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MUSCLE ACTIVITY OF SHOULDER JOINTS IN PATIENTS WITH MULTIDIRECTIONAL SHOULDER INSTABILITY DURING PULL, FORWARD PUNCH, ELEVATION AND OVERHEAD THROW

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Abstract. *Multidirectional shoulder joint instability alters the role of dynamic stabilizers, as a result of which the motion patterns of muscles surrounding the shoulder joint are also changed. The aim of this study was to compare the muscle activity of patients with multidirectional shoulder instability and the control group during pull, forward punch and elevation and during overhead throw. Fifteen subjects with multidirectional shoulder instability and fifteen control subjects with normal, healthy shoulders participated in the study. Both shoulders were tested in all subjects. Signals were recorded by surface EMG from eight different muscles during pull, forward punch, elevation and overhead throw. The maximum values of normalized voluntary electrical activity, and the time span among peak muscle electrical activities in percent of total time of a movement cycle were compared with those of the healthy control group. Test results suggest that in the case of patients with multidirectional shoulder instability the different motions are performed in a different way. The results give rise to the assumption that the organism will attempt to ensure centralization of the glenohumeral joint and the reduction of instability is attempted to be ensured by the organism through increasing the role of rotator cuff muscles and decreasing the role of m. deltoideus, m. biceps brachii, and m. pectoralis maior. The analysis of time span shows that in the case of patients with multidirectional shoulder instability, the time difference between the peaks of normalized voluntary electrical activity of the patients is significantly greater than those of the control group. It can be established that the neuromuscular control and proprioception of patients with multidirectional shoulder instability differ from those of the control group.*

Key words: *shoulder joint, multidirectional instability, electromyography, motion pattern*

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INTRODUCTION

Multidirectional instability of the shoulder joint is a complex condition that can be difficult to diagnose and to treat (An & Friedman, 2000, 275; Arendt, 1988, 113; Lebar & Alexander, 1992, 193; Mallon & Speer, 1995, 54). Neer & Foster (1988, 897) first recognized multidirectional instability as a unique and separate condition from unidirectional instability and developed the inferior capsular shift as a specific surgical procedure for its treatment. Multidirectional instability can occur in males and females, in different age groups and in most segments of the population from sedentary individuals to elite athletes and is considered to be a serious and more prevalent condition than previously realized (An & Friedman, 2000, 275). It is characterized by a symptomatic global laxity of the glenohumeral joint (Beasley, Faryniarz, & Hannafin, 2000, 331), and may be present either traumatically, atraumatically, unilaterally, bilaterally, and with or without generalized joint laxity (Brown, Tan, & Kirklez, 2000, 110; Emery & Mullaji, 1991, 406; Lebar & Alexander, 1992, 193). Individuals having multidirectional instability subluxate or dislocate anteriorly, posteriorly or inferiorly with current reproduction of symptoms in at least two directions (Graichen et al., 2005, in press; Poppen &Walker, 1976, 195; Sidles, Harrymann, & Harris, 1991, 646). Symptoms typically are associated with midrange positions of glenohumeral motion and often occur during activities of daily life (Beasley, Faryniarz, & Hannafin, 2000, 331). The glenohumeral joint's relatively poor osseous and capsoligamentous stability necessitates a reliance on stabilization more than any other joint in the human body (Nyland, Caborn, & Johnson, 1998, 50).

Electromyographic studies (Basmajin & DeLuca, 1985; Glousman et al., 1988, 220; Kronberg, Brostorm, & Nemeth, 1991, 181; Morris, Kemp, & Frostick, 2004, 24; Sciscia et al., 2003, 9) showed that in case of multidirectional shoulder instability, the role of m. deltoideus, and m. pectoralis maior is reduced, while the role of m. trapesius, m. supraspinatus, and m. infraspinatus is increased. It was established that m. subscapularis was primarily responsible for anterior stability; and m. infraspinatus primarily for posterior stability (Hovelius, 1982; Ovensen & Nielsen 1985, 149; Ovensen & Nielsen 1986, 436). In the control group and in patients with multidirectional shoulder instability m. subscapularis also plays an important role of stabilization during abduction, rotation, and flexion; m. infraspinatus is also active during abduction and flexion; the role of m. supraspinatus is increased during extension (Kronberg, Brostrom, & Nemeth, 1991, 181; Kronberg, Nemeth, & Brostrom, 1990, 76; Sciscia et al., 2003, 9).

