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original article

Electromyographic activity and scapular dyskenesia in athletes with and without shoulder impingement syndrome

Atividade eletromiográfica e discinesia escapular em atletas com e sem síndrome do impacto no ombro

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Abstract – The objective of this study was to evaluate the presence of scapular dyskinesis and pain, satisfaction and function levels, as well as analyze the activation of scapular stabilizing muscles during isometric tasks of shoulder abduction in athletes with and without SIS. Thirty men athletes were divided into two groups: SIS group and Control group. The volunteers answered the Penn Shoulder Score questionnaire translated into Portuguese, which evaluates pain, dysfunction, and satisfaction with the shoulder. They were also evaluated for the presence of scapular dyskinesis through the Slide Scapular Lateral Test. The electromyographic activity of the upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA) muscles was evaluated during the isometric shoulder abduction in the frontal and scapular planes at angles of 45º, 90°, and 120°. The SIS group had a higher indication of pain and scapular dyskinesis when compared to control group. In the SIS group, higher values of electromyographic ratios between UT/LT and UT/SA were observed in the frontal plane in relation to the scapular plane. The conclusion can be made that pain, scapular dyskinesis, and altered muscle activation pattern was more frequent in the SIS group compared to the Control group. Therefore, exercises that emphasize the scapular muscles should be considered when planning rehabilitation programs for the SIS.

Key words: Electromyography; Scapula; Impingement syndrome.

Resumo – *O objetivo do estudo foi avaliar a presença de discinesia escapular, níveis de dor, satisfação e função, bem como analisar a ativação dos músculos estabilizadores da escápula durante tarefas isométricas de abdução do ombro em atletas com e sem SIO. Trinta atletas do sexo masculino foram divididos em grupo SIO e grupo Controle. Os voluntários responderam ao questionário Penn Shoulder Score para língua portuguesa que avalia dor, disfunção e satisfação em relação ao ombro, e também foram avaliados quanto à presença de discinesia escapular pelo Slide Scapular Lateral Test. A atividade eletromiográfica dos músculos trapézio superior (TS), trapézio médio (TM), trapézio inferior (TI) e serrátil anterior (SA) foi avaliada durante a realização da abdução isométrica do ombro nos planos frontal e escapular nas angulações de 45°, 90° e 120°. O grupo SIO apresentou maior indicativo de dor e discinesia escapular quando comparado ao grupo controle. No grupo SIO, foram observados valores maiores da razão eletromiográfica entre TS/TI e TI/SA no plano frontal em relação ao plano escapular. Pode-se concluir que a dor, discinesia escapular e alterações na atividade muscular foram mais observadas no grupo SIO quando comparado ao grupo Controle. Sendo assim, exercícios que enfatizam a musculatura escapular devem ser considerados no planejamento de programas de reabilitação para a SIO.*

Palavras-chave: *Eletromiografia; Escápula; Síndrome de colisão do ombro.*

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INTRODUCTION

The combined movements of the scapula, humerus, and clavicle during arm elevation meet a balanced and coordinated rhythm of muscle actions, called scapulothoracic rhythm. Through the action of scapular muscles, the scapula acts as a stable base for the rotator cuff muscles and allows maximum efficiency of the shoulder during movement[1]. Any change in this rhythm may predispose a condition known as scapular dyskinesis[2].

Scapular dyskinesis, in turn, has been associated with complaints of shoulder pain. This pain mainly affects individuals who perform physical activities that involve overload and/or repetitive overhead activities[3,4]. Moreover, changes in the scapular kinematics may result in another painful condition, especially during activities that go beyond the 90° of elevation of the arm: the shoulder impingement syndrome (SIS). The SIS is defined as the compression of the soft tissues contained in the subacromial space during movements that reduce the space between the coracoacromial arch and the greater tubercle of the humerus[5-8].

