Rev Bras Cineantropom Desempenho Hum
original article
https://doi.org/10.1590/1980-0037.2022v24e84625

Relationship of scapular dyskinesis with the pattern of activation of periescapular muscles during exercise

Relação da discinese scapular com o padrão de ativação dos músculos periescapulares durante exercicios

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Abstract - The aim of the present study was to analyze the activation pattern of the serratus anterior (SA), upper trapezius (UT), and lower trapezius (LT) muscles during periscapular exercises in individuals with and without ED, and to identify which proposed exercise presents greater activation of the periscapular muscles. Fourteen women, aged between 18 and 30 years, participated in this study, divided into a control group (n = 8) and a dyskinesis group (n = 8). The determination of the presence of ED was performed according to the analysis of scapular movement during arm elevation, using the yes/no classification. To evaluate muscle activation, electromyography signals of the SA, UT, and LT muscles were collected during exercise. The exercise protocol was composed of three repetitions of the exercises: *punch up*, *wall slide*, and *scaption*. The results showed that the ED group showed less activation of the AS and TT than the control group. During the scaption and wall slide exercises, the DE group showed less activation of the AS in relation to those without DE. There was no difference in muscle activation between the exercises. That individuals with dyskinesis have less activation of the muscles that control scapular mechanics and that the type of exercise did not influence the activation of the periscapular muscles.

Key words: Electromyography; Exercise therapy; Scapula.

Resumo - *O objetivo do presente estudo foi analisar o padrão de ativação dos músculos serrátil anterior (SA), trapézio superior (TS) e trapézio inferior (TI) durante exercícios periescapulares em indivíduos com e sem DE, e identificar qual exercício propostos apresenta maior ativação da musculatura periescapular. Participaram deste estudo 14 mulheres, com idade entre 18 e 30 anos, divididas em grupo controle (n = 8) e grupo discinese (n=8). A determinação da presença de DE foi realizada de acordo com a análise do movimento da escápula durante elevação do braço, usando a classificação sim/não. Para avaliação da ativação muscular, sinais eletromiográficos dos músculos SA, TS e TI foram coletados durante o exercício. O protocolo de exercício foi composto por três repetições dos exercícios: punch up, wall slide e scaption. Os resultados mostraram que o grupo DE apresentou menor ativação do SA e TI em relação ao grupo controle. Durante os exercícios scaption e wall slide, o grupo DE apresentou menor ativação do SA em relação àqueles sem DE. Não houve diferença na ativação muscular entre os exercícios. Concluímos que indivíduos com discinese apresentam menor ativação dos músculos que controlam a mecânica da escápula e que o tipo de exercício não influenciou na ativação da musculatura periescapular.*

Palavras-chave: *Eletromiografia; Exercício terapêutico; Escápula.*

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Received: November 18, 2021
Accepted: August 23, 2022

How to cite this article
Spinoso DH, Marin CS, Navega MT. Relationship of scapular dyskinesis with the pattern of activation of periescapular muscles during exercise. Rev Bras Cineantropom Desempenho Hum 2022, 24:e84625. DOI: http://doi.org/10.1590/1980-0037.2022v24e84625

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INTRODUCTION

Positioning and moving the scapula are important for correct shoulder biomechanics[1]. The upward rotation and posterior tilt movements of the scapula during arm elevation allow complete range of motion of the glenohumeral joint[2]. In addition, the scapula is also an attachment point for the serratus anterior (SA), superior trapezius (TS) muscles, middle and lower (TI), and its position is fundamental for maintaining the length-tension relationship of this musculature[2,3].

Scapular dyskinesis (SD) is characterized by the prominence of the medial edge or angle of the scapula, together with a change in its movement, for example, elevation of the scapula or inadequate rotation during arm elevation, which results in dysfunctional movement[4,5]. Among the various causes, the alteration in the neuromuscular control of the periscapular muscles, such as serratus anterior, trapezius and rhomboids, is considered the most common cause[6]. These muscles are important both for the proper mechanics of the scapula, as well as for the integrity of the shoulder function[7].

