POSTUROGRAPHIC AND ELECTROMYOGRAPHIC ASSESMENT OF POSTURAL STABILITY IN PATIENTS WITH DISC-ROOT CONFLICT IN THE LUMBAR PART OF THE SPINE BEFORE AND AFTER THE REHABILITATION TREATMENT

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Summary
Introduction. In the following study, it is assumed that in patients with disc-root conflict in the lower part of the spine and associated symptom of sciatica, disturbances of postural stability control occur.
Aim. The tests were aimed to determine how the disease will affect the standing postural stability and the electrical activity of the muscles of the lower limbs.
Patients and methods. The study was attended by 11 patients aged 47±13.04 years treated during the four weeks rehabilitation process on Daily Rehabilitation Ward in Wiktor Dega Orthopaedic and Rehabilitation Clinical Hospital in Poznan and 10 healthy volunteers aged 30±10.67. Patients were examined twice - before and after 4 weeks of the rehabilitation treatment and the healthy volunteers once only. Evaluation of static postural stability was performed on the balance force platform and the electrical activity of selected lower limb muscles was tested using sufrace electromyography (sEMG).
Results. The study shows differences between patients and healthy group. In some measurements both balance platform and sEMG examinations show statistically significant differences between groups. After the physiotherapeutic treatment it was also observed significant improvement in tested parameters.
Discussion. The results support previous investigations that dysfunctions of the lumbar spine cause abnormalities in neuromuscular control system, revealed as proprioceptive deficits and disturbances of postural stability. Disruptions in both lower limbs – the symptomatic and the asymptomatic limb – show the global influence of the existing pathology on the postural control.
Conclusion. The physiotherapeutic treatment had measurable influence on improvement of tested parameters, which were evaluated on stability platform and with sEMG.

Key words: postural control, sciatica, posturography, surface electromyography

Introduction

Patients with disc-root conflict in the lower part of the spine exhibit weakness of the lower limbs' muscles and impairment of neuromuscular control manifested by deterioration of postural stability [1,2]. Pathology in the lumbar spine usually refers to the levels L4-L5 and L5-S1. Morange et al. reported that irritation of nerve roots at these levels causes deficits in the strength and the changes in the activity of flexors and extensors of ankle joint and flexors of knee joint [1]. This condition is often associated with chronic pain that occurs in the

spine and lower limbs. Local ischemia caused by compression of the nerve root and local inflammation impair sensorimotor neurotransmission to and from the lower limbs [3]. The most sensitive nerve structures are motor fibers and, in the second place, sensory fibers. Their long-term compression contributes to the abnormal central interpretation of the body position which is created on the basis of the signals from proprioceptors present, e.g. in muscles, joints and tendons. Leinonen et al. claim that these elements are also prone to morphological changes during disease process [4].

A theory called "pain-spasm-pain" model, which was widely commented in the literature, implied that stimulation of pain originating in the lumbar spine contributes to reflex muscle contraction of antagonists and agonists of the trunk and lower limbs muscles [5,6,7,8]. This mechanism limits mobility and insures greater stability of the lower segments of the body, causing better protection of damaged structures, centralization of pain and minimalization of frequency of sciatica incidence. However, long term muscle spasm, characterized by an increased amplitude in EMG recordings, will further intensify the pain [9,10]. Increased muscle activity and their abnormal coordination, occurring simultaneously with shortened relaxation time generate fatigue, resulting in greater recruitment of motor units in the muscle [11]. Such situation results in successive overloadings.

Unfortunately, the inclusion of pathological mechanisms in pain management is not meaningless for maintaining a stable upright posture in patients with dysfunction of the low back. Abnormal postural and motor patterns combined with loss of sensory information from proprioceptors results in changes in postural control [4,12]. In this study it was assumed that these changes are manifested in an increased body sway in static positions and in different muscle activity pattern than in the healthy group. In order to verify these assumptions the stability of the body of patients in a static position on the balance platform was tested, and the activity of selected muscles of the lower limbs using sEMG was analyzed.

