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ALTERED POSTURAL CONTROL STRATEGIES IN PEOPLE WITH CHRONIC LOW BACK PAIN: AN OVERACTIVE LATISSIMUS DORSI?

STRATEGII ALTERATE DE CONTROL POSTURAL LA PERSOANELE CU DURERE LOMBARĂ CRONICĂ: POSIBILĂ HIPERACTIVITATE A MARELUI DORSAL/ LATISSIMUS DORSI?

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Abstract

Purpose: The aim of the research is to examine the possible alterations in the functioning of muscles in chronic low back pain (LBP). *Method:* In this prospective study 35 people were selected into LBP and control (C) groups after they had completed the Chronic Pain Grade Scale. 12 muscles were measured with surface electromyography during a functional balance task. *Results:* In rate of muscle recruitment significant increase was found, the LBP group recruited latissimus dorsi muscle (LD) to implement the movement task. During the functional task, the agonist muscles in the LBP group were not recruited as much as in the C group; however, the antagonist muscles were activated more frequently in the LBP group. The activity level of the agonist and stabilizer muscles was higher in the LBP group, whereas the activity level of antagonists was rather lower in the LBP group than in the C one. *Conclusion:* People with LBP recruit more antagonist muscles but use these muscles at a lower activity level. In the recruitment pattern, the role of LD seems to be dominant. Clinicians should consider the role of LD in LBP during the rehabilitation process.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Keywords: *low back pain, electromyography, antagonists, latissimus dorsi*

Rezumat

Scop: Scopul acestui studiu este de a examina posibilele alterări ale funcției musculare în durerea lombară joasă (LBP). *Metode:* Studiul s-a realizat pe un număr de 35 de subiecți, împărțiți în grupul cu LBP și grupul de control (C), în urma complectării Scalei gradate de durere cronică. Au fost evaluate 12 grupe musculare cu ajutorul electromiografiei, în timpul executării testului de echilibru funcțional. *Rezultate:* S-a depistat o rată crescută de recrutare musculară a marelui dorsal/ latissimus dorsi (LD), la subiecții din grupul LBP, în momentul menținerii echilibrului funcțional. S-a observat de asemenea o recrutare mai redusă a mușchilor agoniști la subiecții LBP decât la pacienții din grupul de control; cu toate acestea,

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mușchii antagoniști au fost activați mai frecvent la pacienții LBP. Nivelul de activare a mușchilor agoniști și stabilizatori a fost mai mare la pacienții LBP, în timp ce nivel de activitate a antagoniștilor a fost mai redus la acești pacienți, față de cei din grupul C. *Concluzii:* Persoanele cu dureri lombare recrutează mai mult mușchii antagoniști dar folosesc acești mușchi la un nivel de activitate mai redus. În cadrul paternului de recrutare, rolul marelui dorsal pare să fie dominant. Clinicienii ar trebui să ia în considerare rolul marelui dorsal în cadrul procesului de recuperare a pacienților cu dureri lombare.

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Cuvinte cheie: *durere lombară joasă, electromiografie, antagoniști, marele dorsal*

Introduction

Lumbar spine stability is provided by the vertebrae, discs, ligaments, and muscles. If any of them are impaired, lumbar spine instability may occur [1]. Co-ordinated action occurs within groups of synergistically acting muscles and extends to agonist and antagonist muscle interactions, and proprioception from muscles is a primary sensory mechanism for motor control. Muscle actions must be precisely coordinated to occur at the correct timing, for the appropriate duration, and in the correct combination of forces [2]. No single muscle possesses the dominant responsibility in providing lumbar spine stability [3-5] but the role of the antagonists has been emphasized. Generally, the muscles that were antagonists to the dominant moment of the task were most effective at increasing stability [3, 4]. In case of instability, prolonged muscular compensation to maintain the mechanical stability of the spine may lead to chronic LBP [4]. The role of stabilizer muscles is evident, improving only one of them has a significant effect on the function of other stabilizers muscle and in reducing the intensity of lumbar pain [6, 7].