Several authors suggest that abnormalities in the shoulder and scapular movement are most commonly caused by the imbalance of the scapular muscles[9-12]. In asymptomatic individuals during the movement of shoulder abduction, the upward rotation and posterior tilt of the scapula progressively increase with arm elevation, since there is greater muscle activity of the serratus anterior and lower trapezius during the movement, although the activation of the upper trapezius in the last degrees of amplitude is also necessary[2,13]. However, in symptomatic individuals, the upper trapezius is more active due to the compensatory strategy that these individuals perform due to decreased activation of the serratus anterior muscle. This imbalance found in individuals with SIS results in decreased upward rotation of the scapula, increased anterior tilt of the scapula, and consequently less maintenance of the subacromial space[11,14]. Thus, the abnormal kinematics of the shoulder increases propensity to impact during arm elevation[8,11].

Considering the clinical importance that shoulder impingement syndrome has, the objective of this study was to analyze the pain, satisfaction, and function levels of the shoulder, as well as analyze the presence of scapular dyskinesis and the activation of scapular stabilizing muscles during isometric tasks of arm elevation in athletes with and without shoulder impingement syndrome.

METHODOLOGICAL PROCEDURES

Study Design and Sample

This is an observational cross-sectional study on a convenience non-probability sampling, composed of 30 male volunteers that are amateur athletes of five teams (handball, volleyball, swimming, judo, and jiu-jitsu) in the city of Petrolina - PE—men that practice sports that overload and require constant shoulder elevation. Their data are shown in Table 1. After presenting the project, 17 athletes reported that they felt pain in the shoulder joint and expressed desire to participate in the study. However, only 15 athletes met the inclusion and exclusion criteria to form the SIS group. From this, another 15 asymptomatic athletes were selected to compose the control group, thus ensuring two equal groups.

Volunteers in the control group needed to present the dominant asymptomatic shoulder, whereas in the SIS group volunteers were included that had signs, symptoms, and a confirmed diagnosis of SIS, reporting shoulder pain for at least six weeks and presenting pain on palpation and positive results in at least two of the tests (Neer, Hawkins, and Jobe)[15]. The volunteers who had a history of surgery, fractures, or degenerative joint diseases in the upper limb were not included in the study. All volunteers needed to practice physical activity for at least six months with a minimum frequency of four times per week and weekly duration of more than six hours of training. Furthermore, the SIS group only included volunteers that had not done physical or medication therapies (use of anti-inflammatory drugs) for at least six months. All signed a Term of Free and Clear Consent and the study was approved by the Research Ethics Committee of the University of Pernambuco under protocol 274/10.

Their height was determined using a scientific portable stadiometer (Seca, Hamburg, Germany), and the total body mass was measured on a mechanical scale properly calibrated (Filizola, São Paulo, SP, Brazil) with all procedures in accordance with the standards of the International Society for the Advancement of Kinanthropometry (ISAK).

Table 1. Standard mean and deviation of anthropometric data, age, as well as absolute and relative frequency of the functional dominance of groups evaluated

Characteristic	SIS (n=15)	Control (n=15)
Age (years)	22.00±3.87	20.27±1.79
Body Mass (kilograms)	73.37±8.57	75.70±12.49
Height (meters)	1.76±0.08	1.75±0.06
Right-handedness	14 (93.3%)	14 (93.3%)
Left-handedness	1 (6.7%)	1 (6.7%)

Evaluation Procedures

Each volunteer underwent an initial assessment to determine to which group he would belong. Then, the volunteer was asked to fill out a questionnaire that assesses the pain, satisfaction, and function of the shoulder using the Penn Shoulder Score in Portuguese (PSS-Brazil). The score ranges from zero to 100 points, the maximum score being indicative of no pain, high satisfaction, and good function[16].

The assessment of the scapular dyskinesis was obtained through the Slide Lateral Scapular Test, which consists of measuring the distance between the inferior angle of the scapula to the corresponding spinous process. The measurement was made with the individual standing upright and the shoulder at 0°, 45°, and 90° of abduction. A positive test result occurs when the difference between the measurements of left and right exceeds 15 mm[3].

From these data, the order of tasks was drawn, and then trichotomy, antisepsis with alcohol, and mild abrasion of the skin was carried out in places where the differential electrodes and the reference electrode would be positioned. Surface electrodes of the trapezius muscle - upper fibers (UT), middle fibers (MT), and lower fibers (LT) - were positioned with tape, longitudinally over the muscle belly, approximately in the direction of the muscle fibers, according to the recommendations of SENIAM[17]. However, to place the electrode in the serratus anterior muscle (SA), recommendations proposed by Hintermeister et al.[18] were followed. The reference electrode was positioned on the ulnar styloid process of the contralateral limb of the one being evaluated.