The purposes of this study were to define a detailed sequence of muscular activity patterns in selected shoulder girdle muscles during pull, forward punch, and elevation and during overhead throw, as well as to determine whether there were any differences as compared to healthy subjects. An improved understanding of muscle activity patterns during different movements may benefit many aspects of injury prevention, and even rehabilitation after injury.

MATERIAL AND METHOD

Subjects

Fifteen subjects with multidirectional shoulder instability and fifteen control subjects with normal, healthy shoulders participated in the study. Both shoulders were tested in all subjects. Subjects in the multidirectional shoulder instability group were tested after the original clinical diagnosis and did not receive any treatment or intervention before the test session. Pagnani and Warren (1994, 173) and Brown et al (2000, 110) classify multidirectional instability according to three subsets that include (1) acute trauma, repetitive trauma or no trauma; (2) generalized joint laxity or isolated shoulder laxity; and (3) unilateral or bilateral symptoms. The fifteen subjects with multidirectional instability tested in the current study were representative of all three subset categories. Of the 30 shoulders tested in the multidirectional instability group, 18 were symptomatic and 12 were asymptomatic (9 subjects were symptomatic bilaterally and 6 unilaterally). Given that bilateral symptoms occur relatively frequently in multidirectional instability, it was not possible to test homogeneous samples of unilateral subjects. Four of six subjects with unilateral instability had symptoms in the dominant limb, whereas two had symptoms in the non-dominant limb. Patients were diagnosed and selected for inclusion to the multidirectional instability group on the following criteria: (1) functionally significant inability to keep the humeral head centered in the glenoid fossa, especially in positions not at the extremes of motion; (2) the absence of an injury mechanism likely to tear the glenohumeral ligaments; (3) spontaneous reductions of translations; (4) glenohumeral translations that duplicated the symptoms of concern to the patients; (5) a diminished resistance to translation in multiple directions as compared with a normal glenohumeral joint; and (6) an absence of traumatic lesions (Matsen, 1994, 59).

Exclusion criteria for subjects with multidirectional shoulder instability were mental incompetency, psychiatric or emotional difficulties related to voluntary instability and any musculoskeletal, neurological or genetic abnormality other than shoulder instability. Control subjects had no history of shoulder injuries, complaints or surgery. Before participating in the study, subjects were required to indicate limb dominance and to provide informed consent. Before starting movement tests, a specialist of orthopaedics physically examined each of the subjects, on the basis of which the Constant score was taken (Constant & Murley, 1987, 160; Constant, 1997, 39). Table 1 summarizes the data of the subjects examined. The current study was administered according to ethical guidelines and procedures outlined by the Regional, Science and Research Ethics Committee of Semmelweis University under no. 114/2004.

Table 1. Summary of subject data

	Control group		MDI patients	
	Female	Male	Female	Male
Number (N)	10	5	10	5
Age (year)	24.6 ± 6.12	28.1 ± 5.1	24.5 ± 4.6	29.2 ± 3.1
Height (cm)	168.9 ± 22.3	175.9 ± 14.9	166.9 ± 13.1	178.3 ± 12.1
Weight (kg)	66.1 ± 5.5	77.1 ± 8.4	60.3 ± 3.1	71.1 ± 4.1
Constant score	100/100	100/100	92/93	91/93

Measurement method

In order to analyze the muscles of the shoulder joint and the upper limb, we used the surface electromyography unit of the ZEBRIS CMS-HS (ZEBRIS, Medizintechnik GmbH, Germany) computer-controlled motion analysis system located at the Biomechanical Laboratory of the Department of Applied Mechanics of Budapest University of Technology and Economics.

Activities of (1) m. pectoralis maior, (2) m. infraspinatus, (3-5) m. anterior, middle and posterior deltoid, (6) m. supraspinatus with m. trapesius (upper trapesius), (7) m. biceps brachii, and (8) m. triceps brachii were recorded in parallel. Ag-AgCl mono-polar surface electrodes (blue sensor P-00-S, Germany) were attached to the skin over the muscle belly, in the main direction of muscle fibers with an interelectrode center-to-center distance of 30 mm. The reference electrode was taped to the seventh cervical spine process and to the acromion. Electrodes were placed using the recommendations of SENIAM (De Leest et al., 1996, 222). The locations of electrodes are shown in Figure 1. EMG investigation was performed on both sides.

