Acta of Bioengineering and Biomechanics
Vol. 11, No. 1, 2009

Bioelectric activity of selected muscle groups in people with impingement syndrome

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The aim of this study was to assess the changes of the bioelectric activity of the selected muscles and their impact on the functioning of the shoulder joint in people with impingement syndrome. The study covered 58 subjects aged between 24 and 85, who were treated for impingement syndrome in the years 2004–2006. The average duration of the disease was 40 months. The following muscles were tested for bioelectric activity using surface myography: deltoid, supraspinatus, infraspinatus, latissimus dorsi, greater pectoral and biceps brachii on the healthy and the diseased sides. A significant drop in activity of the deltoid and the infraspinatus muscles on the diseased side was observed. The following muscles showed comparable activity on both sides: the supraspinatus, latissimus dorsi and the greater pectoral muscle. The activity of the biceps brachii muscles grew during resisted movements. The drop in the activity of the deltoid and the infraspinatus muscles on the affected side is an important factor responsible for changes of the active mobility of the shoulder and for the development of instability of the shoulder joint. A similar activity of the latissimus dorsi, greater pectoral and biceps brachii muscles on both sides indicates a development of the compensatory mechanisms and the role of those muscles in the dynamic stabilisation of the shoulder joint.

Key words: *impingement syndrom, bioelectric activity of selected muscles*

1. Introduction

Impingement syndrome that consists in repetitive micro-injuries of the rotator cuff, the tendon of the long head of the biceps brachii and subacromial bursa, resulting from a mechanical conflict with the elements of the coracoacromial fornix, was described for the first time in 1972 by NEER [20]. The basic symptoms of the impingement syndrome are pain, progressive limitation of the active mobility of the shoulder and a growing feeling of instability of the shoulder joint defined as a fear of subluxation or a sensation of the head of the humerus shifting during movement described by patients as clicking inside the joint. One of the reasons for the above-listed complaints may be the changes taking place inside muscles that are important for the proper functioning of the shoulder girdle caused by mechanical injury or by adaptive or compensatory changes occurring as a result of the impingement syndrome.

Proper functioning of the shoulder girdle requires smooth cooperation of many anatomical structures, among which three anatomical joints should be listed: shoulder joint, sternoclavicular joint and acromioclavicular joint; functional joints, which include: subacromial joint, scapulopectoral joint and the sheath of the tendon of the long head of the biceps brachii [15]. In terms of functionality, the group of muscles responsible for both the mobility and the dynamic stabi-

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Received: September 11th, 2008
Accepted for publication: March 23rd, 2009

lisation of the shoulder joint during motion play an important role in the biomechanics of the shoulder. The muscles can be divided into three subgroups:

- scapulobrachial muscles that are attached between the scapula and the head of the humerus: deltoid, supraspinatus, infraspinatus, subscapular, teres minor major musle;
- biarticular muscles that have one of their insertions attached to the scapula: biceps and triceps brachii;
- trunk muscles with initial attachment on the spine and thorax and ending on the scapula or the humerus: greater and smaller pectoral muscle, anterior serratus muscle, quadrilateral muscle, latissimus dorsi, rhomboid muscle, levator scapulae.

The nerves of the acromial plexus and the so-called mechanoreceptors that take part in proprioception are responsible for coordination of the functioning of the articulations and muscles of the shoulder girdle. Proprioception was defined [14], [16] as the function of sensing both motion (kinesthesia) and position of the joint and it plays a significant role in the integration of the static and dynamic stabilisers of the joint.

The share and role of individual muscles during performance of defined movements of the shoulder joint has, so far, been a subject of numerous studies and controversy. From a clinician point of view, the most useful division of muscles into functional groups was presented by DZIAK and TAYARA [5] (table 1).

Particular attention is paid to the role of the deltoid muscle and the rotator cuff muscles in ensuring a proper function of the shoulder [3]. The first evaluation of the activity of those muscles during elevation of the arm was made on the basis of an electromyographic examination [27]. That evaluation showed a significant growth of activity of the deltoid and supraspinatus muscles that caused the researchers to believe for some time that those muscles play the major role in elevation of the arm. The supraspinatus muscle was defined as an ‘initiator’, since its activity was highest within the initial 30° of elevation and was followed by an increase of the deltoid muscle’s activity, which ensured achieving the physiological range of motion. This observation was confirmed by experiments [1], [2], [29], which consisted in selective paralysis of the supraspinatus muscle, which resulted in a 100% growth of activity of the deltoid muscle in the initial phase of motion in comparison with the values obtained at the normal function of the supraspinatus. The same study showed that stopping the elevation at 90° angle resulted in falling of the arm, which proves that the activity of the supraspinatus muscle continues until reaching 90° angle and then gradually fades.

