographic assessment. The electrodes had been placed on the skin's surface, making the method non-invasive. The gathered data was transmitted via Bluetooth to a connected computer. The BIOFEEDBACK 2000 x-pert system is equipped with 5 distinct modules, with the EMG module featuring two channels (EMG 1 and EMG 2). Correct electrode placement is crucial for accurate data collection. Since this study focuses on lumbar pathology, the electrodes were positioned at the lumbar level on both sides of the spine. The EMG 1 channel recorded data from the right paravertebral muscles, while the EMG 2 channel captured information from the left side. The neutral electrode was placed centrally on the spinous process of the L3 vertebra. The electrodes were positioned approximately 2 cm from the spine. Before electrode placement, the skin was cleaned to remove any dust or oil that could affect the measurements. The electrode attachment points are shown in the accompanying image, labeled as Figure 1.

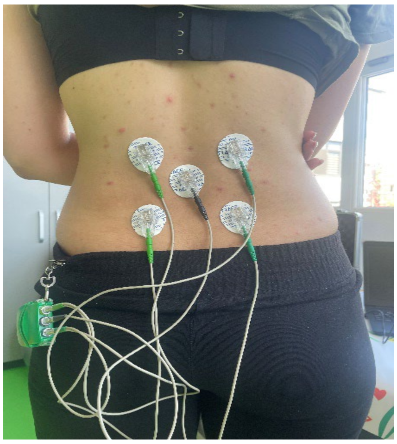

Fig. 1. *Electrode placement*

Assessments had been performed with the patient in orthostatic position, while standing.

The baropodometric analysis of the

subjects was performed using the RSscan pressure platform, which allowed the assessment of parameters related to plantar pressure, the foot's anthropometric parameters, and the contact surface. The equipment used to determine the parameters consists of an RSscan pressure platform and the associated FootScan Gait Analysis software. Evaluation through the RSscan platform primarily involved collecting data on the percentage distribution of weight, depending on the load applied to the platform in the orthostatic position. From a recording perspective, the subject maintained the orthostatic posture during the data collection, evenly distributing the weight across both lower limbs as presented in Figure 2.

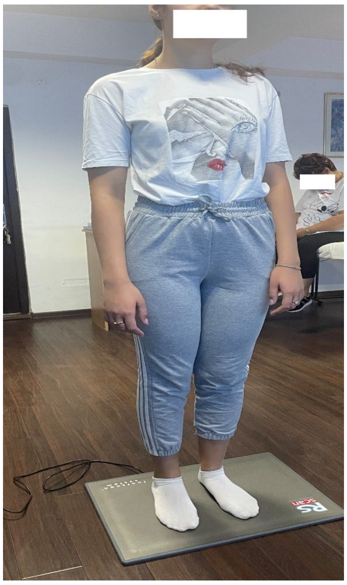

Fig. 2. *Baropodometric assessment*

4. Results

Data was collected for all 20 patients, in static, orthostatic position in 2 different moments. An initial assessment had been performed (T1), while after completion of the therapeutical protocol a new assessment had been performed (T2).

The statistical analysis was performed on the maximum, minimum, and mean values of the EMG recordings, with the average values being obtained based on a frequency and amplitude analysis, using recordings within a range of -10% from the maximum/minimum value. This approach was necessary because, in the case of EMG recordings, we cannot calculate an average of the values.

We have considered for a detection of paravertebral balance a symmetrical index left/right.

It is observed that for all the analyzed values, both maximum and mean values, there is a favorable trend towards values closer to 1, which signifies left/right balance, as described in Table 1

The statistical analysis of the EMG-static measurement results involved calculating the variation of the maximum values recorded by the EMG 1 sensor, which showed a large difference in the mean values of the EMG 1 static recordings. The t-test indicates a statistically significant difference in the means, with p=0.0001, tobs=5.03, and df=19.