In a study, the authors have investigated the effect of a 10-minute deep upper trunk flexion exercise on the activity pattern of trunk muscles. They postulate that because of the deep flexion exercise, extensors become relaxed, the ligaments become stretched in the lumbar region, and these changes lead to temporary spinal instability. Due to the instability, the activity of the trunk muscles may change. Healthy subjects were asked to be in a sitting position and perform and then maintain this bending position for 10 minutes. Before and after this deep flexion stretch, various exercises were performed, such as maintaining a plank posture, or an isometric back extension posture, and perform a walking exercise. During the abovementioned activities, they have recorded the EMG activity of the rectus abdominis (RA), the abdominal external oblique (EO), and the erector spinae (ES) muscles. They found that there were no differences in the functioning of the agonist muscles, but the functioning of the antagonists changed significantly. When the subjects made the plank exercise, the activity of the ES muscles decreased significantly after the maintained deep flexion posture compared to the activity before the bending exercise. The activity of the flexor muscles, when the back extension exercise was performed, was also lower after the deep flexion. Researchers have come to the conclusion that the instability, which is caused by the static deep flexion occurring in the lumbar region, primarily affects the activity of the antagonist muscles. The motor control is affected because antagonist co-activation has been deteriorated by the increased joint laxity. Based on their results, researchers claim that antagonist muscles may be the indicator of stability problems, and by examining the antagonist muscles, we can identify the minor changes in spinal instability earlier [8].

Pain and motor control

There are several studies which support the notion that pain can change the motor control [9]' [10]. Neuromuscular dysfunction may be caused by the low afferent variability of the peripherial proprioceptive receptors. Abnormal articular afferent information may decrease the gamma motor neuron excitability causing proprioceptive deficiencies, and joint damage may decrease alfa-motor neuron excitability reducing voluntary activation [11-13]. Reduced proprioceptive input may cause neuromuscular deficiencies; this constant malfunctioning of neuromuscular control and flawed regulation of dynamic movements may lead to inappropriate muscular activity (i.e., overutilization or underutilization). These studies suggest that altered neural control is a protective reaction of the body to limit provocation of the painful area. Which may cause further deteriorations, and it exacerbates the symptoms through the sensitization of the peripheral and central nervous systems (lowering of pain threshold), and it promotes dysfunctional movement patterns. Motor control changes result in modified muscle recruitment patterns, reduced postural robustness, and proprioceptive dysfunction [14].

In our study, we examined the postural muscle activity pattern in LBP group compared with pain-free subjects. We postulate that the rate of recruitment of trunk muscles responsible for posture can change due to back pain; therefore, individuals with LBP will react differently during a weight-bearing task.

Methods

Participants

35 subjects (24 women, 11 men) were included. The mean age of women was 24 years (SD 3.99), and it was the same (24 years; SD 3.69) in case of men. 91.3% of the subjects were right-handed. Those conditions except pain which were likely to affect the posture and the activity of muscles (neurological, internal organ problems, gynecological illnesses, further operations, balance and perception disorders) were considered as the exclusion criteria of the assessment. All procedures were performed in compliance with relevant laws of the country, wherein the study was conducted, and are in line with the Declaration of Helsinki. The subjects took part in the research voluntarily; they were informed about the procedures, and they gave their informed consents.

Measures

Functional exercise during the EMG measurement

The subjects were in a standing position, one of their legs was resting on a foot stool (30 cm high). The arms were held in a straightforward position, parallel to each other. The eyes focused on one point on the wall, which was 3 m from the subject. On a verbal command, the leg on the stool was lifted up about 2 cm high; this position had to be maintained for 2 seconds, and then the leg was put back onto the stool. Then the position of the lower extremities was interchanged. Our intention was to examine a functional posture, but not in a comfortable, stable position, so we made the exercise more difficult. The subjects had to balance their body in one leg standing position, with arms elevated forward in 90°, and changing the weight distribution; therefore, the postural control was challenged more. Because of the unstable and weight-bearing position, we expected the increased activity of the prime mover trunk and hip muscles. During this exercise, we recorded the EMG signals for 5 seconds (Figure 1).