Patients

The study was conducted in October and November 2010 on Daily Rehabilitation Ward in Wiktor Dega Orthopaedic and Rehabilitation Clinical Hospital in Poznań. They were attended by 11 patients (8 women, 3 men) aged from 28 to 65 years (47±13.04 years), who have been diagnosed by MRI with disc herniation at the level of L4/L5 or L5/S1. During the last 4-5 years patients experienced recurrent pain in the lumbar region of the spine radiating to one of the lower extremities. Studies were conducted during the remission of symptoms. The electroneurography (ENG) showed impaired conduction of the sciatic nerve of symptomatic limb. Patients' results were compared with the healthy volunteers' results. There were 10 healthy subjects (8 women, 2 men), aged from 23 to 54 years (30 ± 10.67 years), who had no disc-root conflict in the lumbar area of spine, nor symptoms of the sciatica. Four participants were excluded, because of the ambiguous clinical profile due to the number of comorbidities. Any of the study participants was diagnosed with central nervous system disease affecting to maintain a stable posture. The study was conducted in accordance with the Declaration of Helsinki and with the approval of Ethics Committee of the Karol Marcinkowski University of Medical Sciences in Poznań.

Methods

Balance platform and the sEMG tests including the selected muscles of the lower limbs were used to recognize the changes that occur in the pattern of postural control in patients with disc-root conflict in the lumbar region of the spine. Beyond the initial examination patients had the second examination after 3 weeks of treatment, in order to determine the effects of the rehabilitation on examined parameters. The test position during

the two trials, both on the platform and the sEMG registration, was relaxed standing position in which symptomatic lower limb was positioned in a line behind asymptomatic limb. Participants were instructed to look at a picture placed in front of them, at their height of eye. The test position was called "tandem". The measurement lasted 30 seconds.

The balance platform ("Good Balance" by Metitur) used during the study measurements, is equipped with sensors responsible for recording the distribution of forces exerted by the center of foot pressure (COP). The stability of the upright posture was analyzed on the basis of the average COP displacement velocities (mm/s) in two directions anterior-posterior (AP) and lateral (L), and also on the basis of the average center of the COP spectrum (mm), which is a measure of the level of the COP oscillations measured in directions AP and L.

Eight-channels KeyPoint System was used for sEMG studies (Medtronic A/S, Skovlunde, Denmark). SEM signals were recorded bilaterally from four muscles as follows: gluteus maximus, rectus femoris, gastrocnemius and extensor. Standard Ag/AgCl surface electrodes with active surface $5mm^2$ were used. They were placed in parallel on the muscle's surface over the skin. The active electrode was put on the muscle's belly while negative on its tendon distally. Recordings were amplified at 50 μV/D and filtered at 20Hz and 10 kHz respectively. Mean amplitude of sEMG recording was evaluated and numer of so called „events" was counted. Event is understood as the rapid increase or decrease (fluctuation) of amplitude more than 30% lasting more than 1 second. Significant frequency of events indicates the heterogeneity of recording.

In order to confirm the disturbances of transmission in fibres of ischiadicus nerve which might have been the reason of pain radiation, the electroneurographic (ENG) studies were performed with the reference to motor fibers of peroneal nerve. Rectangular stimuli with duration of 0.2ms were delivered via bipolar electrode at 1Hz frequency while their intensity ranged from 0 to 100mA. Recordings of M-waves (compound muscle action potentials) were performed from extensor digiti muscles with pair of standard electrodes placed over their bellies and distal tendons. Additionally long-latency F-wave evoked potentials following stimulation of peroneal nerves were recorded and their frequencies during twenty positive M-waves recordings were analysed. ENG tests were performed to ascertain the pathology in transmission of the motor fibres peripherally (M-wave studies) or within L5-S1 ventral roots (F-waves examinations).