For the variation of the maximum values recorded by the EMG 2 sensor, it is observed that the difference in the means between the two moments is large, with the t-test showing a statistically significant difference in the means, p=0.006, tobs=3.12, df=19. In the case of the variation of the minimum values recorded by the EMG 1 sensor, it shows a large difference in the average values, and the t-test indicates a statistically significant difference in the means, p=0.0001, tobs=5.085, df=19. The variation of the minimum values recorded by the EMG 2 sensor (static) shows a large difference in the average values for the EMG 2 static recordings, with minimum amplitudes, and the t-test indicates a statistically significant difference in the means, p=0.0001, tobs=4.41, df=19. The variation of the mean values recorded by the EMG 1 sensor shows a large difference in the average values for the EMG 1 static recordings for the average amplitudes, and the t-test indicates a statistically significant difference in the means, p=0.0001, tobs=7.22, df=19, while the variation of the mean values recorded by the EMG 2 sensor (static) shows a large difference in the average values for the EMG 2 static recordings, and the t-test indicates a statistically significant difference in the means, p=0.0001, tobs=5.39, df=19.

Our results also included an analysis of how the proposed and applied kinetic program influenced the rebalancing of the paravertebral muscles, leading to a redistribution of plantar loading and, consequently, a redistribution of body weight in the anteroposterior and left/right directions as seen in Figure 3. This indicates a rebalancing at spinal level and a reduction in loading on the specific area.

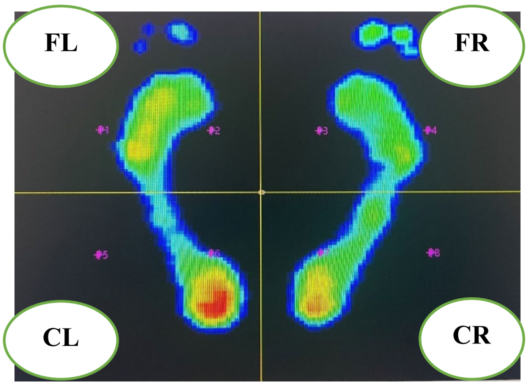

Fig. 3. *Image obtained from the RsScan pressure platform.*

We have considered as follows: FL – Left Forefoot, CL - Left Calcaneus, FR - Right Forefoot, CR-Right Calcaneus. These had been referencing plantar areas from which data on plantar loading were collected.

To highlight changes in the pressure measured on the pressure platform, the following coefficients were proposed for calculation:

- For T1, before initiating the rehabilitation program: Left/Right Balance: R11 = (FL + CL) / (FR + CR)
- For T2, after completing the rehabilitation program: Left/Right Balance: R21 = (FL + CL) / (FR + CR)

Collected data by The RSscan foot pressure platform are detailed in Table 2 and Table 3, each table presenting the situation measured before and after the completion of the proposed therapeutical protocol.

For T2, a good left/right rebalancing is observed. This aspect reflects the effect of the kinetic program, which had as its main objective the left/right paravertebral rebalancing, which also correlates with the evolution of symmetry highlighted through electromyographic assessment.

The variation in the values of the left/right balance coefficient before (R11) and after (R21) completing the kinesitherapy rehabilitation program for the group of 20 patients shows a small difference in means between T1 and T2, and the t-test indicates that it is not statistically significant, p=0.491, tobs=-0.702, df=19. Although a numerical improvement in parameters was observed in terms of rebalancing, statistically, this improvement was not significant.

Table 1

The results of the left/right symmetry-static report, including the maximum, minimum, and mean values, derived from the EMG-static measurements before (T1) and after the completion of the rehabilitation protocol.