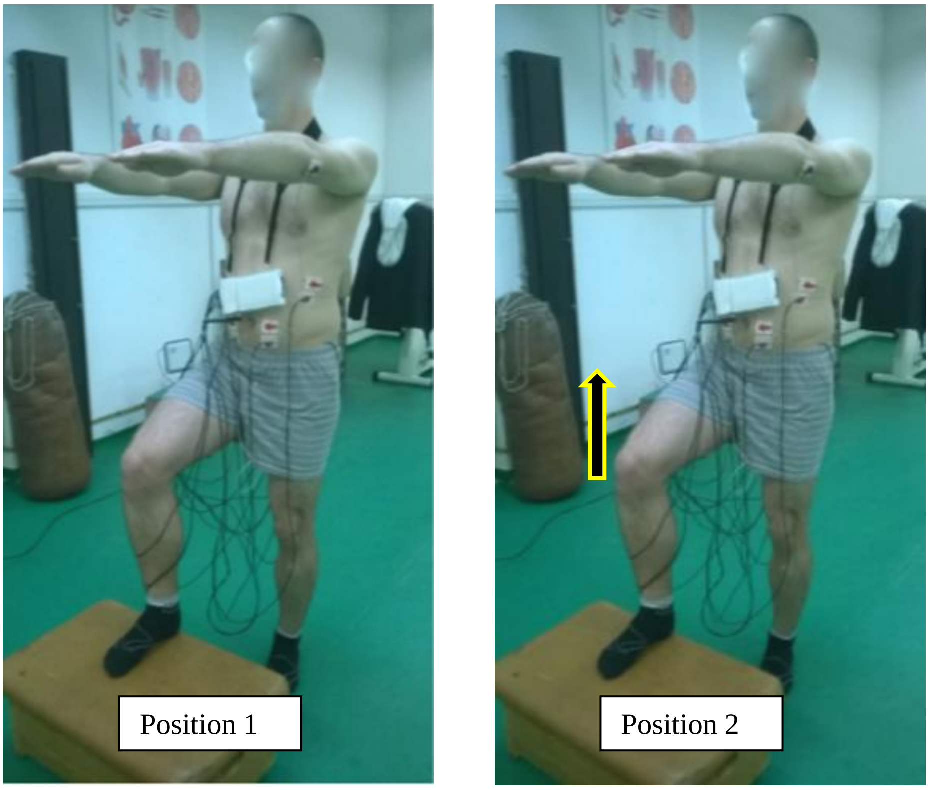

Figure 1: The functional task.
In the case of Position 1 the right leg of the subject was resting on a foot stool and then (Position 2) on a verbal command, the right leg on the stool was lifted up about 2 cm high; this position had to be maintained for 2 seconds, and then the leg was put back onto the stool. Then the position of the lower extremities was interchanged, therefore the task was repeated with the left leg.

EMG analysis

The surface EMG (TelemyoMini 16, Noraxon U.S.A. Inc. Scottsdale, Arizona, USA) electrodes were put on the assessed muscles according to the muscle belly. In the examination, we measured the rectus abdominis (RA), latissimus dorsi (LD), lumbar multifidus (MF), gluteus medius (GM), and gluteus maximus (GMax) muscles. The electrodes were placed and sort out and the skin surface was prepared according to the recommendations of SENIAM (http://seniam.org), the sampling rate was 1000 Hz. We assessed the muscles of both sides of the body (L: left, R: right), altogether with 10 channels. We chose these particular muscles because they play a significant role in trunk and pelvic stability.

Design and Procedures

The examination took place in a motion analyzation room in quiet circumstances. The procedure took a half an hour and the measured movement was coordinated by a physiotherapist.

Grouping

The grouping of the participants was according to the Chronic Pain Grade Scale [16]. 12 subjects, the members of the groups grade (G) II and G III were the subjects with chronic LBP, and there were 12 people without any complaints in the control (C) group. The subjects of G I were characterized by very low pain intensity, but they were affected by the pain. Therefore, we excluded G I subjects (n=11) from the further data processing.

Data analysis

We defined the recorded muscles as agonists, antagonists, and stabilizers considering the movement task, based on the book of Kinesiology of the Musculoskeletal System by Neumann [17] (Table 1.). Ipsilateral (ila.) muscle refers to the muscle located on the actual side of the body, where leg lifting occurred. Contralateral (cla.) describes the muscle located on the opposite side of the body of the leg lifting. Bilateral (bla.) muscles are located on both parts of the body.