Considering the importance of the scapula, ED can generate clinical implications, such as decreased subacromial space, increased impact syndrome symptoms, increased risk of impact of internal glenohumeral structures, muscle imbalance, change in strength, activation and muscle overload of the scapular girdle, as well as alterations in the humeral scapular rhythm, which can lead to decreased range of motion, as well as joint instability, which contributes to altered kinematics[5,6,8-10]. In this sense, exercises involving the periscapular musculature, such as punch up, arm elevation in the plane of the scapula, have been included in rehabilitation protocols for various shoulder disorders associated with ED, with the objective of restoring the stability of the scapula[6]. According to Glousman, studies that dynamically analyze electromyographic activity can help form the basis of rehabilitation programs for the optimal choice of exercises[11].

Thus, the analysis of electromyographic activity during periscapular exercises can contribute to the understanding of which exercises activate the scapula musculature in greater proportion to be used in shoulder rehabilitation programs, as well as helping to understand the differences in the pattern of muscle activation of individuals with and without ED.

In view of the clinical implications in which ED may be related and the need for studies to identify the best exercises for activation of the periscapular muscles, the aim of the present study was to verify the pattern of activation of the SA, TS and TI muscles during exercises punch up, wall slide and scaption in individuals with and without ED and identify which of the proposed exercises have greater muscle activation. The hypothesis of this study is that individuals with ED will present less activation of the SA and TI muscles. Furthermore, it is hypothesized that the SA muscle will show greater activation during the punch up exercise and the TI muscle during the wall slide and scaption exercises.

METHODS

Subjects

This is a cross-sectional study in which university women with and without scapular dyskinesis were recruited. The eligibility criteria for this study were:

female, aged between 18-30 years, with no degenerative diseases in the joints of the shoulder complex, no history of injuries or trauma to the upper limbs, symptoms related to the cervical spine or instability of the glenohumeral joint and history of fracture or surgery in the upper extremity. In addition, the volunteers could not complain of shoulder pain. Table 1 presents the characterization of the sample.

Table 1. Anthropometric characteristics.

	Control (n = 8)	Scapular dyskinesis (n = 8)	P
Age (years)	22.10 ±0.53	22.87 ± 1.45	0.115
Body Mass (Kg)	54.85 ±8.95	57.06 ± 10.42	0.928
Stature (m)	1.61 ±0.06	1.62 ± 0.09	0.672
BMI (kg/m2)	21.10 ±2.92	21.12 ±1.61	0.231

BMI: body mass index

Assessment procedures

The assessment procedures were performed in a single day. First, the volunteers were validated to obtain personal data. Then, the movement of the scapula was analyzed to classify the volunteer in the group with or without scapular dyskinesis. Subsequently, the electromyographic signal of the SA, TS and TI muscles was collected during the performance of periscapular exercises.

Assessment of moving scapulae

The presence or absence of scapular dyskinesis was evaluated during a clinical examination consisting of inspection of the positioning and movement of the scapula during flexion and abduction of the upper limb using two 2-kg dumbbells for each upper limb. The kinematics of the scapula was observed, showing whether or not there were alterations in its symmetry. In this evaluation, the classification proposed by Uhl et al.[12] of yes/no was used, with the category "Yes" encompassing the Type I, II and III change patterns and the category "No" including Type IV, suggested by Kibler et al.[13].

Electromyography

The electromyographic data of the SA, TS and TI muscles were collected during the performance of periscapular exercises. To capture the electromyographic signals, an 8-channel EMG System do Brasil® (São José dos Campos -SP, Brazil) biological signal acquisition module was used, with analog band-pass filters with a cut-off frequency of 10-1000 Hz and calibrated with 2000 Hz sampling frequency, with 16 bits of resolution and simultaneous sampling of signals, software for data collection, processing and storage.

Ag/AgCl surface electrodes (Miotec®), in bipolar configuration, with a capture area of 1 cm in diameter and an inter-electrode distance of 2 cm were used. Before placing the electrodes, trichotomy and cleaning of the skin with alcohol were performed. For the electromyographic analysis of the SA, TS and TI muscles, the electrodes were placed on the skin of the volunteers in the sitting position, with the spine erect, with the arms hanging in a vertical position, in the direction of the muscle fibers, following the recommendations of SENIAM (TS: distance of 50% between the acromion and the C7 vertebra, TI: 2/3 between the superior angle of the scapula and the spinous process of the eighth thoracic vertebra, SA: between the region of the seventh and eighth ribs).