Later, the volunteer was asked to perform three maximum voluntary isometric contractions (MVIC) with the shoulder positioned at 90° of abduction in the scapular plane, holding a load of 2 kg in both hands for 6 s. A two-minute interval was allowed between each contraction to avoid fatigue. To normalize the data, instead of maximum voluntary isometric contraction, the maximum amplitude recorded during three MVICs was used due to fewer variations between the values for each person, less risk of muscle strain and fatigue, and better control of differences in muscle activation[19,20].

The activity proposed to the volunteer was to maintain, by means of isometric muscle contraction, the arm abduction in the scapular and frontal planes for eight seconds at different angles (45°, 90°. and 120°). The volunteers performed the unilateral movement with the dominant limb in all activities and in MVICs. A universal goniometer was used for accurate determination of the various angles of arm abduction and for scapular plane orientation. There was a 2-minute interval between each activity to minimize the effects of muscle fatigue.

Electromyography

To collect the trapezius (UT, MT, and LT) and SA muscles' electromyographic signal, four channels connected to the electromyograph Myosystem Br-1 (*Datahominis* Tecnologia Ltda®, Uberlândia - Brazil) were used, which caught the myoelectric activity through surface, differential, and simple electrodes with a gain of 20 times, consisting of two parallel rectangular pure silver bars (10 x 2 x 1 mm with a distance of 10 mm between bars) (*Datahominis* Tecnologia Ltda®, Uberlândia - Brazil).

The software Myosystem Br-1 version 3.5 *(Datahominis* Tecnologia Ltda®, Uberlândia - Brazil) was used for the EMG signal processing. Just six seconds of contraction of the eight seconds collected were used for data analysis, excluding the first and last second. Data was collected at a sampling frequency of 4000 Hz, and digital band-pass filters of 15-500 Hz were applied. The raw values of EMG amplitude are represented by the root mean square (RMS) and were subsequently normalized with the maximum value of MVIC.

Electromyographic ratio

The ratio of muscle activity between UT/LT and UT/SA in each task could be assessed by calculating the EMG ratio. For this, the normalized value of UT was divided by the normalized value of LT and SA, respectively. The ratio would be considered low if it was less than 0.3, which means the activation of LT or SA is three times higher compared to UT. If the value of the ratio was close to or greater than 1, it is interpreted as a similar muscle activation between the two muscles or greater predominance of UT over SA and LT[21].

Statistical analysis

Statistics were analyzed using the *SPSS* version 16.0 software. The normality of the data was verified through the Shapiro-Wilk test. The chi-square test was used to compare the dyskinesis and the t test of unpaired Student for the scores of the PSS-Brazil. In the intragroup analysis, ANOVA repeated measures and post hoc Tukey was used for EMG activity and comparisons between groups were analyzed by the t test of unpaired Student. All of them had a significance level of 5%.

RESULTS

PSS-Brazil and dyskinesis

The intergroup comparison revealed differences between the total scores of the PSS-Brazil as well as the values of the areas of pain, satisfaction, and function ($p < 0.02$). Greater scapular dyskinesis was observed in the SIS group when compared to the control group ($p = 0.01$). (Table 2).

Electromyography - Scapular plane

The results for the control group indicated that the EMG activity of all muscles evaluated was greater at angles of 90° and 120° in relation to 45° ($p < 0.03$), and EMG activity of the SA was greater at 120° when compared to 90° ($p < 0.01$). For the SIS group, the results showed that the EMG activity of all muscles evaluated, with the exception of LT, was greater at angles of 90° and 120° in relation to 45° ($p < 0.03$). Moreover, it was observed that at 120° of abduction, the MT had lower EMG activity compared to other muscles ($p = 0.02$) (Table 3). No statistical difference was observed in the intergroup comparison ($p > 0.09$).

Table 2. Absolute and relative frequency of scapular dyskinesis and mean scores of the PSS-Brazil of the control and SIS group.

