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Hip strategy alterations in patients with history of low disc herniation and non-specific low back pain measured by surface electromyography and balance platform

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Purpose: The appearance of pathology in the lumbar spine, such as a previous episode of low disc herniation or non-specific low back pain contributes to improper activation of the hip muscles. The aim of the study was to detect alterations in hip strategy manifested by differences in balance parameters and rectus femoris and gluteus maximus activity in people with previous episode of pain radiation to one lower limb caused by low disc herniation or non-specific low back pain. Methods: We studied 11 patients with history of low-disc herniation, 9 patients with history of non-specific low back pain and 10 healthy subjects. Hip strategy alterations were detected by measuring rectus femoris and gluteus maximus activity in bilateral surface polyelectromyographic recordings and by stability measurements on a balance platform. Results: In the surface polyelectromyography study, in both patients' group the value of the average amplitude was higher and the amount of the fluctuations was lower than in healthy subjects. There were no significant differences in stability parameters. Conclusions: A changed pattern of hip muscles activity was detected in the patients without changes in stability parameters. Greater disorder occurs in people in with previous episode of pain radiation to one lower limb caused by low disc herniation than in people with non-specific low back pain.

Key words: *low back pain, postural control, surface electromyography, hip strategy, balance platform*

1. Introduction

Patients with low back pain (LBP) exhibit disorders in neuromuscular control which are manifested by alterations in postural stability [8], [9], [14]. It is assumed that there are two strategies responsible for maintaining anupright standing position: the ankle strategy and the hip strategy [14], [23], [26]. The ankle strategy can be simply illustrated as an inverted pendulum moving above the ankle joint caused by adequate activation of the calf muscles that control the tilt of the body, especially in the anterior-posterior direction [22]. The hip strategy, in turn, can be compared to the action of a double inverted pendulum with two degrees of freedom, assuming that the knee joint is locked in extension. Then the first degree of freedom is the angle of the ankle joint torque and the second degree of freedom is the angle of the hip joint torque.

Most studies report that the ankle strategy is more involved during quiet standing, while the hip strategy is involved in more difficult conditions [23], [26]. However, Sasagawa et al. [27] noticed that even during standing without any disturbances the muscles of the hip strategy are active. Therefore, interference appearing in the ankle joint as a deviation from the vertical position activates the hip strategy muscle in a counter phase motion [12]. The flexors and extensors act as sagittal hip stabilizers (SHS) that keep

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the joint still. Ting [29] listed the following hip strategy muscle involved in sagittal plane: *erector spinae*, hamstrings, abdominals and *quadriceps*. This list would be complemented by the *gluteus maximus*, a muscle, that affects the lumbar spine stability and through direct attachment to the thoraco-lumbar fascia it is a connection between the spine and lower limbs, acting synergistically with *erector spinae* and hamstrings [25].

There are some studies reporting reduced hip strategy in patients with LBP [23], [28]. These studies concentrated on impaired erector spinae activity, which was manifested in a higher baseline amplitude of the surface polyelectromyographic (sEMG) recording [5], [7]. These results suggested that it could be caused by long-term maintenance of rigid position as a result of muscle reflex to pain.

In our study we evaluated the postural control in patients with history of LBP focusing on stability parameters combined with activity of the lower limbs' SHS – *gluteus maximus* and *rectus femoris*. We divided LBP patients into two group – one for patients with history of pain radiation due to the root compression by low disc herniation (LDH), and another for patients with history of non-specific low back pain with radiation without nerve compression (NLBP). This division allows us to differentiate the influence of etiology on magnitude of alterations in the hip strategy. The research was carried out using sEMG and balance platform in three positions: normal standing with eyes open, normal standing with eyes closed and tandem position. We hypothesized that in people with a history of LBP the standing with closed eyes [13] and in tandem position will be more difficult tasks, and may highlight the differences between the patients and the control group.

