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Original Article

Surface electromyography studies in standing position confirm that ankle strategy remains disturbed even following successful treatment of patients with a history of sciatica

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Abstract. [Purpose] It is hypothesized that ankle strategy can be changed in patients with a history of sciatica. The aim of this study was to detect residual disturbances following successful treatment. [Subjects and Methods] In patients with a history of sciatica (N=11) and pseudo-sciatica (N=9), differences in muscle activity were recorded with bilateral surface polyelectromyography and stability measurements (center of foot pressure sway and center of spectrum) in normal standing and tandem positions. Results were compared with recordings in healthy people (N=9) to identify abnormalities in electromyographic and postural studies. [Results] Increased amplitude of electromyographic recordings from the gastrocnemius and extensor digiti muscles on the affected side was detected more in patients with a history of sciatica than pseudo-sciatica syndromes in tandem position. Fewer amplitude fluctuations were observed in both positions preferably in patients following sciatica. Changes in center of foot pressure sway and center of spectrum during balance platform studies were detected in normal standing position in this group of patients. No similar abnormalities in electromyographic and postural studies were detected in healthy people. [Conclusion] Sciatica and pseudo-sciatica evoke persistent disturbances in activity of muscles responsible for ankle strategy. Electromyography differentiates the two groups of patients better than postural studies.

Key words: Postural control, Surface electromyography, Sciatica and pseudo-sciatica

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INTRODUCTION

The control of human posture partly depends on proper patterns of muscle activity[1)]. After receiving efferent impulses from the central nervous system, muscles usually react to balance disturbances by extra-recruitment of specific motor units with appropriate temporal and spatial relations[2, 3)]. Depending on the range of the destabilizing stimulus, optimal strategies for balance recovery are activated[4)]. The distal-proximal sequence of muscles' actions, defined as "the ankle strategy" is realized when a person stands in an upright bipedal position on a wide support plane with attempts to reduce the influence of destabilizing forces[5–8)]. Muscles acting at the ankle are activated first in response to impulses destabilizing upright posture, inducing body shifts mainly in the sagittal plane[9, 10)].

It can be assumed that ankle strategy can be changed in patients with a history of sciatica, and from a clinical point of view, balance training is required to prevent the recurrence of low back pain. Previous studies revealed that other joints in the lower

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extremities are stabilized in these conditions by passive properties of muscles and surrounding tissues[11]. The activity of lower extremity muscles is coordinated by spinal centers receiving afferent input from many types of proprioceptors, which results in adaptation of muscle motor unit recruitment[12, 13]. In bipedal upright position in healthy subjects, the center of foot pressure (COP) is kept minimally forward from the ankle and oscillates in a limited area created by the contour of the foot support surface[11]. Patients with chronic low back pain of different etiologies present the abnormal patterns in sustaining a stable upright position. The sway of COP in the upright position in these patients is pathologically increased, particularly in the sagittal plane. The mechanism of this disturbed coordination remains unclear[12, 14, 15].

From the report by Chen et al., it can be assumed that patients with sciatica present changes in proprioception and a significant decrease in force and endurance in paravertebral and lower extremity muscles[16]. These muscles' dysfunctions as well as diminished physical activity in patients with low back pain are likely to disturb maintenance of a stable posture[14, 17]. Geisser et al.[18] and Jacobs et al.[15] provided evidence for increased amplitudes on electromyography (EMG) recordings from back and lower extremity muscles in patients with low back pain. This increase is a sign of abnormal extra-activity of all muscles engaged in posture control, which primarily limits COP sway[14, 15, 19]. This prolonged muscles abnormal activity leads to greater muscle fatigue, resulting in a further increase in COP sway[1, 17].

The question arises whether there are persistent alterations in activity in muscle motor units engaged in ankle strategy following the successful treatment of sciatica and pseudo-sciatica. Such alterations should be detectable by surface-recorded polyelectromyography and by COP sway velocities and center of spectrum measurements. Examinations revealing such alterations may enable the choice of optimal physiotherapeutic procedures to prevent subsequent postural disturbances.

SUBJECTS AND METHODS

Twenty patients (11 women and 9 men) aged 35–55 years (45.5 years on average) with a history of low back pain radiating to one leg were studied. A control group of 9 healthy volunteers (5 women and 4 men) aged 26 to 51 years (46.4 years on average) with a good health status were also studied. All had similar anthropometric features. Each subject was informed about the aim of the study. Written consent for participation in this project and data publication was obtained from every participant. Ethical considerations conformed with the Declaration of Helsinki, and approval was also received from the Bioethics Committee.