Further experiments allowed the researchers to observe, on the basis of the EMG record, that in the consecutive phase of elevation the activity of the infraspinatus and teres minor muscles was increasing [18], [19], [25]. This results form the fact that external rotation of the arm is necessary for achieving the maximum physiological range of motion. Those observations indicate that the role of the infraspinatus and teres minor muscles is as important as the role of the supraspinatus muscle. It is believed that the share of the deltoid muscle in ensuring the proper motion range is approximately 41%. With only the infraspinatus muscle active it reaches 72% and with the infraspinatus and teres minor active – 64% [11]. This distribution looks different when the motion is performed with resistance or at increased velocity. In both cases, the activity of the muscles examined rises significantly, especially for the infraspinatus and the deltoid muscles [21].

Table 1. Division of muscles into functional groups according to DZIAK and TAYARA [5]

Type of motion	Share of muscles
Elevation of shoulders	quadrilateral, scapular levator, serratus anterior, rhomboid
Adduction of scapulas	quadrilateral, rhomboid
Abduction of scapulas	serratus anterior, greater pectoral
Abduction of arm	deltoid (center part), supraspinatus, biceps brachii, greater pectoral
Arm flexion	deltoid (front part), greater pectoral, coracobrachial
Arm external rotation	infraspinatus, supraspinatus, teres minor, deltoid (rear part)
Arm internal rotation	subscapular, teres minor, latissimus dorsi, greater pectoral
Arm adduction	greater pectoral, latissimus dorsi
Arm extension	deltoid (rear part), triceps brachii, teres minor and major

In terms of shoulder mechanics, the role of the quadrilateral and the serratus anterior muscles is also important. They are both in the group of muscles that elevate the arm and play a significant role in stabilisation of the scapula and its movements in relation to the thorax. Their synergistic collaboration causes the scapula to change position, where its lower angle travels upward and to the side, the upper angle moves closer to the spine and the acetabulum moves upward, all of which create conditions that are necessary to achieve the movement range exceeding 90° angle. This explains the increase in activity of those muscles which is visible in the EMG record. On that basis, the researchers reached a conclusion that elimination of function of two of the four following muscles (del, supraspinatus, quadrilateral and serratus anterior) disables elevation of the arm.

The role of the subscapular muscle requires a separate description. It is believed that full flexion of the shoulder joint is not possible without participation of this muscle, responsible for the internal rotation of the arm [15].

The role of the biceps brachii is controversial [10]. Some researchers believe it to be supplementary muscle without much importance for the mobility of the shoulder joint; others, however, think that it has a special role, especially when the rotator cuff muscles' function of flexion and abduction of the arm is impaired.

Table 2. Comparison of muscle groups under examination, depending on type of motion

External and internal rotation	Abduction	Flexion and extension
1 – infraspinatus muscle	2 – supraspinatus muscle	7 – deltoid muscle (front part)
2 – supraspinatus muscle	5 – deltoid muscle (center part)	4 – greater pectoral muscle
3 – latissimus dorsi muscle	6 – biceps brachii muscle	6 – biceps brachii muscle
4 – greater pectoral muscle	4 – greater pectoral muscle	8 – triceps brachii muscle

As was already mentioned, the share of the muscles of interest in active stabilisation of the shoulder joint is also important. Table 2 presents muscles that play a significant role in sustaining compactness of the shoulder joint. Among the muscles of the rotator cuff, the subscapular muscle is the most important stabiliser of the shoulder joint [31]. It prevents frontal, backward and upward shifts of the head of the humerus during elevation of the arm and its activity is maintained for as long as the movement takes. The remaining muscles of the rotator cuff are characterised by variable activity. In the initial phase of movement, a large share of the supraspinatus muscle can be observed, while in the final phase the infraspinatus and teres minor muscles dominate in ensuring stability of the joint [6], [12]. Therefore, cooperation of all of the four muscles is of great importance to the proper compactness of the joint and failure in functioning of one of them, caused by e.g. mechanical injury, results in instability, whose direction and size depend on the extent and location of the injury [7], [26], [32].