Materials

The study was, carried out at the Wiktor Dega Orthopaedic and Rehabilitation Clinical Hospital in Poznan. It involved 11 patients with LDH (8 women, 3 men, age: 47 ± 13.04), 9 patients with NLBP (6 women, 3 men, age: 48 ± 8.97) and 10 healthy subjects (8 women, 2 men, age: 30±10.67). The inclusion criteria for patients with the LDH were: LBP with pain radiation to one of the lower limbs caused by lumbar disc herniation at L5/S1 level confirmed in the MRI, sciatic nerve conduction disorders found in the nerve conduction study and positive clinical trials (positive straight leg raise test (SLR) [17], poor reflexes of the quadriceps tendon and Achilles tendon, weakness of muscles innervated by L5-S1 neuromers). The inclusion criteria for patients with NLBP were: no change in the disc confirmed by MRI, no abnormalities in sciatic nerve conduction found in the nerve conduction study and pain radiation from the region of the spine to the one of the lower limbs with a tenderness of the sacroiliac-joint along with a positive Patrick's test without an identified positive SLR test and poor reflexes. All of the patients underwent a 20-day rehabilitation period after which there were no significant neurological symptoms and pain.

The study on the function of the hip muscles was conducted 6 months after successful treatment. None of the above-mentioned symptoms were reported or detected on the day of examination. No changes in nerve conduction study were found, therefore no needle (invasive) EMG recordings were necessary.

Individuals who had never complained of pain radiation from the spine to the lower extremities and who had no pathological changes in lumbar spine MRI and conduction disorders in the nerve conduction study were included in the group of healthy subjects.

The exclusion criteria for all of the groups were: a history of trauma in the lower extremities or the spine, balance disorders caused by central nervous system disorders, dizziness, and advanced rheumatic changes.

The study was conducted in accordance with the Declaration of Helsinki and with the approval, of the Ethics Committee of the Karol Marcinkowski University of Medical Sciences in Poznań.

2. Materials and methods

Information about stability of the upright posture and changes of muscle activity in the lower extremities was obtained from sEMG (8-channel Key-Point, Medtronic A/S, Skovlunde, Denmark) and the balance platform("Good Balance" by Metitur).Other principles and standards of using these apparatus were described elsewhere [16], [20], [31], [32].

Patients were examined in two positions: standing motionlesslyin an upright position with the feet spaced parallelly, 20 centimeters from each other; first with eyes open (EO) and then with eyes closed (EC) in normal standing. Further, with the limbs set, one foot behind the other – in tandem position (T) (Fig. 1). In patients the limb with pre-existing symptoms (affected side) was in the back, while in the case of healthy people in the back was a random leg. Each measurement took 30 seconds. On the balance platform we considered the parameter of the average center of pressure (COP) sway velocity (mm/s) measured for the tested positions in two directions: anterior-posterior (AP) and lateral (L). The velocity of the COP sway was calculated by evaluating the whole amount of displacements. A higher velocity indicated greater disturbances in maintaining a stable posture.