Right leg lifting			
	agonists	antagonists	stabilizers
	R RA	R Gmax	L GM
	R GM	R LD	L Gmax
		L LD	L MF
			R MF
Left leg lifting			
	agonists	antagonists	stabilizers
	L RA	L Gmax	R GM
	L GM	L LD	R Gmax
		R LD	R MF
			L MF

Table 1: Categorisation of the muscles
(Abbrevations: R: right, L: left, RA: m. rectus abdominis, GM: m. gluteus medius, Gmax: m gluteus maximus, LD: m. latissimus dorsi, MF: m. multifidus lumborum)

EMG amplitudes (in microvolts) in time domain (in milliseconds) were used for analysis. We assessed the activity level of the muscles and the rate of the recruitment. The muscles' peak activation levels were obtained during the task and EMG signals were normalized to the peak activation levels. The rate of recruitment was expressed as the percentage of the total group members who have activated a muscle above the activation threshold. The activation threshold was set at the level of 45% of the maximal amplitude [18]. Lancosh FIR filters were applied: a band-pass filter (cut-off frequencies of 20 and 350 Hz) and a rejector filter (cut-off frequencies of 50 and 60 Hz). Then the integrated EMG was calculated, therefore no smoothing was applied.

Statistical Analysis

The data gathered were analysed with the help of STATISTICA 12 (Statistica Inc., Tulsa, Oklahoma, USA) using Mann–Whiney U test and Fisher's exact test.

Results

The rate of recruitment

We found that the differences in activity ratio of muscles in the LBP and C groups are bigger during right leg lifting. During right leg lifting, we can see that the agonist muscles did not recruit in the LBP group as much as in the C group. On the other hand, the antagonists ila. Gmax and bla. LD were activated more frequently in the LBP group than in the C group. Using Fisher's exact test, we found significant difference in the case of the LD activation pattern comparing the EMG data of the LBP and the C groups, when we examined the rate of recruitment of the muscles. This difference was marked during the lifting of the right leg and in the muscles on the right side (P=0,046). In case of the cla. and ila. MFs, there were also difference detected in recruitment; in the

LBP group, these muscles were activated more frequently. Stabilizer muscles were mostly over-recruited in the LBP group compared to the C group, but this tendency was not significant in this sample (Figure. 2, 3).

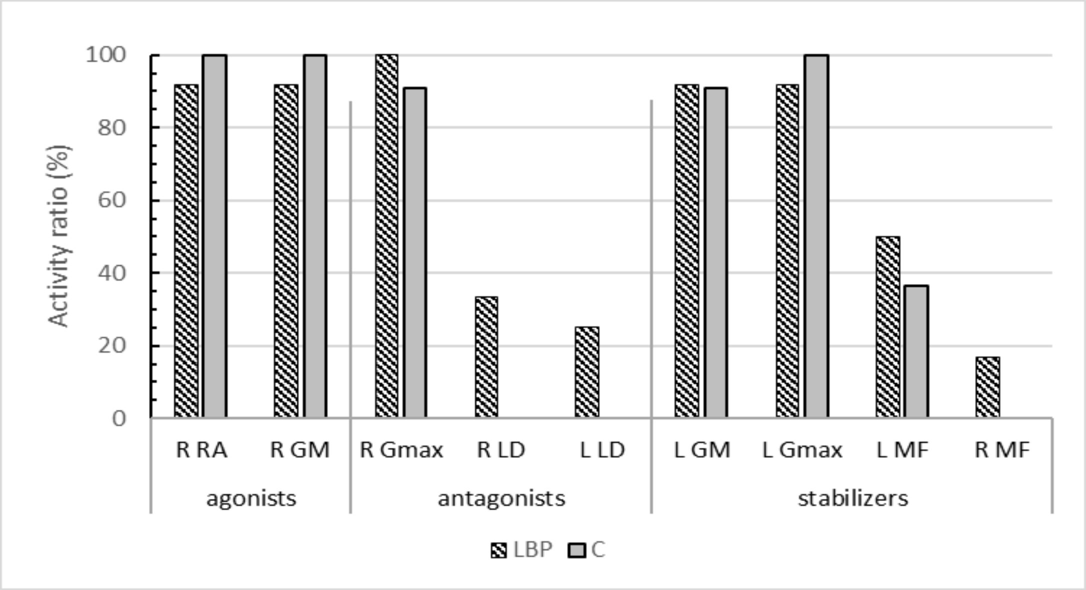

Figure 2: Activity ratio of muscles during right leg lifting.