Following sciatica in 11 patients, the cause of pain was found to be unilateral L5-S1 disc-root conflict confirmed by magnetic resonance imaging (MRI) and clinical assessment[20]. These patients previously reported characteristic radiation of pain in the lower extremity in an L5-S1 dermatome distribution, with decreased sensory perception and weakness of muscles innervated by L5-S1 nerve roots. The straight leg raising test (SLR) was also positive. Abnormalities on MRI at L5-S1 were not found in the other 9 patients. Tenderness in the sacroiliac joint was detected during clinical evaluation. Patrick's and Gaenslen's tests were also positive in patients with pseudo-sciatica syndrome. Pretreatment electroneurography (ENG) showed a decrease in amplitude in M-wave evoked potentials and frequency of recorded F-waves following stimulation of L5-S1 motor fibers only in patients with a root conflict.

A previous study described the function of muscles acting at the ankle 6 months following successful treatment[21]. No sciatica or pseudo-sciatica symptoms were reported or detected on the day of examination. No changes in motor fiber transmission of neural impulses during ENG were found; therefore no invasive needle EMG recordings were necessary.

The results of surface (sEMG) and postural examinations performed once were compared to results obtained in the control group (Table 1).

A rehabilitation physician qualified each subject for the study and conducted a clinical examination. Neurophysiological recordings (ENG and sEMG) were performed by neurophysiologists . The neurophysiologists did not know which group a subject (healthy volunteer or patient) belonged to. Physiotherapists performed COP sway velocity/center of spectrum measurements with the same rigour as neurophysiologists.

The Metitur Good Balance (M Good Balance System®) platform was used for the evaluation of sway velocity and measurements of the center of spectrum for the tested posture (COP) in static conditions (Fig. 1A and 1B). First, measurements were performed for normal standing position (NS) with feet placed parallel 20 cm apart. A patient was asked to stand motionless in an upright position for 30 s with eyes open.

The second test position with eyes open (lasting 20 s) was standing posture with the feet in tandem position (T). A patient was instructed to stand motionless in an upright position for 20 s with eyes open and with the feet in tandem position. The previously affected leg was the posterior. The average COP sway velocity in mm/s was calculated for both tested postures for changes in anterior-posterior direction. The velocity of COP sway was calculated by evaluating the total amount of displacement. A higher velocity indicated greater instability of posture related to disturbances in ankle strategy realization. The other parameter was the COP center of spectrum measured in mm and counted with Fourier transform formulas. The center of spectrum was the median value of body oscillations in the anterior-posterior direction according to a description by the Metitur Good Balance platform manufacturer. The resolution of precise COP center of spectrum measurement was estimated at 0.05 mm. Other principles of postural studies have been presented elsewhere[22].

The assessment of the function of muscles engaged in ankle strategy was performed with sEMG recorded from the gastrocnemius and extensor digiti muscles in both extremities. Pairs of standard bipolar AgCl-gelled electrodes with 5 mm^2

Table 1. Results of examinations performed with balance platform and surface electromyography

Normal standing (NS)					
Examined parameter	Healthy subjects N=9	Following sciatica N=11		Following pseudo-sciatica N=9	
COP sway velocity (mm/s)	4.7±1.9	5.5±2.1		4.9±1.4	
COP center of spectrum (mm)	0.33±0.03	0.41±0.07*		0.37±0.1	
Examined muscle		Affected side	Unaffected side	Affected side	Unaffected side
(Amplitude in µV)					
sEMG gastrocnemius	238.3±115.2	240.9±151.6	245.4±155.3	248.9±97.5	251.1±146.3
sEMG extensor dig.	115.5±95.4	120.9±108.4	127.7±102.1	105.5±77.3	102.2±40.2
(No of fluctuations)					
sEMG gastrocnemius	10.5±5.2	1.6±1.5**#	1.2±0.9**#	3.4±2.5*	3.0±1.1*
sEMG extensor dig.	11.9±5.2	10.7±4.4	9.6±2.9	9.0±4.9	8.9±4.8
Tandem position (T)					
Examined parameter	Healthy subjects N=9	Following sciatica N=11		Following pseudo-sciatica N=9	
COP sway velocity (mm/s)	13.1±8.4	16.1±8.8		15.7±3.9	
COP center of spectrum (mm)	0.49±0.13	0.5±0.17		0.49±0.11	
Examined muscle		Affected side	Unaffected side	Affected side	Unaffected side
(Amplitude in µV)					
sEMG gastrocnemius	383.3±245.3	748.2±356.8*#	338.1±211.9	502.2±349.5	311.1±207.3
sEMG extensor dig.	319.4±203.7	681.8±455.1*#	310±263.6	561.1±231.5	383.3±246.2
(No of fluctuations)					
sEMG gastrocnemius	11.7±6.0	4.3±2.9**#	4.4±2.5*	4.7±2.8*	5.4±3.9*
sEMG extensor dig.	13.5±5.5	6.5±4.4*	9.4±4.9	7.7±3.2*	8.1±3.7