The role of the tendon of the long head of the biceps brachii in stabilisation of the shoulder joint was brought up during arthroscopic examinations [22]. Interoperative electrical stimulation of the tendon caused an increased compression of the head of the humerus in relation to the acetabulum. Further examination by means of electromyography showed that although the activity of the long head of the biceps brachii is insignificant in people with healthy shoulder joints, it distinctly rises in people with frontal instability of the joint, especially during elevation of the arm that is rotated externally. That activity is also significantly greater in the final phase of movement and under load [22], [24]. The results of those examinations allowed the researchers to reach a conclusion that the long head plays a major role in ensuring frontal stability of the joint by preventing excessive shifting of the humerus head. This is particularly visible in those patients, who suffer from a confirmed damage to the rotator cuff. In those cases, the long head also functions as the lower and upper stabiliser [17], which is important because by preventing the upward shifts of the humerus head it also protects the head and rotator cuff from excessive compression against the shoulder process.

The role of the deltoid muscle in the stabilisation of the shoulder joint has not been thoroughly explored and described so far. It is believed that this muscle functions as a lower stabiliser of the head of the humerus when the limb is in resting position and prevents its forward shifts during elevation of externally rotated arm in the case of frontal joint instability [30].

The aim of this study was to evaluate the changes of bioelectric activity of the chosen muscles in people with impingement syndrome and the effect they have on the functioning of the shoulder joint.

2. Material and methods

2.1. Patients

The study covered 58 people (39 females and 19 males) aged between 24 and 85 (56 years on average) treated for impingement syndrome at Orthopedic and

Trauma Ward of the Provincial Specialistic Hospital in Legnica in the years 2004–2006. In 57 cases, the changes affected only one shoulder and both shoulders in one case. The mean duration of complaints was 40 months.

2.2. Instrumentation and procedures

The measurement of the bioelectric activity of muscles was carried out using an apparatus for electromyography Octopus AMT-8 (Bortec Biomedical Ltd.), which enables measuring the electrical signals from eight channels simultaneously. Bipolar electrodes (Norotrodes) were used for the measurement. The active surface of the electrode is covered with silver chloride, and the contact surface was covered with a hypoalergic gel ensuring proper conductivity. The electrodes have to be placed parallel to the muscle fibers.

Examples of movements in track of EMG records

Placement of electrodes for measuring bioelectric activity of the selected muscles during performance of a given type of movement is presented in the figure.

The signals from the surface of the muscles examined were registered on both the healthy and the affected sides during the performance of unresisted movements: internal and external rotation, abduction, flexion and extension of the arm, and during maximum isometric contraction at an attempt to perform a movement against resistance in a closed kinematic chain.

The measurements enabled the registration of raw signals, which were subjected to modulation, filtering and smoothing by means of the 4th grade Butterworh band filter, which provided the RMS that was analysed [13].

3. Results

The measurements of muscular activity were subjected to statistical analysis and presented in tables 3–8. The distribution of the EMG signals recorded had been significantly different from the normal EMG distribution (which was verified by means of the Shapiro–Wilk test), thus non-parametric tests of independent variables were employed for comparing the mean EMG values of the muscle groups analysed (the Wilcoxon test). The mean and maximum values show that the activity of the infraspinatus muscle on the affected side is diminished during unrestrained movements as well as during maximum isometric contraction at the attempt of external rotation in the closed kinematic chain. In the case of the supraspinatus muscle, the mean and maximum values show that its activity has risen in both trials in comparison with the healthy side.

Table 3. Statistical characteristics of the EMG signals [mV] from selected muscle groups during external and internal arm rotation

	Muscles							
	Infraspinatus		Supraspinatus		Latissimus dorsi		Greater pectoral	
	Intact shoulder	Affected shoulder	Intact shoulder	Affected Shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder
Mean	0.130	0.038	0.017	0.028	0.011	0.007	0.026	0.020
SD	0.115	0.036	0.013	0.020	0.010	0.005	0.016	0.012
Median x_{med}	0.055	0.040	0.014	0.031	0.005	0.008	0.022	0.021
Minimum x_{min}	0.000	0.001	0.000	0.001	0.000	0.002	0.000	0.002
Maximum x_{max}	0.323	0.235	0.033	0.065	0.027	0.015	0.052	0.037