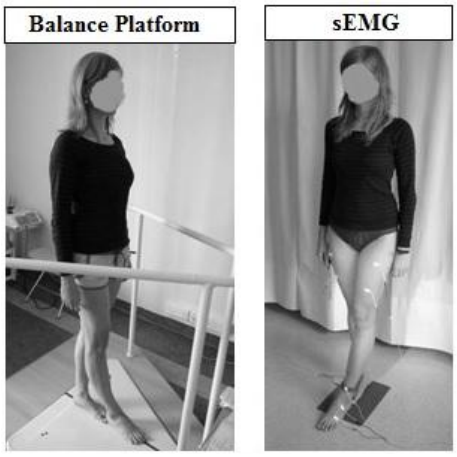

Figure 1. Positions during the test on the balance platform and during sEMG recordings.

The three-week of physiotherapeutic treatment included manual techniques of soft tissues relaxation in the lumbar spine area, pelvis and lower limbs, proprioception training and physiotherapeutic procedures (sollux lamp, laser therapy, electrotherapy).

Results

The results of studies on the stability of standing posture in patients with disc-root conflict in the lumbar spine are shown in table I. In a test on the balance platform, patients showed significantly greater than in healthy group COP oscillations in lateral direction. The COP oscillations were analyzed on the basis of the average centre of the COP spectrum. Statistically significant differences were not observed for COP excursion in the anterior-posterior direction (sagittal plane), or for the average COP displacement velocities of the two planes (sagittal and frontal). The data collected from tests on the platform were similar for both groups after the physiotherapeutic treatment. In the sEMG recordings of lower limbs' muscle activity, the average amplitude was higher in patients for both limbs - symptomatic and asymptomatic. Statistically significant differences in amplitude between the groups, appeared in the recording from distal muscles - the gastrocnemius of the symptomatic extremity ($p<0.05$) and the extensor digiti of symptomatic extremity ($p <0.05$) and asymptomatic as well ($p<0.01$). In the second study, statistically significant changes between the groups were not observed. During the sEMG analysis for records' homogeneity based on the number of so called "events", we found out that healthy people showed more heterogeneous records of the lower limbs muscle activity compared with patients. Significant differences in the number of the events occurred in the first study. They were related to recordings of distal muscles activity - the gastrocnemius of the symptomatic extremity ($p<0.001$) and asymptomatic ($p <0.01$) and the extensor digiti of the symptomatic extremity ($p <0.01$). After treatment, the differences between the two groups decreased, but remained statistically significant in the case of registration of the gastrocnemius of the asymptomatic extremity ($p <0.05$), the extensor digiti of symptomatic extremity ($p <0.01$) and asymptomatic ($p<0.01$) and in the recording of the gluteus maximus of the asymptomatic extremity ($p<0.05$).

Table I. Comparison of tested groups analyzed on the balance platform (average velocity of COP, average centre of COP spectrum) and in the sEMG (average amplitude, the average number of events). The mark "*" indicates significance at p <0.05, the mark "**" indicates significance at p <0.01, and the mark "***" indicates significance at p <0.01.