*Antagonist muscles and bla. MFs (stabilizers) were recruited more often in the LBP group than in the C group, although agonist muscles were recruited less often in the LBP group. * P<0.05*

(Abbrevations: R: right, L: left, RA: m. rectus abdominis, GM: m. gluteus medius, Gmax: m gluteus maximus, LD: m. latissimus dorsi, MF: m. multifidus lumborum)

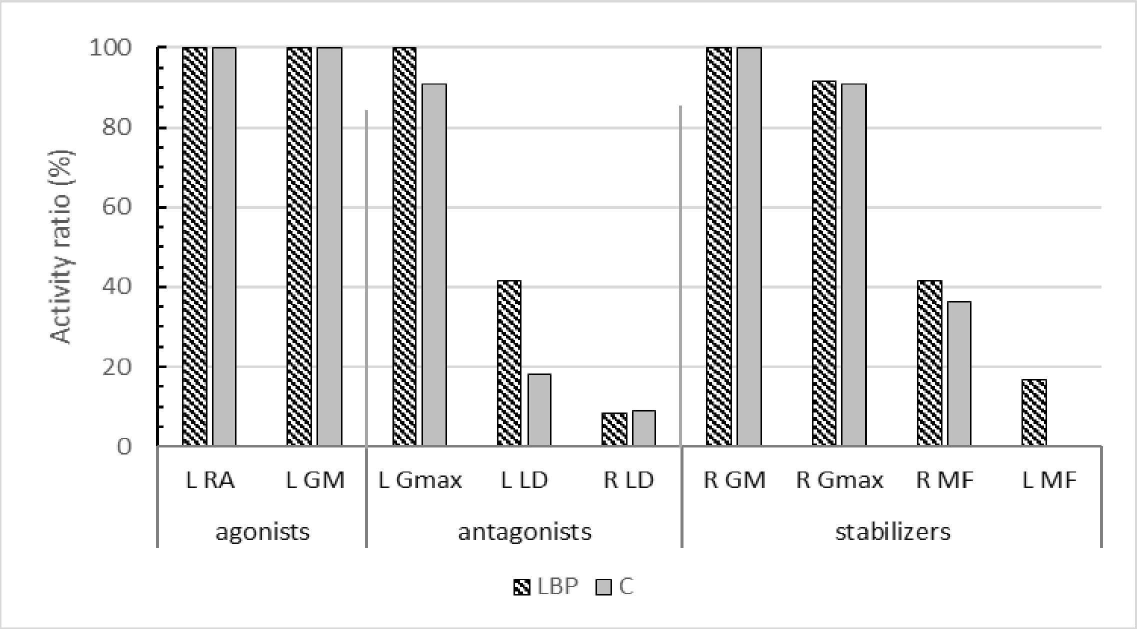

Figure 3: Activity ratio of muscles during left leg lifting.

Antagonist and stabilizer muscles were recruited more often in subjects with LBP. On the other hand, in the case of agonist muscles, we could not find any difference between the groups.

(Abbrevations: R: right, L: left, RA: m. rectus abdominis, GM: m. gluteus medius, Gmax: m gluteus maximus, LD: m. latissimus dorsi, MF: m. multifidus lumborum)

Electrical activity of muscles

Comparing the activity levels of the muscles, we did not find statistically significant differences between the LBP and C groups. On the other hand, we could see clear tendencies. During the one leg stance task, the activity level of agonist and stabilizer muscles was higher in the LBP group, while the activity level of the antagonist muscles was rather lower in the LBP group than in the C group (Figure. 4).