Periescapular exercise protocol

The protocol consisted of three exercises that aim to activate the periscapular musculature, as described below:

Punch Up: the volunteers were positioned supine on the stretcher with the dominant upper limb in 90-degree humerus flexion holding a 2 kg dumbbell. The orientation was to perform shoulder dislocation in order to protrude the scapulae[14].

Wall Slide: the volunteers were positioned in a standing position facing a wall with a slight inclination of the trunk, with the forearm in contact with the wall in 90 degree flexion shoulder and elbow and with an elastic band placed between your hands. The orientation was to slide the forearm upwards and at the same time perform a force with the arms to out against the elastic band in order to adduce the scapula[15].

Scaption: the volunteers were positioned standing with the dominant upper limb holding a 2 kg dumbbell. The orientation was to perform an elevation of the arm in the scapular plane, with the thumbs pointing upwards in order to maintain neutral shoulder rotation[16]. Figure 1 show the protocol exercises.

Before starting the assessment protocol, a familiarization of the perescapular exercises was performed. Between familiarization and the start of data collection procedures, an interval of 5 minutes was given. The evaluation protocol consisted of performing 3 repetitions for each proposed exercise. The sequence of the evaluated movements was defined by means of directed randomization and the evaluation interval between each movement was 5 minutes.

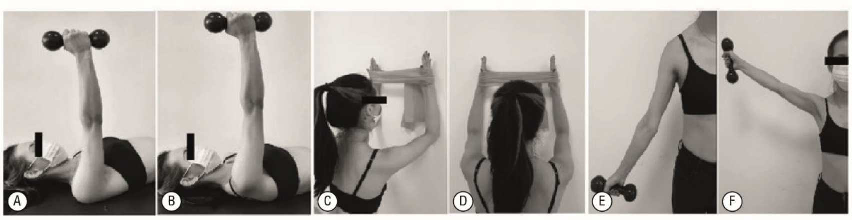

Figure 1. Perescapular exercises protocol.

Data analysis

To analyze the electromyographic data, specific routines developed in a Matlab environment (Mathworks, Natick, MA, USA) were used. To calculate the amplitude of the electromyographic signal during the exercises, a linear envelope was created by means of whole-wave rectification and signal smoothing, using a 4th-order low-pass filter, with a cutoff frequency of 10 Hz. of the linear envelope value was normalized by the value of the peak amplitude of the linear envelope between the three trials[17]. The data were expressed as a percentage of the linear envelope with the highest value.

Statistical analysis

Statistical analysis was performed using the PASW Statistics 18.0® (SPSS) software. After checking the normality and homogeneity of the data, the Repeated Measures Anova test was applied to compare groups and conditions. In all statistical tests, a significance level of $p<0.05$ was adopted.

RESULTS

There was a significant difference between groups ($p = 0.019$) and interaction between groups and conditions ($p = 0.033$). Bonferroni's Pos Hoc showed that when comparing the groups, the volunteers with ED had less SA activation ($p = 0.001$) and TI ($p = 0.049$) compared to the control group.

Regarding exercises, the group with ED showed SA activation 13% lower during the Scaption exercises ($p= 0.026$) and 8% in the Wall Slide exercise ($p = 0.024$), compared to the group without dyskinesis. Table 2 shows the activation percentage of the groups. There was no difference between groups for the push-up exercise.

Table 2. Electromyographic activation during periscapular exercises.

	Control			Scapular Dyskinesis		
	TS	TI	SA	TS	TI	SA
Scaption	90.13±09.90	94.99±03.39	95.23±04.94	90.18±08.20	83.02±13.49	80.08±11.16*
Punch Up	83.10±13.47	91.23±04.91	84.30±06.57	84.29±09.20	83.07±14.17	84.87±08.58
Wall Slide	82.87±05.24	91.10±03.21	92.27±04.87	85.39±09.02	90.58±05.66	84.44±05.68*

Mean ± standard deviation values. TS: upper trapezius, TI: lower trapezius, SA: Serratil Anterior. *denotes significant difference

DISCUSSION

This study evaluated the electromyographic activity of the TS, TI and SA muscles during the performance of periscapular exercises in individuals with and without ED. The initial hypothesis was partially confirmed, given that the volunteers with ED had less activation of AS and TI compared to the group without dyskinesis. However, there were no significant differences in the magnitude of muscle activation when comparing the three exercises analyzed in this study.