Patient Code	T1 Symmetry left/ right for max values	T2 Symmetry left/ right for max values	T1 Symmetry left/ right for min values	T2 Symmetry left/ right for min values	T1 Symmetry left/ right for mean values	T2 Symmetry left/ right for mean values
P1	1,04	1,00	3,50	1,00	1,17	0,99
P2	1,13	1,00	1,03	1,00	1,26	1,02
P3	0,79	1,00	1,00	0,00	0,91	1,00
P4	3,62	1,00	1,43	1,00	1,91	0,98
P5	1,25	1,00	0,00	-5,83	1,10	1,00
P6	0,51	1,00	0,57	1,00	0,54	1,00
P7	0,58	1,00	0,47	1,00	0,51	1,01
P8	0,88	1,00	1,07	1,00	1,17	0,97
P9	0,80	1,00	3,13	-0,71	1,49	1,00
P10	1,10	1,00	0,79	1,00	0,94	1,00
P11	2,22	1,00	1,83	-2,32	2,05	1,00
P12	0,73	1,00	0,84	-1,84	0,80	0,99
P13	0,28	1,00	0,65	-0,02	0,62	0,99
P14	0,60	1,00	0,57	-7,25	0,55	0,99
P15	0,77	1,00	0,44	1,00	0,44	1,00
P16	1,04	1,00	1,10	1,00	1,28	1,03
P17	2,01	1,00	1,67	1,00	1,79	0,99
P18	1,53	1,00	1,34	1,00	1,42	0,99
P19	0,83	0,69	0,66	0,86	0,82	1,03
P20	3,10	1,50	0,69	0,00	3,82	0,57
Minim	0,28	0,69	0,00	-7,25	0,44	0,57
Maxim	3,62	1,50	3,50	1,00	3,82	1,03
Mean	1,24	1,01	1,14	-0,31	1,23	0,98
Standard deviation	0,87	0,14	0,86	2,36	0,77	0,10
Quartila 3 75%	1,46	1,00	1,41	1,00	1,47	1,00
Mediana 50%	0,96	1,00	0,92	1,00	1,14	1,00
Quartila 1 25%	0,74	1,00	0,59	-0,54	0,66	0,99

Table 2

The results of the assessment using the RsScan pressure platform and the values of the coefficients R11 before undergoing the rehabilitation program (T1)

Patient Code	**T1 FR [N]**	**T1 CR [N]**	**T1 FL [N]**	**T1 CL [N]**	**R11**
P1	36,29	20,61	25,12	17,98	0,76
P2	25,81	27,46	23,59	23,14	0,88
P3	23,42	24,04	27,73	24,81	1,11
P4	27,06	19,58	29,5	23,86	1,14
P5	36,21	16,21	28,63	18,94	0,91
P6	27,72	18,12	32,25	21,91	1,18
P7	23,42	29,73	21,51	25,34	0,88
P8	21,04	32,47	22,33	24,16	0,87
P9	33,35	11,99	33,26	21,4	1,21
P10	29,24	13,67	32,44	24,64	1,33
P11	25,54	24,87	28,7	20,89	0,98
P12	17,63	33,18	17,43	31,77	0,97
P13	31,82	18,94	34,26	14,98	0,97
P14	18,91	24,93	28,54	27,62	1,28
P15	22,54	24,63	19,84	32,98	1,12
P16	24,04	27,39	24,46	23,1	0,92
P17	25,97	30,02	25,91	18,09	0,79
P18	23,27	26,8	17,46	32,47	1,00
P19	20,82	24,17	24,21	30,81	1,22
P20	29,85	17,4	33,65	19,11	1,12
Minim	17,63	11,99	17,43	14,98	0,76
Maxim	36,29	33,18	34,26	32,98	1,33
Mean	26,20	23,31	26,54	23,90	1,03
Standard Deviation	5,31	6,05	5,23	5,13	0,17
Quartila 3 75%	29,24	27,39	29,50	25,34	
Median 50%	25,54	24,17	25,91	23,14	
Quartila 1 25%	22,54	18,12	22,33	19,11	

Table 3

The results of the assessment using the RsScan pressure platform and the values of the coefficients R21 before undergoing the rehabilitation program (T2).