Table 4. Statistical characteristics of EMG signals [mV] from selected muscle groups during external and internal rotation in closed kinematic chain

	Muscles							
	Infraspinatus		Supraspinatus		Latissimus dorsi		Greater pectoral	
	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder
Mean	0.077	0.042	0.018	0.030	0.012	0.006	0.018	0.015
SD	0.064	0.029	0.016	0.027	0.013	0.008	0.013	0.012
Median x_{med}	0.046	0.030	0.012	0.025	0.007	0.002	0.023	0.011
Minimum x_{min}	0.012	0.002	0.000	0.002	0.000	0.001	0.001	0.001
Maximum x_{max}	0.215	0.105	0.048	0.077	0.050	0.025	0.042	0.037

Table 5. Statistical characteristics of EMG signals [mV] from selected muscles during arm abduction

	Muscles							
	Supraspinatus		Deltoid		Biceps		Greater pectoral	
	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder
Mean	0.092	0.099	0.191	0.128	0.029	0.026	0.007	0.008
SD	0.080	0.074	0.059	0.089	0.021	0.014	0.007	0.006
Median $x_{\text{med.}}$	0.072	0.099	0.200	0.129	0.022	0.024	0.002	0.008
Minimum x_{min}	0.000	0.001	0.055	0.025	0.000	0.000	0.000	0.000
Maximum x_{max}	0.269	0.275	0.301	0.323	0.082	0.057	0.017	0.017

Table 6. Statistical characteristics of EMG signals [mV] from selected muscle groups during external and internal rotation in closed kinematic chain

	Muscles							
	Supraspinatus		Deltoid		Biceps		Greater pectoral	
	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Intact shoulder
Mean	0.092	0.053	0.224	0.136	0.102	0.111	0.042	0.040
SD	0.056	0.035	0.130	0.162	0.092	0.116	0.025	0.024
Median x_{med}	0.097	0.044	0.200	0.040	0.050	0.045	0.034	0.044
Minimum x_{min}	0.010	0.002	0.006	0.011	0.002	0.002	0.010	0.001
Maximum x_{max}	0.248	0.126	0.490	0.430	0.325	0.323	0.087	0.077

Table 7. Statistical characteristics of EMG signals [mV] from selected muscles during unrestrained flexion and extension of arm

	Muscles							
	Deltoid		Greater pectoral		Biceps brachii		Triceps brachii	
	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder
Mean	0.139	0.089	0.027	0.020	0.019	0.022	0.042	0.027
SD	0.047	0.059	0.017	0.017	0.008	0.008	0.025	0.015
Median x_{med}	0.140	0.076	0.024	0.012	0.020	0.021	0.045	0.026
Minimum x_{min}	0.002	0.002	0.007	0.001	0.002	0.005	0.002	0.002
Maximum x_{max}	0.215	0.215	0.067	0.057	0.050	0.039	0.078	0.057

Table 8. Statistical characteristics of EMG signals [mV] from selected muscle groups during external and internal rotation in closed kinematic chain

	Muscles							
	Deltoid		Greater pectoral		Biceps brachii		Triceps brachii	
	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder	Intact shoulder	Affected shoulder
Mean	0.123	0.111	0.039	0.047	0.107	0.085	0.115	0.106
SD	0.064	0.127	0.028	0.046	0.123	0.118	0.084	0.071
Median x_{med}	0.140	0.054	0.026	0.029	0.040	0.023	0.081	0.075
Minimum x_{min}	0.010	0.014	0.010	0.001	0.012	0.005	0.025	0.025
Maximum x_{max}	0.201	0.430	0.108	0.151	0.435	0.420	0.352	0.306

As for the long rotators – latissimus dorsi muscle and the greater pectoral muscle that cooperate with the subscapular muscle during internal rotation of the arm – the EMG readout indicated diminished activity of those muscles on the affected side for both unrestrained and resisted movements.

The Wilcoxon test was performed in the process of statistical analysis for the purposes of evaluating the differences observed in the activity of the muscles investigated.

On the basis of that test it can be concluded that in the case of the infraspinatus muscle, greater, statistically significant ($p < 0.05$) activity was observed during unrestrained external rotation, while no statistically significant difference was recorded for both sides during the maximum isometric contraction. The supraspinatus muscle showed a statistically significant electromyographic activity in both measurements on the affected side. As for the long rotators, the results of the test did not reveal any statistically significant differences between the sides under examination.