More and more studies have been linking ED with altered activation of scapular muscles[18-22]. Shoulder exercises can improve muscle activation and coordination, being the main strategy for treating shoulder disorders associated with ED[23]. This study showed that, during exercises, volunteers with ED activate less the SA and TI, in relation to those who do not present alteration in the kinematics of the scapula.

The findings of this study corroborate Araújo et al.[18] who show less SA activation during the push-up performance, in volunteers with ED, concluding that these individuals have a deficit in the activation of this musculature. Pirauá et al.[19], also found low levels of AS activity during push up exercise on an unstable surface in individuals with ED. Other studies, which relate electromyographic activity in individuals with ED also showed that compared to the control group, those who had ED had a lower activation of AS, converging with the results obtained in this study[24,25].

Considering that the AS is an important muscle for stabilization and for the rotations of the scapula and that in ED there are changes in the position and movement of this bone, the lesser activation of the AS in individuals with ED can contribute to a decrease in the upward rotation of the scapula during the arm elevation associated with anterior scapular inclination, which may favor the compression of subacromial structures[19,20,26].

As for the activity of the TI muscle, this study found a decrease in its activation in the ED group compared to the control group. These data corroborate with Smith et al.[21] who analyzed the muscle activity of TS and IT, showing a decrease in IT in individuals with ED during arm elevation in the scapular plane. On the other hand, some studies diverge from these results showing an increase in IT electromyographic activity in ED during exercise, hypothesized that the increase in IT activation would be a neuromuscular strategy to compensate the decrease in AS muscle activity[18,19]. Decreased TI activation can contribute to elevation and less upward rotation of the scapula during shoulder abduction and flexion movements, which can lead to damage to the arthrokinematics of the glenohumeral joint and reduction of the subacromial space and the rotator cuff tendons[10].

This study found no significant difference for the TS muscle both in the comparison between groups, as in the comparison between the proposed exercises. This finding differs from Lin et al.[27] who showed an increase in TS activation during arm elevation movement. The difference with our results can be explained by the fact that the volunteers in this research are asymptomatic. According to the literature, the decrease in SA and TI activation in individuals with shoulder dysfunctions is associated with greater activation of the TS and elevation of the clavicle, as a strategy to achieve greater shoulder ranges of motion[28,29].

Furthermore, it was expected that exercises performed in a posture against gravity would provoke greater activation of the TS in relation to the punch up exercise, as it is a movement that individuals with ED tend to elevate the scapula due to the weakness of the SA and TI[30]. Exercises that minimize the activation of the TS in relation to the SA are recommended to improve the stabilization of the scapula and provide a more selective strengthening of the SA31. However, in the present study there was no difference in the activation of SA, TI and TS when comparing the proposed exercises, which can also be justified by being individuals with ED without pain.

It is suggested that further studies be carried out involving the symptomatic population, in order to understand the changes in the pattern of activation due to pain that affect the movement kinematics, as well as the analysis of the activation of the periscapular muscles during different exercises to contribute to the elaboration of effective treatments for this population.

This study has as a limitation the low sample size, which may have influenced the non-significant results between the proposed comparisons.

CONCLUSION

This study led to the conclusion that individuals who have ED have a deficit in AS and IT muscle activity compared to individuals without dyskinesis and that exercise did not influence the pattern of muscle activation in young people without shoulder pain complaints.

COMPLIANCE WITH ETHICAL STANDARDS

Funding

The present study was financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Unesp's Institutional Scientific Initiation Scholarship Program (PIBIC).

Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee Universidad State of São Paulo – 4.612.923 and the protocol (32400820.2.0000.5406) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: CSN, DHS, MTN; Performed the experiments: CSM, DHS; Analyzed the data: CSM, DHS; Contributed reagents/materials/analysis tools: CSM; DHS. Wrote the paper: CSN, DHS; MTN.