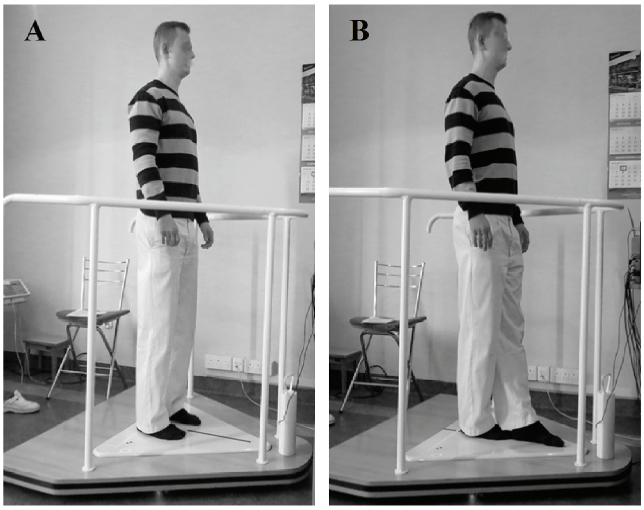

Fig. 1

The activity of two muscles, *gluteus maximus* and *rectus femoris*, on both sides were recorded by sEMG. Muscle activity was tested in three positions (EO, EC and T). EMG real-time analysis was performed. The Key Point system enables automatic acquisition of mean frequency and amplitude parameters. Due to the fact that the activity of motor units in all EMG recordings ranged from 70 to 90 Hz, the parameter of the mean amplitude fluctuation was mainly analyzed in the sEMG recordings. The sample rate was between 10 to 400 Hz. Sensitivities in sEMG recordings were adjusted at 200 μV/D and time base at 4 s/D. Upper 10 kHz and lower 20 Hz filters of the recorder were applied. Pairs of the bipolar standard AgCl gelled electrodes with 5 mm^2 recording surface located on the skin over the muscle's belly and its tendon were used. These are standard settings used in Key Point System during sEMG recordings used by our team in other studies as well [6], [31]. Parameters of mean amplitude and number of "fluctuations" recorded in muscles of both lower extremities were analyzed in both the healthy group and the patient groups. The amplitude of recruited motor unit action potentials was measured as the maximal-minimal value of negative-positive inflections with reference to the isoelectric line. The average values of changes in sEMG amplitudes were analyzed from three trials. Fluctuation was defined as the period of the temporal amplitude change (either an increase or decrease) lasting more than 1 second during the sEMG recording of the muscle's motor unit activity. Changes at 30% to the background of the recording were assumed to be significant. A recording with a greater number of fluctuations was called a heterogeneous one.

Statistics

All statistical analyses were performed using Statistica software version 7.0. Both groups of the patients were compared to the group of healthy subjects. To examine the significance of differences Student's *t*-test with Welch correction and the Kruskal–Wallis test depending on the normality of the analyzed parameter were used. Differences were accepted as significant at $p < 0.05$. The results were analysed in Excel 2007.

3. Results

The results of the study are illustrated in Table 1. The average velocity of the COP measured on the balance platform revealed no significant differences. However, almost all of the examined positions indicated that patients with LDH had a higher average velocity than subjects in the healthy group. The average velocity obtained by NLBP patients was similar to that obtained by those in the healthy group.

In the sEMG study, more significant differences between the groups were observed in the amount of fluctuations than in the amplitude value. In every position the amount of the fluctuations was lower in patients with LDH than in the healthy subjects. There were significant differences in the *gluteus maximus* muscle as well as in the *rectus femoris* in both limbs, although there were greater differences on the dysfunctional side and usually for the *rectus femoris* muscle. Statistically significant differences were observed in the EO and EC positions.

In patients with NLBP the differences were smaller than those with LDH, but they were also statistically relevant as compared to those of the healthy subjects. Similarly to the patients with LDH, the greatest differences were in the position of EO and EC. However, in this group greater differences can be seen for the *gluteus maximus* muscle.

The value of the average amplitude in both patients' groups was higher compared with the values obtained by the healthy individuals. In the EO and EC positions, a significantly higher average amplitude was recorded from the activity of the *rectus femoris* muscle on the unaffected side ($p < 0.05$); in the