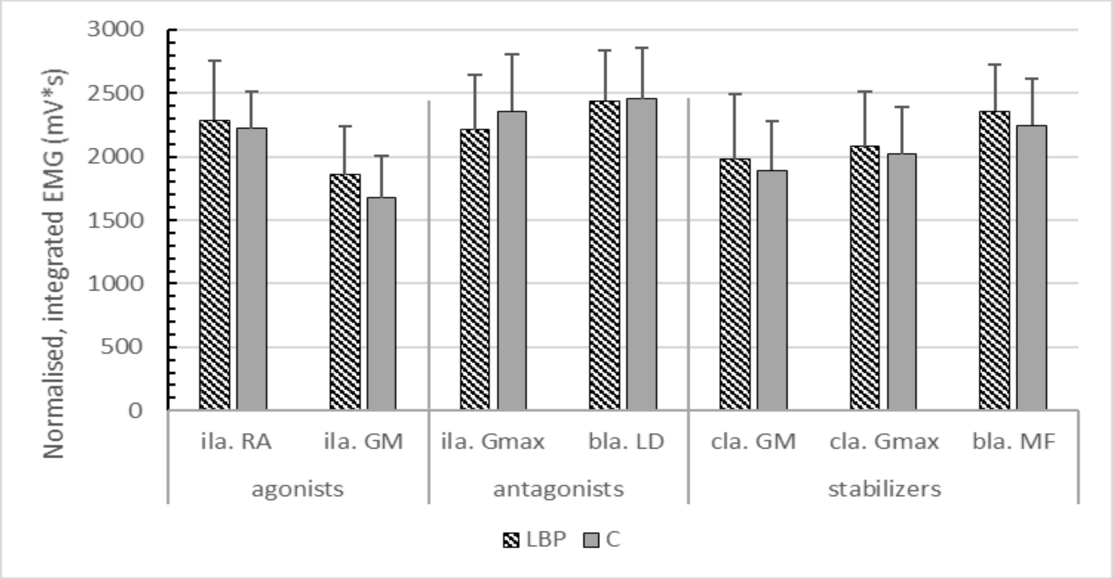

Figure 4: Electrical activity of muscles.

This figure shows the assessed muscles' EMG activity. The LBP group activated agonist and stabilizer muscles at a higher level, and antagonists at a lower level compared to the results of the C group.

(Abbrevations: ila: ipsylateral, bla: bilateral, cla: contralateral, RA: m. rectus abdominis, GM: m. gluteus medius, Gmax: m gluteus maximus, LD: m. latissimus dorsi, MF: m. multifidus lumborum)

DISCUSSION AND CONCLUSION

The rate of recruitment – the role of LD and Gmax in lumbar stability

The main finding of our study was that the postural muscles were recruited differently in LBP, and our results showed that subjects with LBP recruited antagonist muscles and used LD muscle to implement a weight-bearing movement in contrary to the C group, where LD muscle was activated in lesser extent. Antagonists Gmax and LD were recruited more often by the LBP group in contrast with the C group. It is known from a former study that these bridging (multi-joint) muscles make connection between the pelvis and the upper and lower extremities by the thoracolumbar fascia (TLF). Hence, parts of these muscles provide a pathway for mechanical transmission between the pelvis and the trunk. TLF plays an important role in transferring forces between spine, pelvis and legs and in the stabilization of the lower lumbar spine and sacroiliac joint. The tension of the TLF can be influenced by contraction or stretching of a variety of muscles. It is noteworthy that especially muscles such as the LD and Gmax are capable of exerting a contralateral effect especially on the lower lumbar spine and pelvis. It implies that the one-sided Gmax and cla. LD can both tension the TLF; thus, they have an important role in lumbar stability [19]. These findings and our results confirm the statement that no single muscle possesses a dominant responsibility in providing lumbar spine stability [3-5]. Generally, the muscles that were antagonist to the dominant moment of the task were most effective in increasing the stability [3, 4].