The analysis of the readout showed a decrease in activity of the deltoid muscle on the affected side (center part) both during unrestrained abduction and during resisted abduction. While the supraspinatus muscles showed comparable activity on both sides during unrestrained movement, the application of resistance produced a difference in favour of the intact shoulder, yet it was not as significant as in the case of the deltoid muscle. It is also important that the comparison of activity of the greater pectoral and biceps brachii muscle between the sides did not show any significant differences in terms of the mean values. It should be emphasized that apart from cooperation in abduction, the biceps brachii muscle has the function of a dynamic stabiliser of the shoulder joint.

Further analysis of the results obtained, also by means of the Wilcoxon test, allowed finding out a statistically significant decrease of bioelectric activity on the affected side that concerned the deltoid muscle and occurred during both unrestrained and resisted abduction. As for the supraspinatus and the greater pectoral muscle, a significant difference in favour of the intact shoulder was observed during resisted abduction. Whereas, a comparison of activity of the biceps brachii muscles between the sides did not reveal any significant differences of activity.

The results presented in both tables show the lowest activity in the region of the deltoid muscle (front part) on the affected side during both unrestrained flexion and isometric contraction. Moreover, the activity of the biceps brachii muscle on the affected side seems to be comparable with that of deltoid one and even slightly higher during unrestrained movement than during resisted flexion, when the activity was clearly diminished on the intact side. The greater pectoral muscle showed a different behaviour – its activity during unrestrained movements was clearly reduced and during resisted movements was comparable to that on the intact side. The activity of the triceps brachii muscle, the only arm extensor in this group, showed a similar behaviour. It is significantly diminished on the affected side during unrestrained extension of the arm and comparable to that on the intact side during resisted movement.

Verification of the correctness of the aforementioned observations was performed by means of the Wilcoxon test, which confirmed a statistically significant reduction of activity of the following muscles on the affected side: deltoid, greater pectoral, biceps brachii and triceps brachii. Whereas, the comparison of activity of the deltoid, greater pectoral and triceps brachii during the maximum isometric contraction in the closed kinematic chain did not show any statistically significant differences. Only in the case of the biceps brachii, the researchers observed a statistically significant reduction of activity.

Additionally, for the purpose of a more detailed examination of the behaviour of the long head of the biceps brachii during active movements of the shoulder joint, a comparison of the activity of muscles during unrestrained flexion and abduction and during maximum isometric contraction was made between the intact and the affected sides. Calculations proved that the strength of the EMG signal increased significantly at an attempt of movement in the kinematic chain during the isometric contraction in relation to the activity during unresisted flexion and abduction of the arm, both on the intact and the affected sides.

4. Discussion

The evaluation of the bioelectrical activity performed by means of surface electromyography of the selected muscles on the intact and the affected sides showed a very significant decrease of the activity of the deltoid muscle, of its center as well as front part, and of the infraspinatus muscle on the affected side. However, there was no statistically significant difference in the activity of the supraspinatus muscle between the sides examined. REDDY et al. [23] presented similar results based on the comparative analysis of the EMG readouts from the same muscles that were examined in this study and from the subscapular muscle taken from people with impingement syndrome and healthy people. The highest fall of the bioelectrical activity of the deltoid, infraspinatus and subscapular muscle occurred in the initial phase of motion, i.e. within the first 60°. They did not observe any significant difference in the activity of the supraspinatus muscle between the people with impingement syndrome and the healthy people. Based on the results obtained those authors arrived at a conclusion that the developing instability of the shoulder joint in the impingement syndrome is caused by the described changes of activity of the selected muscles of the rotator cuff. This conclusion seems fully justified, taking into account the special role of the subscapular and the infraspinatus muscles in the active stabilisation of the shoulder joint [6], [7], [12], [25], [31].