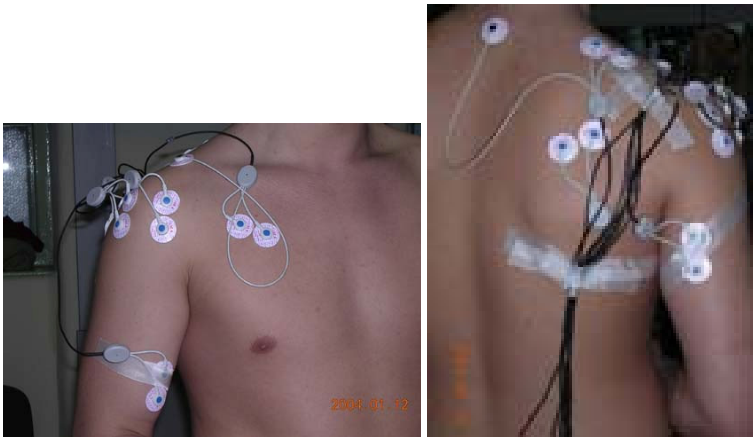

Fig. 1. Locations of surface EMG electrodes

The amplitude of the raw EMG signal is quasi-stochastic (random) and can be represented by a Gaussian distribution function: the amplitude ranges from -2000 to +2000 mV and the usable energy of the signal is limited to the frequency spectrum of 10-500 Hz. The accuracy of the differential amplifier is measured by the Common Mode Rejection Ratio (CMRR > 80, dB-noise < 2 μV). The ANVOLCOM model was used to check the cross-talk of different muscles (Hermes et al., 1999). Changes in the electric potential of muscles were detected and prime processed as described in literature (Myers et al., 2004, 1013).

Procedure

Tests are performed with males stripped to the waist and with females in bra, so that the surface electrodes can be stuck easily to the muscles of the shoulder and the upper limb. The approximately 30 minute test includes the following major steps:

- Following depilation and de-greasing of the shoulder, the thorax, and the upper limb, the surface electrodes stuck on the muscle groups specified are connected to the measurement system according to the respective channel distribution by cables and a data collection unit.
- Subjects perform the following isokinetic movements: (a) pulling, (b) forward punch, and (c) elevation (Table 2). Before the measurement the end points of the

movements and the movement itself were taught to the subjects so that they could repeat the movement in the same manner. Each phase of the pull, forward punch and elevation exercises were performed at 40 beats per minute, standardized with the aid of a metronome. Exercises involving the use of elastic resistance were performed at a distance away from the point of fixation, where the subject could perform at least three repetitions while maintaining consistent metronome speed.

- Subjects perform the following dynamic movements: (d) slow overhead throw and (e) rapid overhead throw. A tennis ball was used for overhead throw, whereas performing slow overhead pitch muscles were investigated during target throw. The target was 5 meters away. The rapid overhead throw was performed with maximal speed. During the rapid pitch subjects were asked to throw the ball as fast as they can, in the position as it was natural for them, into a large "golf"-net allowing the subjects to throw into a direction and with the technique they wished.

Table 2. Definitions of motions examined

Type of motion	Initial position	Motion	Final position
Pull	arm: 45 degrees of anteflexion elbow: extended forearm: 90 degression of pronation	in saggital plane	arm: 10 degrees of dorsal flexion elbow: 100 degrees of flexion forearm: 90 degrees of pronation
Forward punch	arm: neutral position beside the trunk elbow: 90 degrees of flexion forearm: 90 degrees of pronation wrist: 30 degrees of dorsal flexion	in saggital plane	arm: 70 degrees of anteflexion elbow: extended forearm: 90 degrees of pronation wrist: 30 degrees of dorsal flexion
Elevation	arm: 20 degrees of anteflexion elbow: extended forearm 90 degrees of pronation wrist: extended	In plane of scapula, appr. 20 degrees of anteflexion to the frontal plane	arm: 140 degrees of elevation elbow: extended forearm 90 degrees of pronation wrist: extended

Assessment parameters

The root mean square (RMS) values (Illyes & Kiss, 2005, 282; Jurak & Kocsis, 2002, 500) of EMG signals were calculated for consecutive segments of 50ms. In order to allow comparison of the activity in specific muscles and the activity in specific muscles among different individuals the EMG was normalized.