Table 1

Normal Standing (eyes open)					
Examined parameter	Healthy group	Patients with LDH		Patients with NLBP	
COP displacement velocity (mm/s)	*N* = 10	*N* = 11		*N* = 9	
anterior-posterior direction	4.72 ± 1.93	5.53 ± 2.09		3.9±1.38	
lateral direction	2.51 ± 0.74	3.69 ± 1.5		2.32±0.72	
EMG Amplitude (μV)		Affected limb	Unaffected limb	Affected limb	Unaffected limb
Gluteus medius	41.67 ± 22.62	51.36 ± 21.91	48.64 ± 15.18	96.67 ± 153.54	94.44 ± 154.12
Rectus femoris	72.22 ± 71	153.64 ± 149.68	184.55 ± 133.89 * ↑	135.56 ± 96.84	168.89 ± 122 * ↑
No. of fluctuations		Affected limb	Unaffected limb	Affected limb	Unaffected limb
Gluteus maximus	11.89 ± 6.25	5 ± 3.97 ** ↓	6.45 ± 4.57 * ↓	6.22 ± 6.85 * ↓	7.44 ± 8.2
Rectus femoris	11.61 ± 7.39	3.18 ± 2.99 *** ↓	4.09 ± 4.13 ** ↓	5 ± 7.1 * ↓	5.22 ± 7.08 * ↓
Normal Standing (eyes closed)					
Examined parameter	Healthy group	Patients with LDH		Patients with NLBP	
COP displacement velocity (mm/s)	*N* = 10	*N* = 11		*N* = 9	
anterior-posterior direction	6.52 ± 2.67	7.58 ± 1.11		5.62±1.08	
lateral direction	3.03 ± 0.88	3.48 ± 1.1		2.48±0.64	
EMG Amplitude (μV)		Affected limb	Unaffected limb	Affected limb	Unaffected limb
Gluteus medius	91.94 ± 150	55 ± 19.87	53.18 ± 14.54	53.33 ± 27.84	45 ± 24.75
Rectus femoris	85.56 ± 122.58	125.91 ± 144.58	190.91 ± 168.55 * ↑	123.89 ± 100.43	183.33 ± 148.16 * ↑
No. of fluctuations		Affected limb	Unaffected limb	Affected limb	Unaffected limb
Gluteus maximus	10.06 ± 5.93	6 ± 4.4	7.55 ± 5.61	5.22 ± 6.83 * ↓	7.33 ± 7.23
Rectus femoris	9.5 ± 6.44	4.64 ± 3.17 * ↓	3.55 ± 3.86 ** ↓	6.78 ± 6.74	4.78 ± 5.59
Tandem Position					
Examined parameter	Healthy group	Patients with LDH		Patients with NLBP	
COP displacement velocity (mm/s)	*N* = 10	*N* = 11		*N* = 9	
anterior-posterior direction	13.00 ± 8.46	16.15±8.78		15.69±3.97	
lateral direction	16.56 ± 10.99	19.79±8.68		17.73±3.7	
EMG Amplitude (μV)		Affected limb	Unaffected limb	Affected limb	Unaffected limb
Gluteus medius	75 ± 55.44	125 ± 131.66	89.09 ± 92.57	111.11 ± 97.13	55 ± 33.91
Rectus femoris	132.5 ± 124.95	306.82 ± 300.55 * ↑	220 ± 259.11	224.44 ± 121.97	76.11 ± 41.21
No. of fluctuations		Affected limb	Unaffected limb	Affected limb	Unaffected limb
Gluteus maximus	11.56 ± 4.95	8.45 ± 4.48	8.82 ± 5.69	6.78 ± 6.89 * ↓	7.11 ± 6.47
Rectus femoris	9.89 ± 5.96	6 ± 4,29	6.82 ± 5.78	6.89 ± 5.18	7.44 ± 5.68

T position, a significantly higher average amplitude was recorded only in patients with LDH from the activity of the *rectus femoris* muscle on the affected side ($p < 0.05$).

4. Discussion

We investigated the hip strategy of balance control in patients with recurrent, severe unilateral pain due to previous episodes of LDH and NLBP who were pain-free at the time of testing. We hypothesized that changes in motor control would have an influence on COP velocities and would also manifest themselves as different patterns of SHS activity in comparison with the healthy participants.