		Healthy volunteers N=10	Patients N=11			
			I study		II study	
Balance Platform						
Parameter (average)						
Velocity of COP in A-P directions (mm/s)		13.00±8.46	16.15±8.78		13,43636±5.18	
Velocity of COP in L directions (mm/s)		16.56±10.99	19.79±8.63		14.82±7.09	
Centre of COP spectrum in A-P directions (mm/s)		0.49±0.13	0.57±0.17		0.47±0.09	
Centre of COP spectrum in L directions (mm/s)		0.36±0.06	0.57±0.19 ** ↑		0.41±0.15	
sEMG						
Muscle			symptomatic side	asymptomatic side	symptomatic side	asymptomatic side
Gluteus maximus	Amplitude in µV	75±55.44	125±131.66	89.09±92.57	105.45±82.75	92.27±62.74
Rectus femoris		132.5±124.95	306.82±300.55	220±259.11	189.09±110.86	100.45±82.96
Gastrocnemius		383.33±245.28	748.18±356.84 ** ↑	338.18±211.98	486.36±247.07	284.55±178.40
Extensor digiti		319.44±203.74	681.82±455.12 ** ↑	510.00±263.63 * ↑	600±493.96	400±252.98
Gluteus maximus	No. of events	11.56±4.95	8.45 ±4.48	8,82 ± 5.69	7.91±5.74	6.27±5.40 * ↓
Rectus femoris		9.89±5.96	6 ± 4.29	6.82 ± 5.78	7.36±5.57	6.64±5.00
Gastrocnemius		11.67±6.04	4.27±2.90 *** ↓	4.45±4.52 ** ↓	7.55±5.14	7.00±4.36 * ↓
Extensor digiti		13.5±5.50	6.55±4.41 ** ↓	9.45±4.89	7.36±4.57 ** ↓	7.64±4.63 ** ↓

Discussion

The obtained results confirmed previous assumptions about the disturbances of postural stability control in patients with disc-root conflict in the lower part of spine. In the first test on the balance platform, patients had higher average COP displacement velocities of the two planes (sagittal and frontal) than a group of healthy participants, although those results were not statistically significant. Other studies have described similar correlations [13,14]. Asseman et al. presented a study in which a group of young athletes was tested on the platform in three static test positions. Deprivation of vision resulted in not only an increase in COP oscillations, but also in the average velocity growth of the COP excursion [15]. This result confirms that the increase in the average velocity of COP is undesirable and may arise as a result of artificially imposed postural control disorders (such as deprivation of sight for the test) or the disease. In addition, the results show that the average value of the center of the COP spectrum in lateral direction ($p<0.01$) is significantly higher in patients. The reason for these results is most likely affected hip strategy, responsible for controlling the stability of the trunk in the frontal plane. This strategy involves the muscles surrounding the hip joint and requires synchronous response in case of a balance disturbing stimuli [16,17]. The results of tests on the platform, presumably testify disorders of passive and active stability control of the body, and therefore the partial loss of proprioceptive information from pathological muscle fibers, tendons and ligaments [1,4,10].

It turns out that the results of the second study showed a reduction in both the average COP sway and the average center of the COP spectrum, reaching values comparable to the group of healthy. This may suggest that implied rehabilitation have the improved postural control in patients.

The sEMG record in the group of patients showed deficits in the function of the analyzed muscles. The muscles that were examined included: gluteus maximus, rectus femoris, gastrocnemius and the extensor digiti of both lower extremities. In healthy subjects, the increase in the amplitude of the sEMG recording appears with recruitment of new motor units or by a stronger activation of previously stimulated units, thus compensating the loss of strength in fatigued muscle [18]. The results showed higher average values of the amplitudes for most of examined muscles in patients, both in symptomatic and asymptomatic limb. In the selected test position - a tandem that reduces the support plane, which additionally disturbs the stability of the body, gastrocnemius and extensor digiti of the symptomatic leg were characterized by the highest values of the amplitudes ($p<0.01$). In the course of sciatic neuralgia, pressure on the roots L4-L5, L5-S1 effects on dysfunction of flexors and extensors of the ankle joints and flexors of knee joints [1]. Clinical manifestation of pathological alterations in the muscle is pain, numbness, reduced mass, strength and endurance and also the appearance of inverted patterns of motor units activity [19,20]. Therefore, presumably in the group of patients increased amplitude of muscle innervated from damaged spinal levels L4-L5 and L5-S1.