Normalized values were calculated for each muscle by the internationally recommended normalization method by maximal voluntary electrical activity (MVE) (Schuldt et al., 1987, 126; Soderberg & Cook, 1983, 1434). Muscle activity was categorized as: under 20% inactive; 20-40% minimum activity; 40.01-75% medium activity; 75.01-100% maximum activity (Kelly et al., 2002, 837).

The time broadness among peak muscle electrical activities in percent of total time of a movement cycle represents the time difference between peaks of normalized electrical activity in a motion cycle (Figure 2). The time broadness can describe to what extent the muscles involved in producing a motion simultaneously during a motion cycle. The time broadness provides indirect information on coordination.

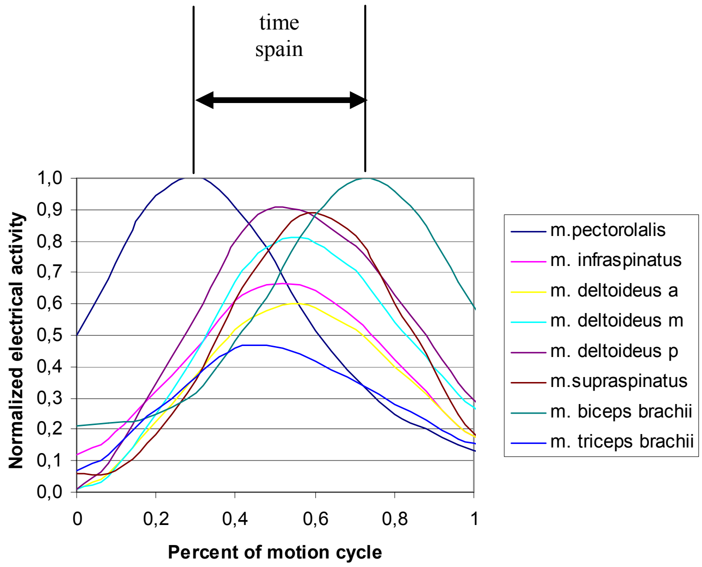

Fig. 2. The definition of time broadness among the peaks of the normalized electrical activities

Data analysis

Statistical analysis was carried out using the MS Excel Analysis ToolPak. The mean and standard deviation of MVE% were determined for each muscle during the different movement types. The time broadness among peak muscle electrical activities in percent of total time of a movement cycle was calculated separately at each subject (Winter, 1990). The mean and standard deviation of time broadness were determined by groups. Comparisons of MVE% and the time broadness among peak muscle electrical activities between the two groups were made by unpaired t-tests with ά set at 0.05.

RESULTS

Normalized voluntary electrical activity

The mean values of MVE%, standard deviation (SD), grading of the activity of each muscle group and significant differences between the two groups are summarized in Table 3.

Table 3. Average (standard deviation) and classification of MVE a) pull b) forward punch c) elevation d) slow overhead throw e) rapid overhead throw.