REFERENCES

1. Moghadam AN, Rahnama L, Dehkordi SN, Abdollahi S. Exercise therapy may affect scapular position and motion in individuals with scapular dyskinesis: a systematic review of clinical trials. J Shoulder Elbow Surg 2020;29(1):E29-36. http://dx.doi.org/10.1016/j.jse.2019.05.037. PMid:31420226.
2. Hall SJ. Biomecânica básica. 7th ed. Rio de Janeiro: Guanabara Koogan; 2016. Biomecânica do Membro Superior; p. 167-71.
3. Kim JS, Ahn DH, Park DH, Oh JS. Electromyographic activity of the serratus anterior and pectoralis major during isometric scapular protraction at different resistance intensities in subjects with and without a winged scapula. Clin Biomech 2019;61:199-204. http://dx.doi.org/10.1016/j.clinbiomech.2018.12.018. PMid:30594768.
4. Kibler WB, Sciascia A. Current concepts: scapular dyskinesis. Br J Sports Med 2010;44(5):300-5. http://dx.doi.org/10.1136/bjsm.2009.058834. PMid:19996329.
5. Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'scapular summit'. Br J Sports Med 2013;47(14):877-85. http://dx.doi.org/10.1136/bjsports-2013-092425. PMid:23580420.
6. Bley AS, Lucarelli PRG, Marchetti PH. Discinese escapular: revisão sobre implicações clínicas, aspectos biomecânicos, avaliação e reabilitação. Revista CPAQV 2016;8(2):1-10.
7. Kiyomoto HD, Araújo RC. Análise eletromiográfica dos músculos estabilizadores da cintura escapular [thesis]. São Paulo (SP): Universidade São Judas Tadeu, Faculdade de Ciências Biológicas e da Saúde; 2007. 130 p.

8. Kibler WB, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg 2012;20(6):364-72. http://dx.doi.org/10.5435/JAAOS-20-06-364. PMid:22661566.
9. Meininger AK, Figuerres BF, Goldberg BA. Scapular winging: an update. J Am Acad Orthop Surg 2011;19(8):453-62. http://dx.doi.org/10.5435/00124635-201108000-00001. PMid:21807913.
10. Camargo PR, Neumann DA. Kinesiologic considerations for targeting activation of scapulothoracic muscles - part 2: trapezius. Braz J Phys Ther 2019;23(6):467-75. http://dx.doi.org/10.1016/j.bjpt.2019.01.011. PMid:30797676.
11. Glousman R. Electromyographic analysis and its role in theathletic shoulder. Clin Orthop Relat Res 1993;288:27-34. PMid:8458143.
12. Uhl TL, Kibler WB, Gecewich B, Tripp BL. Evaluation of clinical assessment methods for scapular dyskinesis. Arthroscopy 2009;25(11):1240-8. http://dx.doi.org/10.1016/j.arthro.2009.06.007. PMid:19896045.
13. Kibler WB, Uhl TL, Maddux JW, Brooks PV, Zeller B, McMullen J. Qualitative clinical evaluation of scapular dysfunction: a reliability study. J Shoulder Elbow Surg 2002;11(6):550-6. http://dx.doi.org/10.1067/mse.2002.126766. PMid:12469078.
14. Brum DPC, Carvalho MM, Tucci HT, Oliveira AM. Avaliação eletromiográfica de músculos da cintura escapular e braço durante a realização de exercícios com extremidade fixa e carga axial. Rev Bras Med Esporte 2008;14(5):466-71. http://dx.doi.org/10.1590/S1517-86922008000500013.
15. Cricchio M, Frazer C. Scapulothoracic and scapulohumeral exercises: a narrative review of electromyographic studies. J Hand Ther 2011;24(4):322-34. http://dx.doi.org/10.1016/j.jht.2011.06.001. PMid:21820276.
16. Tsuruike M, Ellenbecker TS. Scapular muscle electromyographic activity during abduction exercises in the scapular plane in three positions. Int J Sports Phys Ther 2019;14(6):935-44. http://dx.doi.org/10.26603/ijspt20190935. PMid:31803526.
17. Boarati EL, Hotta GH, McQuade KJ, Oliveira AS. Acute effect of flexible bar exercise on scapulothoracic muscles activation, on isometric shoulder abduction force and proprioception of the shoulder of individuals with and without subacromial pain syndrome. Clin Biomech 2020;72:77-83. http://dx.doi.org/10.1016/j.clinbiomech.2019.12.001. PMid:31838214.
18. Araújo RC, Pirauá ALT, Beltrão NB, Pitangui ACR. Activity of periscapular muscles and its correlation with external oblique during push-up: does scapular dyskinesis change the electromyographic response. J Sports Sci 2018;36(5):571-7. http://dx.doi.org/10.1080/02640414.2017.1324205. PMid:28537843.
19. Pirauá ALT, Pitangui ACR, Silva JP, Passos MHP, Oliveira VMA, Batista LSP, et al. Electromyographic analysis of the serratus anterior and trapezius muscles during push-ups on stable and unstable bases in subjectswith scapular dyskinesis. J Electromyogr Kinesiol 2014;24(5):675-81. http://dx.doi.org/10.1016/j.jelekin.2014.05.009. PMid:24997890.
20. Tooth C, Schwartz C, Colman D, Croisier J-L, Bornheim S, Brüls O, et al. Kinesiotaping for scapular dyskinesis: the influence on scapular kinematics and on the activity of scapular stabilizing muscles. J Electromyogr Kinesiol 2020;51:102400. http://dx.doi.org/10.1016/j.jelekin.2020.102400. PMid:32105914.
21. Smith M, Sparkes V, Busse M, Enright S. Upper and lower trapezius muscle activity in subjects with subacromial impingement symptoms: is there imbalance and can taping change it? Phys Ther Sport 2009;10(2):45-50. http://dx.doi.org/10.1016/j.ptsp.2008.12.002. PMid:19376471.
22. Tsuruike M, Ellenbecker TS. Adaptation of muscle activity in scapular dyskinesis test for collegiate baseball players. J Shoulder Elbow Surg 2016;25(10):1583-91. http://dx.doi.org/10.1016/j.jse.2016.03.004. PMid:27265682.