The researchers wish to emphasise the significant reduction of the deltoid muscle's activity that was confirmed during the tests, since this muscle is not directly involved in the mechanical conflict with the coracoacromial ligament, as it is in the case of the supraspinatus muscle, which along with the disease duration leads to the damage to its anatomical structure. Despite that fact, the authors observed significantly reduced activity of the deltoid muscle in comparison with the supraspinatus muscle, both during unrestrained movement and the maximum isometric contraction. The explanation of this phenomenon can be found in SOLEM–BERTOFT's [28] description of a compensatory mechanism preventing compression of the tendon of the supraspinatus muscle, called the strategy of avoiding pain, that develops as the complaints progress. Constant pain while performing movements causes a reflexory inhibition of activity of the certain muscles at the relapse into complaints, which results in the change of a motion pattern, i.e. arm is raised by elevation of the shoulder and inclination of the trunk towards the healthy side. Similar observations were made by ITOI et al. [8]. They evaluated the activity of muscles during abduction, adduction, internal and external rotation in people with damaged rotator cuff and observed significant growth of activity following local administration of analgesics to the underarm region. According to studies on biomechanics of the shoulder joint [25], the deltoid muscle has the major share in elevating the arm and this explains the significant fall of its activity that is observed in all of the patients regardless of the disease duration or intensity of symptoms.

Based on the results of this study one may draw a conclusion that the fall of bioelectrical activity of the deltoid muscle is not an effect of pathological changes inside this muscle, but a sequel of the reflexory adaptive changes aimed at prevention of repetitive injuries of the rotator cuff that cause growing pain. Therefore, during the period of increased pain, the therapy should concentrate on analgesia, not on increasing joint mobility and muscle strength.

The most controversial muscle in the biomechanics of the shoulder joint is the biceps brachii, especially its long head. Some of researchers [10] believe it to be insignificant for the mobility and stability of the shoulder joint. The authors' studies on the bioelectric activity of the long head of the biceps brachii during unresisted abduction and flexion and during the maximum isometric contraction in closed kinematic chain showed, just as SAKURAI et al. [24], a statistically significant growth of activity of that muscle under applied resistance both on the healthy and affected sides. This means that the heavier the load on the limbs, the more important the role of the long head of the biceps brachii as the flexor, abductor and dynamic stabiliser of the shoulder joint. Moreover, the comparison of the values obtained on the healthy and affected sides during abduction of the arm indicated a lack of any significant differences in the activity of the long head between the sides. This stays in agreement with the views of those authors, who claim that the role of the long head of the biceps brachii as an active stabiliser increases significantly during elevation of the arm with growing external rotation. Connected with such high activity, yet not with a mechanical conflict, are inflammation of the sheath, subluxation or even rupture of the long head's tendon [22]. Based on the analysis, one can say that the long head of the biceps brachii has a major impact on the mobility and stability of the shoulder joint, especially when under load. The evaluation of the bioelectric activity of the greater pectoral and latissimus dorsi muscles did not show statistically significant differences between the diseased and the healthy sides with the exception for significantly lower activity of the greater pectoral muscle on the diseased side that occurs at an attempt of arm abduction in the closed kinematic chain. This fact, however, does not cause the external rotation to increase, since there was no statistically significant correlation between the range of that movement and the activity of the listed muscles. This allows one to think that the long rotators play a secondary role in comparison with the subscapular muscle and have no significant impact on the mobility of the shoulder joint. The importance of their role seems to lie in the active aligning of the head of the humerus that consists in lowering the head during the elevation of the arm [5]. The lasting activity of both of those muscles, comparable with those on the healthy side, confirms the developing of the compensatory mechanisms caused by the attenuation of the stabilising function of the short rotators: subscapular and infraspinatus muscles. This confirms the view of the supporters [5], [8] of the NMF therapy of shoulder complaints, who claim that the strengthening of both long rotators and the learning of the active aligning of the head of the humerus are of significant importance for recreation of the proper motion patterns and an increase in the stability of the shoulder joint.

5. Conclusions

1. Bioelectric activity of muscles of the shoulder girdle differs between the healthy and the diseased sides.

2. The highest fall of the bioelectric activity on the diseased side concerned the deltoid and infraspinatus muscle, while the activity of the supraspinatus did not change. The fall of the bioelectric activity was caused by the reflexory adaptive changes defined as the strategy of avoiding pain.

3. High bioelectric activity on the diseased side of the biceps brachii, greater pectoral and latissimus dorsi muscles confirmed the development of the compensatory mechanisms caused by impairment of the function of the infraspinatus muscle and indicated the importance of those muscles as dynamic stabilisers of the shoulder joint.

This study was approved by the Human Subjects Protection Committee of Medical University, Wrocław, Poland.

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