Type of motion		M. pectoralis maior	Anterior part of m. deltoideus	Middle part of m. deltoideus	Posterior part of m. deltoideus	M. supra-spinatus	M. infra-spinatus	M. biceps brachii	M. triceps brachii
Pull	Control group n=15	**30.47 (22.86)**	37.67 (24.16)	**65.47 (27.81)**	95.60 (7.23)	52.07 (25.71)	59.60 (28.03)	**45.60 (25.00)**	49.80 (27.82)
		+	+	++	+++	++	++	++	++
	MDI patients n=15	**9.23 (7.23)**	29.15 (31.45)	**39.67 (34.12)**	97.12 (11.78)	67.67 (30.91)	69.17 (45.67)	**21.21 (2.63)**	42.45 (34.12)
		0	+	+	+++	++	++	+	++
Forward punch	Control group n=15	**58.67 (30.85)**	**75.13 (19.35)**	**53.87 (27.36)**	**27.53 (17.28)**	**34.13 (16.57)**	50.27 (23.21)	**55.53 (29.95)**	**50.67 (28.70)**
		++	+++	++	+	+	++	++	++
	MDI patients n=15	**7.60 (2.15)**	**59.15 (26.06)**	**39.23 (35.67)**	**46.78 (11.56)**	**59.89 (17.78)**	54.13 (19.98)	**23.67 (9.34)**	**32.00 (26.78)**
		0	++	+	++	++	++	+	+
Elevation	Control group n=15	31.93 (26.68)	**90.00 (14.64)**	89.67 (21.22)	80.13 (19.44)	80.73 (28.50)	**68.60 (26.08)**	**58.47 (23.43)**	47.33 (26.94)
		+	+++	+++	+++	+++	++	++	++
	MDI patients n=15	21.67 (6.78)	**27.12 (23.67)**	83. 90 (19.95)	84.56 (34.98)	91.89 (16.87)	**81.80 (34.56)**	**28.98 (14.67)**	36.34 (6.78)
		+	+	+++	+++	+++	+++	+	+
Slow overhead throw	Control group n=15	67.15 (25.97)	68.27 (21.40)	52.93 (24.82)	**39.67 (27.30)**	**51.60 (21.79)**	**54.20 (24.10)**	33.20 (21.65)	53.07 (15.72)
		++	++	++	+	++	++	+	++
	MDI patients n=15	63.20 (25.10)	59.78 (35.14)	58.78 (23.78)	**76.17 (23.78)**	**75.67 (24.89)**	**67.12 (23.55)**	26.34 (23.34)	48.56 (22.98)
		++	++	++	+++	+++	++	+	++
Rapid overhead throw	Control group n=15	87.07 (23.34)	76.93 (19.40)	82.80 (15.73)	81.27 (17.23)	**89.33 (16.68)**	**87.27 (17.89)**	**87.73 (22.51)**	96.87 (10.36)
		+++	+++	+++	+++	+++	+++	+++	+++
	MDI patients n=15	100	75.67 (17.30)	82.34 (17.00)	88.13 (16.78)	**93.99 (9.00)**	**97.36 (8.81)**	**78.14 (5.14)**	100
		+++	+++	+++	+++	+++	+++	+++	+++

Legend: 0 inactive + minimum activity ++ medium activity +++ maximum activity.
The significant differences ($p<0.05$) in muscle activity were marked in bold.

a) *Pull*

For the control group, the movement is primarily executed by the posterior part of m. deltoideus; this muscle produces maximum activity. The middle part of m. deltoideus, m. supraspinatus, m. infraspinatus, m. biceps brachii, and m. triceps brachii are medium active; the anterior part of m. deltoideus and m. pectoralis maior produce minimal activity. For the control group, the motion was executed by the middle and posterior part of m. deltoideus, m. supraspinatus, m. infraspinatus, m. biceps brachii, and m. triceps brachii, while the anterior part of m. deltoideus is solely active – sometimes in conjunction with m. pectoralis maior. For patients with multidirectional shoulder instability, the motion is executed primarily by the posterior part of m. deltoideus – similarly to the control group –, and this muscle produces maximum activity. M. supraspinatus, m. infraspinatus, and m. triceps brachii are medium active; the anterior and middle parts of m. deltoideus and m. biceps brachii produce minimum activity. M. pectoralis maior is inactive. For patients with multidirectional shoulder instability, m. triceps brachii, m. biceps brachii, the posterior part of m. deltoideus, m. supraspinatus, and m. infraspinatus are actively involved in the motion; in the deceleration phase, m. triceps brachii, m. infraspinatus, m. supraspinatus, and the middle part of m. deltoideus are mainly active.

b) *Forward punch*

For the control group, the anterior part of m. deltoideus produces maximum activity; m. pectoralis maior, the middle part of m. deltoideus, m. infraspinatus, m. biceps brachii, and m. triceps brachii are medium active; the posterior part of m. deltoideus and m. supraspinatus produce minimum activity. For the control group, m. pectoralis maior, the anterior and middle parts of m. deltoideus, m. infraspinatus, and m. triceps brachii are maximum active at starting the forward punch motion; in the deceleration phase, the posterior part of m. deltoideus, m. supraspinatus, and m. biceps brachii are mainly active. For patients with multidirectional shoulder instability, m. pectoralis maior is inactive; m. triceps brachii and m. biceps brachii are minimum active; and all the other muscles examined are medium active. For patients with multidirectional shoulder instability, at the start of the forward punch motion the anterior and posterior parts of m. deltoideus, m. infraspinatus, and m. triceps brachii are involved in producing the motion; in the deceleration phase, m. supraspinatus, m. triceps brachii, and m. infraspinatus are involved.