The global trunk muscles, such as the LD or the ES, are secondarily responsible for spinal stability [20]. Santos et al. have examined subjects who had to raise themselves from a kneeling position to a half kneeling position, which included weight shifting, and then asymmetrical weight bearing. Their results were that the IO and GM muscles reached higher peak amplitude in a short period of time in the C group, and the integrated EMG values were also higher than that of the members in the group with lumbago. It was also interesting that the subjects of the group with LBP activated the ES muscle with higher level and with earlier times of peak amplitude during changing their positions [21]. Our findings concerning the rate of recruitment further supports this interpretation; the subjects with LBP recruited LD, which is a global stabilizer like ES, during performing their exercises displaying an overactivity pattern of LD, which is otherwise a secondary stabilizer muscle. Although our results concerning the activity level seem to be in contradiction with theirs. In our functional exercise, the emphasis was on full weight bearing in one leg standing (more static activation), while in the abovementioned situation, the emphasis was on weight shifting (more dynamic activation). It can explain the differences found in the activity level in case of LD, that is, we recorded lower activity level in contrary to the results of Santos et al., since to hold a position requires lower activity level than to move a body part.

Interestingly, the results show that differences in the activity ratio of muscles of the LBP and C groups are larger under right leg lifting. We hypothesized that the results might be influenced by the subjects' right-handedness nevertheless, we did not measure how side dominance affected the motor pattern in LBP. Regarding this fact and the limited case number further researches are required to clarify the effect of hand dominance and the changes in motor control and motor activation pattern in LBP.

Electrical activity of muscles in LBP

It is well known that MF has an important role in stabilising the spine. MF has also a connection to TLF. Increased tone in the lumbar MF muscle should act to increase the tension created by the TLF between posterior superior iliac spines bilaterally. This increased medially directed tension would lead to force-closure of the sacroiliac joint, thus stabilizing the pelvis [19]. We expected, based on former studies, a lower activity level of the stabilizer muscles, such as MF, in the LBP group. In contrary to our expectation, we found the tendency of higher activity level and higher recruitment rate of MF muscle in the LBP group, together with lower activation level of antagonists, but without statistically significant differences. These findings may suggest that the main factor in the instability is more linked to the antagonist lower activity level and the lack of normal coactivation pattern of agonists and antagonists. That might also be the sign of spinal instability presented in our subjects with LBP, or this type of muscular compensation pattern has led to the development of chronic LBP [4].

Activity of antagonist muscles in LBP

We found that antagonist muscles (Gmax, LD) tended to reach a lower activity level in the LBP group. Recent research has revealed that if there is an increase in the instability around the lower back, or if the subject suffers from LBP, the activity level of the muscles decreases in the antagonists during the performance of a given exercise. Lee et al. have investigated the effect of a 10-minute deep upper trunk flexion exercise on the activity pattern of trunk muscles. They have postulated that because of the deep flexion exercise, spinal instability occurs. They have recorded the EMG activity of the trunk muscles, and found that in the functioning of the agonist muscles, there have been no differences, but the functioning of the antagonist muscles have changed significantly. The researchers have come to the conclusion that the instability, which has been caused by the static deep flexion occurring in the lumbar region, has primarily affected the activity of the antagonist muscles. Based on their results, the researchers claim that the antagonist muscles may be the indicator of stability problems. The tendencies in our results are in line with the abovementioned results. Even acute pain would cause changes in the activity of antagonist muscles. The researchers have injected hypertonic and isotonic solutions into the right longissimus dorsi (extensor) to cause acute pain. They examined the extensors, and the flexor muscles during the performance of trunk extension. The activity of the RA (flexor) muscle has been reduced due to the pain [22]. Their findings suggest that instability reduce the antagonist activity level, and our results provide more evidence for the reduced antagonistic activity in case of LBP.

Conclusion

These findings suggest that people with LBP recruit more antagonist muscles, but they use these muscles in a lower activity level, while the activity of agonist and stabilizer muscles shows an increased tendency. This change in motor control in individuals with LBP seems to be paradox, but it can be postulated that LBP causes lower activity level of the antagonist muscles first, which results in decreased spinal stability. The nervous system might try to repair the impaired stability, thus increasing the activity of the agonist and stabilizer muscles. To enhance the stabilization of the lumbar spine, the affected antagonist muscles are recruited more frequently but with a lower level of activity than in healthy people. We postulate that the change in motor control can be a pain avoidance strategy, based on the stability provided mostly by the superficial muscles instead of the deep, local stabilizing muscles, or a part of a fixation pattern, which is a negative postural control strategy. With higher stability, the pain can be reduced [2]. It has not been explained so far if LBP is caused by the pathological changes or the pain itself causes the chronic muscle and motor control dysfunction of the patients.

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