23. Myers JB, Oyama S. Sensorimotor factors affecting outcome following shoulder injury. Clin Sports Med 2008;27(3):481-90, x. http://dx.doi.org/10.1016/j.csm.2008.03.005. PMid:18503879.

24. Park SY, Yoo WG. Activation of the serratus anterior and upper trapezius in a population with winged and tipped scapulae during push-up-plus and diagonal shoulder-elevation. J Back Musculoskeletal Rehabil 2015;28(1):7-12. http://dx.doi.org/10.3233/BMR-140458. PMid:24561786.

25. Kim SH, Kwon OY, Kim SJ, Park KN, Choung SD, Weon JH. Serratus anterior muscle activation during knee push-up plus exercise performed on static stable, static unstable, and oscillating unstable surfaces in healthy subjects. Phys Ther Sport 2014;15(1):20-5. http://dx.doi.org/10.1016/j.ptsp.2013.01.001. PMid:23972504.

26. Phadke V, Camargo P, Ludewig P. Scapular and rotator cuff muscle activity during arm elevation: a review of normal function and alterations with shoulder impingement. Rev Bras Fisioter 2009;13(1):1-9. http://dx.doi.org/10.1590/S1413-35552009005000012. PMid:20411160.

27. Lin JJ, Hsieh SC, Cheng WC, Chen WC, Lai Y. Adaptive patterns of movement during arm elevation test in patients with shoulder impingement syndrome. J Orthop Res 2011;29(5):653-7. http://dx.doi.org/10.1002/jor.21300. PMid:21437944.

28. Ludewig PM, Braman JP. Shoulder impingement: biomechanical considerations in rehabilitation. Man Ther 2011;16(1):33-9. http://dx.doi.org/10.1016/j.math.2010.08.004. PMid:20888284.

29. Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, LaPrade RF. Motion of the shoulder complex during multiplanar humeral elevation. J Bone Joint Surg Am 2009;91(2):378-89. http://dx.doi.org/10.2106/JBJS.G.01483. PMid:19181982.

30. Borms D, Maenhout A, Cools AM. Incorporation of the kinetic chain into shoulder-elevation exercises: does it affect scapular muscle activity? J Athl Train 2020;55(4):343-9. http://dx.doi.org/10.4085/1062-6050-136-19. PMid:32160060.