	Dyskinesis		PSS-Brazil			
	Present	Absent	Pain	Satisfaction	Function	Total Score
SIS group	14 (93.3%)	1 (6.7%)	19.73±7.18	6.13±2.85	47.20±6.42	73.07±12.75
Control group	6 (40%)	9 (60%)	26.73±4.57	8.13±2.07	56.13±5.44	91.00±11.51
p	0.01	0.01	0.01	0.02	0.01	0.01

Frontal plane

For both groups, increased scapular muscle activation was observed during elevation at 90° and 120° in relation to the angle of 45° ($p < 0.02$). In the control group, the MT was more active in abduction at 45° and 90° compared to the LT and SA muscles ($p < 0.03$). However, when comparing the muscle activity in the angles of 90° and 120°, it can be seen that all the muscles are most active at 120° ($p < 0.02$), except for the MT ($p = 0.06$). In SIS group, the UT indicated greater muscle activity than the LT at a 45° elevation ($p = 0.001$) and greater activation than SA during 90° of elevation ($p = 0.01$) (Table 3). No statistical difference was observed in the intergroup comparison ($p > 0.07$).

Frontal plane vs. Scapular plane

For the control group, the results showed that the tasks in the frontal plane yielded increased activity of the UT, LT, and SA muscles at 120° ($p < 0.03$) and of the MT muscle at 90° and 120° ($p < 0.02$). However, for the LT muscle at 45°, a decrease in electromyographic activity in the frontal plane ($p = 0.01$) was observed.

The results for the SIS group showed increased activity of UT and MT muscles at angles of 90° and 120° ($p < 0.01$), while performing tasks in the frontal plane in relation to the scapular plane. Furthermore, lower activity was observed in the SA muscle when elevating the arm at 45° in the frontal plane ($p = 0.03$) when compared to the scapular plane.

UT/SA and UT/LT ratio

The results for the control group showed that the ratio UT/SA had lower values at 90° and 120° compared to 45° in both planes of task execution ($p < 0.05$). No difference was observed in the values of the ratio UT/LT in comparing the angles ($p > 0.12$). However, it was observed that the values of the ratios UT/SA and UT/LT were higher when carrying out the tasks in the frontal plane ($p < 0.02$).

In the SIS group, we observed a significant increase of the values of the ratio UT/LT when executing the tasks at 45° and 90° in the frontal plane in comparison to the scapular plane ($p < 0.01$). Moreover, the value of the ratio UT/SA showed an increase in the frontal plane only at 120° ($p = 0.02$). In the frontal plane, the results showed that there is a decrease in the values of UT/SA and UT/LT ratios at 120° in relation to the other angles ($p < 0.03$). However, no significant differences were observed in the scapular plane. No statistical difference was observed ($p > 0.16$) in intergroup comparison. (Table 4).

Table 3. Normalized electromyographic records of the Trapezius - upper fibers (UT), middle fibers (TM), and lower fibers (LT) - and Serratus Anterior (SA) muscles during Open Kinetic Chain (OKC) activities on frontal and scapular planes

	Scapular plane					
	SIS group			Control group		
	45°	90°	120°	45°	90°	120°
UT	0.38±0.13	0.51±0.11^{f‡}	0.63±0.11^{a,g‡}	0.39±0.13	0.54±0.14^{f}	0.62±0.12^{g‡}
MT	0.26±0.12	0.39±0.12^{f‡}	0.44±0.14^{g‡}	0.34±0.15	0.48±0.15^{f‡}	0.53±0.21^{g‡}
LT	0.47±0.56	0.52±0.14	0.63±0.20^{b}	0.37±0.13‡	0.57±0.21^{f}	0.67±0.24^{g‡}
SA	0.29±0.10‡	0.64±0.43^{f}	0.74±0.15^{c,g}	0.42±0.51	0.52±0.13^{f}	0.77±0.18^{g,h‡}
	Frontal plane					
UT	0.34±0.14^{d}	0.62±0.13^{e,f}	0.82±0.16^{g}	0.33±0.15	0.57±0.13^{f}	0.87±0.20^{g,h}
MT	0.32±0.21	0.65±0.27^{f}	0.80±0.21^{g}	0.44±0.20^{b,c}	0.86±0.39^{b,c,f}	1.05±0.42^{g}
LT	0.20±0.08	0.49±0.19^{f}	0.88±0.42^{g,h}	0.22±0.11	0.48±0.20^{f}	0.88±0.37^{g,h}
SA	0.23±0.06	0.45±0.10^{f}	0.76±0.18^{g,h}	0.22±0.10	0.46±0.11^{f}	0.85±0.19^{g,h}