c) *Elevation*

For the control group, all three parts of m. deltoideus and m. supraspinatus produce maximum activity; m. infraspinatus, m. biceps brachii, and m. triceps brachii are medium active; m. pectoralis maior produces minimum activity. For patients with multidirectional shoulder instability, the middle and posterior parts of m. deltoideus, m. supraspinatus, and m. infraspinatus produce maximum activity; m. biceps brachii, m. pectoralis maior, the anterior part of m. deltoideus and m. triceps brachii show minimum activity.

d) *Slow overhead throw as target-oriented motion*

Each muscle of the control group is medium active, except for the posterior part of m. deltoideus and m. biceps brachii being minimum active. For patients with multidirectional shoulder instability, the posterior part of m. deltoideus and m. supraspinatus produce maximum activity; all the other muscles examined are medium active.

e) *Rapid overhead throw*

All muscles of each group produce maximum activity.

Time broadness among peak muscle electrical activities

Analysis of the muscle coordination of patients with multidirectional shoulder instability can play an important role in the assessment of the severity of a disease. Coordination can be characterized indirectly by the time broadness among peak muscle electrical activities. The time broadness among peak muscle electrical activities provides information, in this case as well, only for dynamic motions – slow and rapid overhead throw.

In the event of slow target-oriented overhead throw, the time broadness among peak muscle electrical activities in a percentage of the motion cycle is 24.5% for the control group and 35.23% for patients with multidirectional shoulder instability. There is a significant difference between the two groups ($p=0.00015$).

For rapid overhead throw, the time broadness among peak muscle electrical activities is 13.1% for the control group and 28.87% for patients with multidirectional shoulder instability. There is a significant difference (p=0.00023).

Discussion

The stability of the shoulder joint depends primarily on soft tissues, such a muscles and ligaments (Glousman et al., 1988, 220; Kronberg, Nemeth, & Brostrom, 1990, 76; Ovensen & Nielsen, 1986, 436; Ovensen & Nielsen 1985, 149) and to a minor degree on the skeletal structure (Graichen et al., 2005, inpress). To restore stability after recurrent dislocation, soft-tissue reconstruction is often used (Mallon & Speer, 1995, 54; Neer & Foster, 1980, 897; Pagnani & Warren, 1994, 173). Patients with multidirectional shoulder instability often have generalized joint laxity with a large range of shoulder motion and often have muscular imbalance (Glousman et al., 1988, 220; Kronberg, Brostrom, & Nemeth, 1991, 181; Morris, Kemp, & Frostick, 2004, 24; Myers et al, 2004, 1013).

In a previous study of healthy control subjects and professional throwers it was shown that muscle activity occurred simultaneously in agonistic and antagonistic muscles (Illyes & Kiss, 2005, 282). It was concluded that coordinated muscular contraction played a significant role in shoulder joint stability during movements. The goal of our study was to examine how the multidirectional instability of shoulder joints influences the muscle activity pattern. The muscle activity pattern was characterized by maximal value of normalized voluntary electrical activity and by time broadness in the percent of the movement cycle.

Surface EMG electrodes were used, neither of them caused pain or restricted subjects' movements. The amplifiers' bandwidth was sufficient for both types of motion (isokinetic and dynamic).

Processing the data, we used the MVE% of each muscle to compare various muscle activities of different subjects during several movements. The advantage of this type of normalizing method is that it belongs to a dynamic condition and a second set is not needed for determining the RVC. The average activity periods of muscles during the movement cycle and mean time broadness in the percent of the movement cycle were calculated by analyzing all cycles. These two parameters should be considered in evaluating muscle activity patterns. The pattern is different in case there is a difference in any of the parameters above.

The rationale for using EMG to study muscle activation during elementary motion and during throwing movement is to provide a better understanding of muscle firing patterns during these shoulder movements. The movements of pull, forward punch and elevation were isokinetic as the same speed during various movements at different subjects was ensured by metronome. The overhead throw was dynamic motion. Two different types of movements gave us an opportunity to analyze the effect of speed on muscle activity.