Patient Code	T2 FR [N]	T2 CR [N]	T2 FL [N]	T2 CL [N]	R21
P1	29,71	29,71	29,71	29,71	1,00
P2	26,56	27,6	26,65	19,19	0,85
P3	28,6	27	25,52	18,88	0,80
P4	34,57	34,57	34,57	34,57	1,00
P5	29,68	22,03	22,18	26,1	0,93
P6	30,04	20,91	27,8	21,25	0,96
P7	28,44	23,69	22,06	25,8	0,92
P8	23,97	25,77	23,88	26,38	1,01
P9	31,19	15,65	33,19	19,97	1,13
P10	30,41	17,49	37,44	14,66	1,09
P11	23,89	17,67	31,52	26,91	1,41
P12	21,15	29,01	20,14	29,7	0,99
P13	29,66	29,66	29,66	29,66	1,00
P14	32,47	18,21	30,26	19,08	0,97
P15	23,58	25,86	21,29	29,28	1,02
P16	35,44	18,09	28,41	18,07	0,87
P17	31,51	17,51	24,03	26,94	1,04
P18	26,94	21,97	28,87	22,22	1,04
P19	26,38	25,6	22,32	25,7	0,92
P20	36,78	17,79	33,94	11,48	0,83
Minim	21,15	15,65	20,14	11,48	0,80
Maxim	36,78	34,57	37,44	34,57	1,41
Mean	29,05	23,29	27,67	23,78	0,99
Standar Deviation	4,11	5,34	4,95	5,84	0,13
Quartila 3 75%	31,43	27,45	31,21	28,70	
Median 50%	29,67	22,86	28,11	25,75	
Quartila 1 25%	26,43	17,87	22,71	19,11	

5. Discussions

The results that objectively assess the application of the kinetic program, analyzed descriptively and statistically, demonstrate that the implementation of an exercise program focused on training the paravertebral musculature and lower limbs leads to paravertebral rebalancing.

The profile of the subjects analyzed in our study aligns with the existing literature, which indicates that 30-40% of individuals affected by low back pain experience symptoms for more than three months, thus being classified as chronic cases [19].

For postural control and functional mobility, the lumbar paravertebral musculature plays a crucial role [5], as evidenced by the fact that kinetic intervention can lead to an improvement in lumbar paravertebral muscle symmetry.

Kim et al. also conducted a monitoring of electrical activity in the paravertebral musculature to track the effect of lumbar stabilization exercises and found that there was an increase in electrical activity at this level [10].

Coppeta et al., in their study based on documentation, highlighted a significant amount of research regarding the full natural trunk flexion; there is the so-called "flexion-relaxation phenomenon." However, this phenomenon is absent in individuals with chronic lumbar pain, which is why quantification through EMG is useful. Regarding this aspect, the authors conducted such an evaluation and observed abnormal electrical activity in the erector spinae muscle [7].

Numerous studies have investigated lower limb loading in various spinal pathologies, focusing on the motor disturbances that often accompany these conditions. However, several unknowns remain valid in the case of chronic low back pain [24] .

Comparing our study to others, we found that in Miller's study, conducted on 200 male subjects with various musculoskeletal conditions, analyzed using the RSscan pressure platform, four potential correction zones were identified: the forefoot region and the heel region for each lower limb. In this way, the region where plantar pressure is uneven or poorly distributed was identified, along with its relationship to the affected distal muscular chain [9].

For healthy subjects who underwent the same evaluation procedure using the RSscan platform, an uneven distribution of plantar pressure was observed. Based on this information, we can deduce that there is no standardization of plantar pressure, as it is unique to everyone [11]. In this context, the evaluation through plantar pressure platforms demonstrates its effectiveness through successive assessments addressed to the same subject and in the context of a clinically pre-established staging. Taking this information into account, our study successfully correlates the effectiveness of the therapeutic program applied to individuals with lumbar pain with the symmetry of plantar pressure for the right/left hemisoma.

6. Conclusions

To summarize, the present study provides information outlining the correlations between the global posture of patients diagnosed with low back pain (LBP) and their paravertebral muscle status. It can be concluded that, at T1, static EMG indicates a left-right asymmetry in both maximum and average values; at T2, a decrease in both maximum, minimum, and average values is observed in both EMG 1 and EMG 2, which signifies a paravertebral muscle rebalancing. Regarding effect size, a medium effect size is observed for the maximum amplitudes and average amplitude, while for minimum values, a large effect size is highlighted. At T2, a significant improvement in global left/right postural rebalancing is noted under the impact of the kinetic program. The statistical analysis of the data reflecting the evolution of left-right symmetry shows a small difference in means between T1 and T2, and the t-test indicates that it is not statistically significant, p=0.491, tobs=-0.702, df=19. Although a value improvement toward rebalancing was observed, statistically, this improvement was not significant. The extension of the study could be directed towards a detailed analysis of the type of physical exercise that involves significant segmental and global corrections.

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