Studies conducted on the balance platform confirmed previous reports that during quiet standing patients with a history of LBP or with moderate LBP exhibit similar stability as the healthy subjects [3], [7], [11], [21]. In almost all of the positions tested, the values that characterized the average velocities of COP displacements in both directions (AP, L) in the patients were similar to those achieved by the healthy subjects. The paper by Jacobs et al. [7] states that patients with LBP exhibit postural responses that are dominated by movements around the ankle rather than the hip. Decreased participation of the hip joint may be a strategy employed to minimize forces and movement about the trunk, which is aimed at avoiding pain [10]. Also, Brumagne et al. [2] claim that patients with a history of low back pain by stiffening the muscles reduce the contribution of the hip strategy and only more difficult tasks can reveal inefficiency of the hip strategy, thus causing evident loss of postural stability compared to the healthy subjects.

According to some authors [1], [14], [18], [19], visual control is helpful in maintaining a stable upright position for patients with impaired proprioception. However, in our study, as performed on the balance platform, there were no significant differences between the patients and the healthy group in the EC test.

Many researchers indicate a pathology in the activity of the hip muscles in patients with LBP, defining it as a dysfunction of the hip strategy [23], [18], [28]. In our study both the LDH patients and the NLBP patients indicated disorders in SHS muscle activity. These patients had higher sEMG amplitudes of the *rectus femoris* muscle and the *gluteus maximus* muscle in almost all of the positions tested. We found no other studies which also investigated the amplitude of these muscles in patients with a history of LDH or NLBP. However, there is a large number of publications confirming a reduced hip strategy on the basis of superficial trunk muscle analysis [7], [24]. Despite there being no current symptoms of pain in patients, their activity is characterized by a higher amplitude and antagonist muscle co-contraction. This may be caused by the fear of feeling pain and protective function of the muscles, which stiffen the trunk. In addition, many studies confirm that in patients with a history of LPB the appearance of balance disturbances (e.g., in more difficult tasks) causes a delayed response and a decreased amplitude of the trunk muscle than in healthy muscles. Thus it turns out that, despite the pain-free period, pathological changes in the muscles remain [10].

Besides changes in the amplitude height we also observed differences in the variation of sEMG recordings which were manifested by a number of fluctuations. Veiersted et al. [30] described the presence of fluctuations (called “gaps”) as a physiological mechanism preventing muscle fatigue. In our study, we registered a smaller number of fluctuations (more homogeneous records) in both patient groups than in the healthy subjects. We assumed that the constant maintenance of a rigid posture generates chronic fatigue which may result in a lack of neuromuscular coordination. There are studies confirming our conclusions. Veiersted et al. [30] investigated trapezius muscle activity during a constant, repetitive work task. They observed that in the trapezius activity record there occur no, or fewer, silent periods than those which do not perform this type of work. We consider that due to a similar nature of muscle activity (permanent, low-force muscle contraction) this study can be compared to ours and we conclude that the lack of fluctuations in the sEMG recording is evidence of muscle fatigue. It is possible that this situation contributes to the recurrence of pain in patients with previous episodes of LDH and NLBP.

Based on our investigation, pathological changes in SHS muscle activity appeared not only in the affected limb but also in unaffected, contributing to disorder of the whole body motor control. Therefore, it can be assumed that changes in the activity of SHS are not only a consequence of pain which occurred in one of the limbs limiting its function, but is also a result of the adoption of a new, abnormal model of muscle activation.

Methodological considerations

A major limitation of this study was the inability to perform tests on the balance platform with synchronous measurement of muscle activity using sEMG. Other factors that may have affected the study’s unreliability was the lack of homogeneous groups in terms of age. A more detailed study should be conducted on a balance platform with a larger and more varied group of patients in order to evaluate the differences between patients with current pain and patients in the pain-free period.

5. Conclusions

We found the changed patterns of hip muscles activity in patients with recurrent pain radiating to one of the lower limbs caused by LDH or NLBP. However, those changes did not affect significantly the level of stability during quiet standing in the EO, EC and T positions.

This study provides insight into the nature of balance impairments in patients with the NLBP and LDH caused by the pathologically modified pattern of muscular coordination. It is important to consider the possible disorders in muscles during targeted rehabilitation.

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