$P < 0.05$; (a) indicates the statistical difference between UT and MT, (b) between LT and MT, (c) between SA and MT, (d) between UT and LT, (e) between UT and SA, (f) indicates the difference between 45° and 90°, (g) between 45° and 120° and (h) between 90° and 120°. (‡) Indicates the statistical difference between the EMG activity in the scapular plane and frontal plane.

Table 4. Ratio between the activity of the Upper Trapezius and Serratus Anterior (UT/SA) and Upper Trapezius and Lower Trapezius (UT/LT) muscles during Open Kinetic Chain (OKC) activities on frontal and scapular planes

	Scapular plane					
	SIS group			Control group		
	45°	90°	120°	45°	90°	120°
UT/SA	1.35±0.51	1.41±1.80	0.88±0.20‡	1.36±0.53	1.05±0.26a‡	0.83±0.16b‡
UT/LT	1.21±0.60‡	1.02±0.22‡	1.13±0.62	1.19±0.56‡	0.99±0.18‡	1.05±0.50
	Frontal plane					
UT/SA	1.50±0.41	1.41±1.21	1.12±0.24b,c‡	1.87±1.12‡	1.32±0.52a‡	1.05±0.33b‡
UT/LT	1.88±1.10‡	1.44±0.53‡	1.05 ± 0.23b,c	1.57±0.55‡	1.35±0.51‡	1.18±0.62‡

$P < 0.05$; (a) indicates the statistical difference between 45° and 90°, (b) between 45° and 120°, (c) between 90° and 120°. (‡) Indicates the statistical difference between the ratios in the scapular plane and frontal plane.

DISCUSSION

Several studies[1,2,22] have evaluated the relationship between dyskinesis, pain, and muscle activation pattern during arm elevation in order to identify possible changes in symptomatic individuals and their relationship with different degrees of abduction, whether on the frontal or scapular plane.

The dynamic stability of the scapula comes from the muscle action of the trapezius and SA fibers[23], where any impairment in the activation of these muscles can trigger abnormalities in shoulder kinematics and consequently dysfunction of this joint[24,25]. The results of this study showed higher incidence of pain and dyskinesis in individuals with SIS, corroborating with other texts, since changes in scapular motility and positioning are found in 68 to 100% of individuals that have an injury in their shoulder[26]. Complaints of pain are reported in 80% of the cases[26].

Analyzing the results of PSS-Brazil, it can be seen that significant differences were found in the total score and levels of pain, degree of satisfaction, and shoulder function. However, aspects of pain and function, as well as total score, gain prominence because besides the statistical difference, all these aspects differ between groups and are higher than the levels reported in other texts and are considered clinically significant (6.51 for pain, 8.16 for function and 12.1 for total score)[27]. In the present study, we found mean differences of 7.00, 8.93, and 17.3 points in the assessment of pain, function, and total score, respectively.

These findings are extremely important because they demonstrate that many individuals who practice different sports live with significant deficits in function and relevant levels of pain without any follow-up be it therapeutic or preventive. This reinforces the importance of greater attention by different health professionals in monitoring this public in order to act not only in the early detection and treatment, but also in preventing this problem, thus ensuring improved health and functional performance.

In the present study, there was a progressive increase in the activity of all muscles according to the degree of elevation of the arm when analyzing the tasks in the scapular plane of asymptomatic individuals. When Ludewig et al.[10] compared the kinematics and activity of the scapular muscles in asymptomatic individuals and with SIS, they also found that asymptomatic individuals had increased electromyographic activity concurrent with the increase of the angle, especially between the angles of 90° and 120°. Furthermore, in this study it was observed that the SA became more active at 120° of abduction in individuals without SIS, proving thus a greater need for stabilization, upward rotation, and posterior tilt of the scapula in this angle.