In our experiment, patients with multidirectional shoulder instability and the control group were examined and compared to each other.

Analysis of normalized voluntary electrical activity

Gowan et al. (1987, 586) and Kelly et al. (2002, 837) have defined two groups of muscles. M. infraspinatus, m. supraspinatus, and three parts of the deltoid are defined as stabilizers. M. subscapularis, m. pectoralis major, m. latissimus dorsi and m. triceps brachii are defined as accelerators. On the basis of our study this definition could be used not only for throw, but it could be used for pull, forward punch and elevation as well.

The difference between ensuring the stability of the shoulder joint is represented by a significant discrepancy between the average values of MVE% of m. pectoralis maior, the middle part of m. deltoideus, and m. biceps brachii for pull; all three parts of m. deltoideus, m. pectoralis maior, m. supraspinatus, m. biceps brachii, and triceps brachii for forward punch; the anterior part of m. deltoideus, m. infraspinatus, and m. biceps brachii for elevation; and m. supraspinatus, m. infraspinatus, and m. biceps brachii for overhead throw (Table 3). For patients with multidirectional shoulder instability, the joint laxity is compensated by the reduced activity of m. deltoideus, m. biceps brachii, and m. pectoralis maior and by the increased activity of m. supraspinatus and m. infraspinatus. Increased activity may also be due to the fact that in the case of multidirectional shoulder joint instability, the muscles of the rotator cuff are weakened and this weakening can only be compensated by greater contraction (O'Driscoll, 1993, 305). For patients with multidirectional shoulder instability, the activity of the muscles required for launching the motions of forward punch and elevation – the anterior and middle part of m. deltoideus and m. biceps brachii for forward punch and the anterior part of m. deltoideus for elevation – decreases (Table 3), while the activity of muscles preventing the anterior subluxation of the humerus head – m. supraspinatus and the posterior part of m. deltoideus for forward punch and m. infraspinatus for elevation – is significantly increased. The findings are correlated by results in literature (Kronberg, Brostrom, & Nemeth, 1991, 181; Myers et al., 2004, 1013; Sciascia et al., 2003, 9).

Discrepancies in neuromuscular control and proprioception are evidenced by the fact that in case of the control group, one muscle – some part of m. deltoideus in general – presents much higher activity compared to the other investigated muscles. For patients with multidirectional shoulder instability m. pectoralis maior is inactive, but the activity of none of the muscles is at a maximum (Table 3).

On basis of the results it can be determined that the peak muscle electrical activity is significantly higher during dynamic motion, such as the overhead throw, than during isokinetic motion. Peak muscle activity depends on force, on speed and on the proprioception level of muscles. In case of dynamic motion, the increased muscular force required for the centralization of the glenohumeral joint is ensured by a significantly larger contraction of the posterior part of m. deltoideus, m. supraspinatus, m. infraspinatus, and m. biceps brachii in case of patients with multidirectional shoulder instability as opposed to the control group (Table 3). This findings confirmed the results of Glousman et al. (1988, 220) and Kronberg, Bronstrom, & Nemeth (1991, 181).

On the basis of results (Table 3), it can be assumed that the centralization of the glenohumeral joint is attempted to be ensured by increasing the role of the rotator cuff muscles and reducing the role of m. deltoideus, m. biceps brachii, and m. pectoralis maior. M. triceps brachii is involved in the centralization of the glenohumeral joint by longer muscle activity but not with increased electrical activity. The fact that the maximum value of the normalized electrical activity of the anterior part of m. deltoideus, m. pectoralis maior, and m. biceps brachii – playing a role in launching the motion – are decreased, is also intended to decrease instability. In summary, it can be stated that the motion patterns of muscles around the shoulder joint are changed as a consequence of shoulder joint instability, which is contrary to the statement by Morris, Kemp, & Frostick (2004, 24), explaining that the function of shoulder muscles as dynamic stabilizers is in-sufficient in case of joints with multidirectional instability. This discrepancy is likely to be due to the fact that Morris examined only elementary motions and performed tests using intramuscular pin electrodes, which may substantially affect muscular functions.