In the sEMG recordings in both studies, patients appeared to have less events in activity of examined muscles compared with healthy subjects. In the first study, statistically significant difference in the number of events concerned the gastrocnemius muscle of both limbs and the extensor digiti muscle of the symptomatic extremities ($p <0.001$, $p <0.01$). Events are defined as periods of temporary amplitude changes (sudden fluctuation of amplitude by 30% in relation to the average of the recorded potentials) in the sEMG record of muscle activity in standing position. These changes are a physiological phenomenon and are specific to muscles which are active at a low level for a long time. They are the manifestation of temporal and spatial recruitment of new motor units and the deactivation of fatigued ones as a result of long-term activity [18]. Constantly increased amplitude in the sEMG record in

patients may be due to changes in muscle coordination pattern [18-21]. Increased fatigue of constantly strained muscles leads to a reduction of the motoneurons excitability threshold, which in turn contributes to the involvement of an increasing number of motor units, and consequently leads to the development of pathology [22,23]. This implies that the changes recorded in recruitment of motor units in patients' muscles, manifested as higher than normal homogeneity of the sEMG recordings, may be a consequence of the changes in neuromuscular coordination occurring in the CNS, disturbing the physiological defensive reaction to muscle fatigue.

Analysis of sEMG second test carried out on patients showed a significant decrease in the amplitude of muscle: the gastrocnemius of symptomatic extremities and the extensor digiti in both extremities. Slight changes were observed in the number of events appearing in the sEMG recording in comparison to the first test. The largest and statistically significant changes concerned the gastrocnemius muscle of the symptomatic. Crucial function of this muscle is to maintain balance in the upright position, so it can be concluded that the general postural stability has been improved as a result of treatment [24]. Both in the first and second studies, there were large disparities between the two groups regarding recorded events. However, in the second study, the number of events appearing in the sEMG record increased in patients, suggesting that the further rehabilitation would more significantly improve the muscle function.

On the results of this study it can be concluded that the muscle function of both lower extremities is impaired in patients with a similar extent, regardless of the sciatica presence. Chen et al. [22] observed a similar dependence. In their measurements of the stability of patients with unilateral sciatica, both lower limbs appeared to be dysfunctional. Probably reduced activity of patients and stiffening of the body, according to the model of "pain-spasm-pain" leads to changes in muscle coordination of the whole body.

Introduced physiotherapy including proprioception training and relaxation techniques of soft tissue of lumbar area and lower limbs, supplemented by physical therapy led to an improvement of evaluated parameters. Other authors, dealing with the issue of the lumbar spine dysfunction also put attention to the importance of proper rehabilitation focused on improving the muscular coordination. For this purpose, they suggested to increase trunk stabilization and strengthening leg muscles located deeply [25]. It is possible that systematic treatment performed for a longer period of time and prophylaxis in form of properly adjusted stabilization exercises, would affect to achieve even better results.

A large limitation of this study was the inability to carry out tests on the balance platform with a synchronous measurement of muscle activity using the sEMG. Other factors that may affect the unreliability of the results was the lack of homogeneous groups referring to the age and a small number of participants. Further researches may be useful in the development of the methods of rehabilitation and in evaluating its progress in patients with disc-root conflict in the lumbar part of the spine.

Conclusions

1. Tests on the balance platform and sEMG are useful tools in the assessment of postural stability control in patients with disc-root conflict in the lower part of the spine.
2. Analysis of the results obtained from the tests on the platform indicates that the average center of the COP spectrum is a more sensitive parameter than the average velocity of the COP excursion.
3. The results of sEMG record of muscle activity of the lower limbs demonstrate not only differences in the average value of the amplitude, but mainly indicate differences in the homogeneity of the record between the patients and healthy controls.

4. Performed treatment seems to have a measurable impact on improving the disturbed patterns of muscle coordination, hence in the second study, there were less differences between the groups for the parameters evaluated on the platform and in the sEMG.
5. Further analysis and development of researches may be useful in the development of methods of rehabilitation and in evaluating its progress in patients with disc-root conflict in the lumbar part of the spine.

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