In the SIS group, a progressive increase in the activation of all muscles was also seen with the increase in angle on the scapular plane, with the exception of LT. The LT muscle is antagonistic to the UT. Thus, the imbalance in the activation of these muscles may contribute to alterations in scapular kinematics and consequently reduce the subacromial space[10]. The MT, in turn, plays an important role in stabilizing and controlling the scapular position. Cools et al.[20] state that this muscle is active during shoulder abduction because it acts as a stabilizer while contracting eccentrically to control the change of position of the scapula produced by UT and SA. However, it was seen in their study that changes in MT activation can be found in individuals with SIS, agreeing with the results of this study in which the MT showed less activation in the last degrees of abduction in relation to other muscles.

Tucker et al.[23] observed that the MT has different muscle activation between individuals with and without SIS. The MT tends to fix the scapular shaft to allow the controlled upward rotation of the scapula, but changes in the activity of this muscle can compromise the function of scapular positioning and possibly trigger scapular dyskinesis.

In relation to the frontal plane, both the control group and the SIS group had ascending muscle activations with the angles proposed. But increased activity of MT in relation to UT and SA was identified in the control group, where at 120° of abduction this increase was no longer viewed. Cools et al.[20] reported that different trapezius fibers react differently. As the SA contracts, the scapula tends to lateralization, but this displacement tends to be resisted by the LT, which is continuously changing in length to stabilize the rotation axis. The UT in turn exerts higher rotational movement around the axis, complementing the action of the SA. Therefore, although the MT is very strong, it is located near the scapula's axis of rotation, and therefore, its ability to generate torque is decreased, especially in the last degrees of scapular abduction, which explains the behavior of the MT in this study.

As to individuals in the SIS group, the elevation in the frontal plane showed an increase in activity of the UT in relation to the LT at 45°. Cools et al.[20] found delay in the UT activation in individuals with SIS during the first degrees of elevation when comparing the relative latency of the three fibers of the trapezius in people with and without SIS. Thus, the delay in the activation of the LT can lead to a relative increase of the UT. However, the results of this study found that at 90° of abduction, the UT showed higher muscle activity when compared to SA. This behavior can also be seen in the studies of Lin et al.[28] that reported an increase in the activity of the UT and a decrease of the SA by analyzing the pattern of muscle activation in individuals with SIS. The increased UT activation results in the elevation of the clavicle and anterior tilt of the scapula and can be seen as a compensatory strategy used by individuals with SIS in an attempt to raise the arm.

When comparing the muscle behavior between frontal and scapular plains, individuals with SIS showed increase in EMG activity of the UT and MT and lower activation of the SA when compared to the scapular plane. Additionally, analysis of EMG ratios could show the scapular muscle imbalance in individuals with SIS. The proportion of activation between the UT and LT during the 45° and 90° and between UT and SA at 120° was significantly higher in the frontal plane when compared to the scapular plane. The exercises of arm elevation are widely used during rehabilitation by promoting a strengthening of glenohumeral muscles[29]. However, it is important to consider rebalancing the scapular stabilizing muscles prior to glenohumeral strengthening. The exercises in the scapular plane are more indicated to ensure the rebalancing of scapular muscles before a greater activation of the SA and LT.

Limitations - The analysis of the EMG signal and dyskinesis were performed during the execution of isometric tasks, not allowing thus the generalization of the results for dynamic activities. However, isometric contractions provide more reliable results regarding the EMG analysis. Furthermore, this study emphasized the presence of imbalances even while performing tasks considered simple and easy, indicating that additional overload may worsen this condition. However, this hypothesis remains to be tested. Through these results, future studies can investigate specific exercises for the scapular stabilizing muscles in order to better predict which activity contributes to the proper conduct of the scapula and consequently correction of scapular dyskinesis.

CONCLUSION

Individuals with SIS showed differences in pain, dyskinesis, and muscle activation levels when compared to asymptomatic individuals. Moreover, it was observed that muscle imbalance is present in tasks considered simple for trained athletes and that this is most evident in the frontal plane. Therefore, strengthening scapular muscles must be stressed initially in the SIS treatment and performed preferably in the scapular plane.

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