Analysis of the time broadness among peak muscle electrical activities

For patients with multidirectional shoulder instability, the time lag between the maximum values of normalized electrical activity is significantly larger than in the case of the control group. A possible reason for this discrepancy may lie in the different neuromuscular control and proprioception of patients with multidirectional shoulder instability. In our opinion, this is produced as a secondary effect due to joint laxity. Muscle activation different from that of the control group may occur partly as a reflex in order to compensate for the continuously changing position of the humerus head. This is also supported by the tests of Myers et al. (2004, 1013), who demonstrated longer biceps reflex latency in case of shoulder joints with multidirectional instability.

CONCLUSION

In summary, comparision of the results of MVE% and time broadness among peak muscle electrical activities in the percent of the movement may confirm our assumption that the muscular activity patterns of patients with multidirectional shoulder joint instability during pull, forward punch, and elevation and during overhead throw showed significant differences as compared to healthy subjects.

Muscle activity patterns have clinical implications for rehabilitation protocols:

1. By knowing the manner in which different muscles fire during various motions (pull, forward punch, elevation and throw), muscle-specified conditioning protocols could be provided. The demonstration of distinct patterns of muscle activation may have further implications for changes in rehabilitation protocols.
2. When compiling rehabilitation protocols it could be taken into account that not only the strengthening of the rotator cuff, but the strengthening of the posterior part of m. deltoideus and m. triceps brachii are also important because they play an important role in the stabilization of the glenohumeral joint. The increased proprioception of shoulder joints help to reduce the time broadness among peak muscle electrical activities, resulting in decreased instability of the shoulder joint.
3. The maximal activation in all muscles during the different movements suggests the mechanism of muscle injury. Movements executed with low peak amplitudes may minimize the risk of damage for initial muscular training. This is useful in the first part of rehabilitation and for strengthening stabilizer muscles. Large peak amplitudes may exceed the maximal load that repaired and injured muscles can withstand. Exercises with large peak amplitudes can be used in the last period of rehabilitation and the strengthening of accelerator muscles.

The data collected in this study enhance the knowledge of the muscle activity used during pull, forward punch, elevation and throw.

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MIŠIĆNA AKTIVNOST RAMENIH ZGLOBOVA KOD PACIJENATA SA VIŠESMERNOM RAMENOM NESTABILNOŠĆU TOKOM VUČENJA, UDARACA UNAPRED, PODIZANJA I BACANJA PREKO GLAVE

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Višesmerna nestabilnost ramenih zglobova menja ulogu dinamičnih stabilizatora, a kao rezultati će se javiti promene u obrascu kretanja mišića koji okružuju ramene zglobove. Cilj ove studije jeste da se uporedi mišićna aktivnost pacijenata sa višesmernom ramenom nestabilnošću i kontrolne grupe tokom vučenja, udaraca unapred, podizanja i bacanja preko glave. 15 subjekata sa višesmernom ramenom nestabilnošću i 15 kontolnih subjekata sa normalnim, zdravim ramenima su učestvovali u studiji. Oba ramena bila su testirana kod svih subjekata. Signali osam različitih mišića tokom vučenja, udaraca unapred, podizanja i bacanja preko glave beleženi su na površini EMG-a. Maksimalne vrednosti normalizovane dobrovoljne električne aktivnosti u vremenskom intervalu između maksimalne mišićne električne aktivnosti u procentima celokupnog vremena ciklusa kretanja, su upoređeni sa podacima zdrave kontrolne grupe. Rezultati testa pokazuju da u slučaju pacijenata sa višesmernom ramenom nestabilnošću različiti pokreti se izvode na različite načine. Rezultati otvaraju pretpostavku da će organizam pokušati da obezbedi centralizaciju glenohumeralnih zglobova i da smanji nestabilnost povećanjem uloge rotirajućih mišića i smanjenjem uloge m. deltoideus, m. biceps brachii i m. pectoralis major. Analiza vremenskog intervala pokazuje da je kod pacijenata sa višesmernom ramenom nestabilnošću, vremenska razlika između vrhova normalizovane dobrovoljne električne aktivnosti značajno veća nego vrhova kontrolne grupe. Može biti utvrđeno da se neuromišićna kontrola i propriocepcija pacijenata sa višesmernom ramenom nestabilnošću razlikuje od rezultata kontrolne grupe.

Ključne reči: *rameni zglob, višesmerna nestabilnost, elektromiografija, obrazac kretanja.*