COP: center of foot pressure; sEMG: surface recorded electromyogram amplitude. Statistics are shown as mean values and standard deviations. *Differences at p<0.05 between results detected following sciatica and pseudo-sciatica syndromes versus healthy subjects; **differences at p<0.01 are marked; #differences at p<0.05 between results recorded in patients from both groups

recording surface were placed on the skin over the muscle belly and tendon. An eight-channel KeyPoint System (Medtronic A/S, Skovlunde, Denmark) (Fig. 1Abc and 1Bbc) was used according to standards described elsewhere[23)]. Muscle motor unit activity was tested in two positions (NS and T). EMG real-time-analysis was performed. The KeyPoint system enables automatic acquisition of mean frequency and amplitude parameters. Because the activity of motor units in all EMG recordings ranged from 70 to 90 Hz, the parameter of mean amplitude fluctuation was mainly analyzed in sEMG recordings. The sampling rate was between 10 to 200 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 used. Parameters of mean amplitude and number of "fluctuations" recorded in muscles of both lower extremities were analyzed in healthy volunteers and patients. The amplitude of recruiting motor unit action potentials was measured as the maximal-minimal value of negative-positive inflections with reference to the isoelectric line. Fluctuation was defined as a period of temporal amplitude change (increase or decrease) lasting more than 1 second during sEMG recording of muscle motor unit activity. Changes of 30% relative to the recording background were assumed as significant. A recording with a greater number of fluctuations was considered heterogeneous (Fig. 1Ca-c and 1Da-c).

Ethical considerations conformed with the Declaration of Helsinki (1975, revised 1983). Approval was also received from the Bioethics Committee of the University of Medical Sciences in Poznań, Poland. Written informed consent has been obtained from each patient and subject.

All statistical analyses were performed using Statistica PL Inc. software version 7.0. Results of tests for both groups of patients were evaluated with analysis of variance (ANOVA) procedures for repeated measurements. The normality distribution was examined with the Shapiro-Wilk test. Biomechanical and electromyographic parameters did not show a normal distribution at p<0.05. Finally, the Mann-Whitney test for independent data was applied. The level of statistical significance was at p<0.05. More important differences between analyzed parameters in all groups of patients were found at p<0.01.

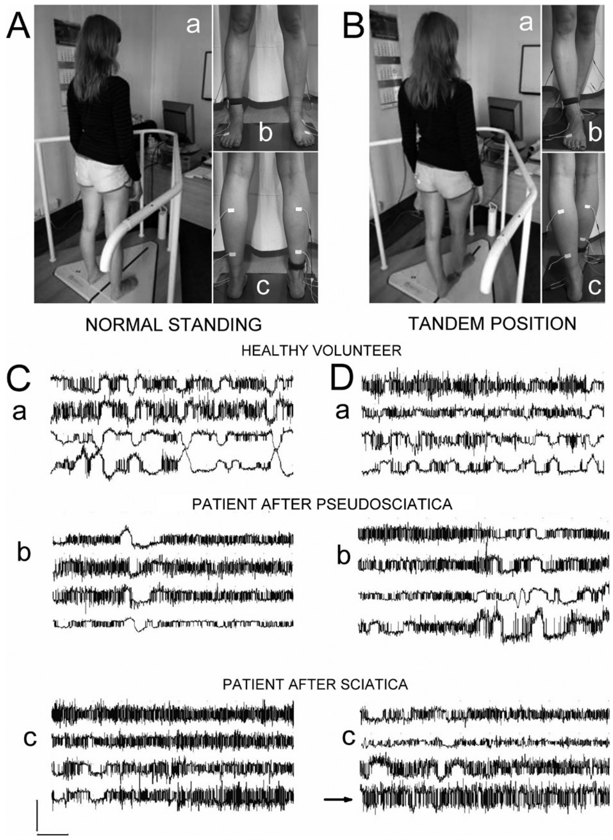

Fig. 1. Photographs illustrating normal (Aa) and tandem (Ba) positions during standing on a balance platform
Bilateral locations of surface electrodes over extensor digiti (Ab, Bb) and gastrocnemius (Ac, Bc) muscles during sEMG examinations performed in normal standing and tandem positions, respectively, are presented. Examples of sEMG original recordings in healthy subjects (Ca, Da), following pseudo-sciatica syndrome (Cb, Db), and following sciatica (Cc, Dc) during normal standing (C) and tandem (D) positions are shown in the lower part of the figure. The two upper traces were recorded from gastrocnemius muscles on right and left sides while the lower two were from extensor digiti muscles in the same manner. Calibration bars for sensitivity (200 µV/D) and time base (4 s/D) used in sEMG recordings are shown in the left bottom corner. Arrowheads mark greater amplitude and less frequent fluctuations in recordings from the extensor digiti muscles of affected legs in patients with sciatica.

RESULTS

Values for COP sway velocity and COP center of spectrum parameters were greater in T than in NS position in all subjects during postural studies (Table 1). Moreover, these studies revealed an increase in COP center of spectrum values during NS recordings only following sciatica in comparison to healthy volunteers ($p<0.05$).

Activity of examined muscles was statistically greater following sciatica during sEMG studies in T position at $p<0.05$, in comparison to healthy volunteers and patients following pseudo-sciatica syndromes. It is noteworthy that mean amplitude values recorded from both examined muscles were greater in T than in NS positions in all patients (Fig. 1, arrow).

The number of fluctuations in raw sEMG recordings from gastrocnemius muscles in both NS and T positions was significantly fewer in patients following sciatica (at $p<0.01$) than following pseudo-sciatica syndromes (at $p<0.05$) in comparison to healthy volunteers. Moreover, the same parameter differentiated patients following sciatica from those following pseudo-sciatica syndromes at $p<0.05$. Fluctuation changes in sEMG recordings from extensor digiti muscles were significant at $p<0.05$ during measurements on the affected sides only in T positions (Table 1; Fig. 1, arrow).

DISCUSSION

The results of sEMG recordings indicated a persistent abnormal pattern in activity of selected ankle muscles following sciatica. This may also suggest abnormalities in ankle strategy confirmed by a significant increase in the COP center of spectrum values in patients in whom stability of upright posture was changed in normal standing. The findings of other authors indicate that patients with low back pain are characterized by disturbed body stability caused by impairments at the lumbosacral spine and reduced proprioception from the lower extremities[12, 14]. Jo et al. described global postural imbalance with disturbances of trunk stability at lumbosacral levels in patients with low back pain[24]. Results of postural examinations performed by della Volpe et al. indicated that changes in lower extremity proprioception in patients with low back pain influenced the number of anteroposterior oscillations of COP in different tested positions[12]. In the present study, all examined subjects presented greater COP sway velocities in T than NS positions, which suggests that the T position is less stable. However, it should be noted that COP sway velocity measurement did not allow for differentiation between patients and healthy volunteers (Table 1), in contrast to COP center of spectrum parameters, but only in NS position. Popa et al. stated that patients with chronic low back pain try to compensate for deficits of postural stability by increasing anteroposterior oscillations, which allows for their differentiation from healthy subjects[25].

The abnormal activity of ankle muscles presented by patients with a history of sciatica may result from disturbances of afferent proprioception, which influences sensory integration processing at spinal and supraspinal centers. During sEMG recordings in T position, an increase in gastrocnemius muscle motor unit activity was found on the previously affected side, but only following sciatica. Such changes were not found in a group of patients with a history of pseudo-sciatica episodes, which differentiated patients in both examined groups. Similarly, Jacobs et al. observed that chronic low back pain is related primarily to wider-band muscle activity, which probably prevents excessive horizontal displacement of the trunk[15]. They also observed an EMG amplitude increase during recording from the gastrocnemius muscle in response to an attempt to cause the patient to lose balance.

In the present study, an additional characteristic property of sEMG recordings from the gastrocnemius muscle was the smaller number of amplitude fluctuations that were more significantly expressed following sciatica compared with pseudo-sciatica syndromes, but were again detected in less stable T position. Tamaki et al. tried to explain these fluctuations in healthy people as temporary and spatial activation of new motor units, and deactivation of motor units acting for a prolonged duration[2]. It seems that a smaller number of fluctuations found in a group of patients with a history of sciatica is a sign of persistently disturbed somatosensory integration, which is too small, however, to evoke a significant change in COP velocity values.

The data presented in Table 1 regarding the parameters of sEMG indicate that the number of detected fluctuations in recordings performed on patients was significantly lower in comparison with healthy volunteers. It is doubtful that changes that were significantly different in the three examined groups were caused by movement-related artifacts, but rather reflected different mechanisms of motor unit activation. Confirmation of disturbances in motor unit activity in muscles on the previously affected side during tandem position recordings in patients following sciatica can be reflected in an increase in sEMG amplitude values. This is in all probability a sign of adaptation in muscle activity in realizing ankle strategy. According to Horak and Nasher, disturbances in realization of ankle strategy may promote abnormalities of trunk muscle activation, resulting in further back pain[6]. The clinical importance of this study consists in the necessity of introducing elements of balance training in rehabilitation of patients with sciatica. The aim is to diminish the probability of lumbosacral pain arising from abnormalities in ankle strategy realization.

The strength of the study is in the application of two complementary functional methods for evaluation of abnormalities in postural control in patients with a history of sciatica; a weakness is the limited number of patients in this study.

In conclusion, the results of this study suggest that an abnormality in activity of gastrocnemius and extensor digiti muscle groups may appear following sciatica, resulting in disturbances of proper ankle strategy realization.

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