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The Restoration of Neuromuscular Control of the Scapulothoracic Muscles and Its Effect on Subacromial Impingement Syndrome

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ABSTRACT

Background: The subacromial impingement syndrome occupies a very large percentage of shoulder pathologies as the rates even reach 44 to 60 percent. It has been proven that in painful conditions, especially in subacromial impingement syndrome, there seems to be an alteration of the person's motor and neuromuscular control ability, especially of the scapula, as changes are observed in the muscle activation of the scapulothoracic muscles, significantly affecting the patient's functional levels. The main objective of this review is to examine the currently available research on the rehabilitation of the neuromuscular control of the scapulothoracic muscles in people with Subacromial Impingement Syndrome and to clarify which techniques can improve motor control of the scapula.
Methods: PubMed, Cochrane Library, MEDLINE, Cumulative Index to Nursing and Allied Health Literature, and Google Scholar were search. All types of study designs were included, except of case reports and case series. The using medical subject headings were ‘impingement syndrome’, ‘shoulder impingement syndrome’ and ‘Exercises scapula stabilization', 'Scapula exercises', 'Scapula rehabilitation'.
Results: The initial search strategy generated 9351 references after duplicate removal. All 324 were kept for full-text review, 6 unique studies were included in the review.
Conclusion: The reported research on restoring neuromuscular control of the scapulothoracic muscles in individuals with subacromial impingement syndrome appears to be very encouraging as their findings show an increase in the individual's ability to voluntarily and involuntarily control their scapula kinematics through better activation of the scapulothoracic muscles.

Keywords: Subacromial impingement syndrome; neuromuscular control; scapula; scapulothoracic muscles; functional capacity

INTRODUCTION

Shoulder pain is one of the (GBD 2016, Disease and Injury Incidence and Prevalence Collaborators, 2017) common presentations with the prevalence ranging between 7% and 26% [1] Globally, about 4% of adults visit their general practitioner for shoulder pain [2]. The 1-year prevalence of shoulder pain among the general population has been estimated to vary between 7% and 30%, while life-time prevalence up to 70% [3-4]. Just about half of the subjects presenting with shoulder pain are related to subacromial impingement syndrome and the overall prognosis is highly variable with nearly 40% of the subjects reporting pain one year after consultation [5].

Shoulder Impingement Syndrome (SIS) has been proposed as the most common source of shoulder pain [6], and is a common diagnostic label for this patient [7]. SIS is the commonest disorder of the shoulder, accounting for 44-65% of all complaints of

shoulder pain [8-9]. Currently, this syndrome is considered a multifactorial condition for which that etiology has been explained by intrinsic and extrinsic mechanisms of rotator cuff pathology [10-11].

SIS is characterized as the painful pathological condition, in the anterior anterolateral region of the glenohumeral joint, in which the soft tissues of the subacromial space are crushed between the head of the humerus and the acromion of the scapula during elevation upper extremity [12].

Neuromuscular control is defined as "the centrifugal reaction of the muscles, which converts the sensory information into physical energy", in other words it is the pre-activation of the muscles in anticipation of a movement or a loading of the joint using information about an activity usually the experience of the individual, for pre-programming the patterns of muscle activity contributing positively to the dynamic stability of the joint [13]. The scapulothorax, which is a muscle-dependent joint, plays an important role in the stability and mobility of the shoulder girdle as its correct position against the movements of the glenohumeral joint provides the centering of the humeral head on the glenohumeral as well as a normal mechadynamic relationship of the glenohumeral muscles contributing to the stabilization of this joint [14].

Individuals with SIS exhibit scapulohumeral muscle weakness as well as deficient neuromuscular control of the scapulothoracic and glenohumeral muscles, specifically, decreased levels and delay of activation of the dentate anterior and lower trapezius, and increased levels of activation of the upper trapezius, as well as coordination deficits between the different degrees of the trapezius muscle. Resulting in unsatisfactory brachial rhythm and reduction of subacromial space during upper extremity elevation and causing SIS [11].

It has been proven that in painful conditions, especially in SIS, there seems to be an alteration of the person's motor and neuromuscular control ability, especially of the scapula, as changes are observed in the muscle activation of the scapulothoracic muscles, significantly affecting the patient's functional levels [15-17].

The significance of scapular stabilization approaches has drawn considerable attention from research scientists, educators, and clinicians [18]. Several systematic reviews have focused on investigating the efficacy of a variety of physical therapy interventions and scapular-focused interventions for subjects with SIS [19-21]. There has been no systematic review available in the literature on the clinical effects of a scapular stabilization approach in patients with subacromial impingement syndrome. Although the SIS is commonly presented, the research on the rehabilitation of the syndrome is sparse. The main purpose of this review is to examine the currently available research on the rehabilitation of the neuromuscular control of the scapulothoracic muscles in people with SIS, and to clarify which techniques can improve motor control of the scapula [9].

MATERIALS & METHODS

Review design: This review was conducted according to the guideline of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [22]. Articles were selected from the following online databases.

Data Sources and Search Strategy: A search strategy was developed based on the intersection of 2 search themes: SIS and neuromuscular control. The following databases were searched: PubMed, Cochrane Library, MEDLINE, Cumulative Index to Nursing and Allied Health Literature, and Google Scholar using medical subject headings and free text related to subacromial impingement syndrome ‘impingement syndrome’, ‘shoulder impingement syndrome’ and

scapular stabilization ‘Exercises scapula stabilization', 'Scapula exercises', 'Scapula rehabilitation'. The initial search strategy generated 9351 references after duplicate removal. All 324 were kept for full-text review, 6 unique studies were included in the review.

Inclusion Criteria: To ensure that all relevant studies were selected, the following inclusion criteria were applied: (a) Original research reports of data collected on individuals presenting with or diagnosed with subacromial impingement syndrome; (b) studies assessing pain or disability or movement as an outcome; (c) availability of full text; (d) studies published in English and other languages with an English version.

RESULT

In 2013, a study was conducted by Worsley et al. [23], regarding the retraining of motor control of the scapulothoracic muscles, over a period of 10 weeks, in young subjects diagnosed with SIS. In this research, 16 people with a diagnosed SIS, average age of 24.6 years, and 16 healthy people, average age of 22 years, participated. The average duration of symptoms in people diagnosed with SIS was 16 months. Pre-intervention, patients reported pain and reduced function compared to the healthy participants (SPADI in patients 20 ± 9.2; healthy 0±0). Post-intervention the SPADI scores reduced significantly ($p<0.001$) by a mean of 10 points (±4). EMG showed delayed onset and early termination of serratus anterior and lower trapezius muscle activity pre-intervention, which improved significantly post-intervention ($p<0.05$-0.01). Pre-intervention, patients exhibited on average 4.6-7.4 less posterior tilt, which was significantly less in two arm elevation planes ($p<0.05$) than healthy participants. Post-intervention, upward rotation and posterior tilt increased significantly ($p<0.05$) during two arm movements, approaching the healthy values. The results of the research prove that after the intervention there was an improvement in the functionality and pain of the patients.

Larsen et al. [24], conducted a study on the retraining of neuromuscular control of the different degrees of the trapezius muscle using biofeedback. A total of 15 people (8 women and 7 men) diagnosed with SIS and 15 healthy people (8 women and 7 men) took part in the research. Sessions with and without visual biofeedback were conducted. Surface EMG was recorded from four compartments of the trapezius muscle. Selective activation was defined as activation above 12% with other muscle parts below 1.5% or activation ratio at or above 95% of the total activation. Without biofeedback significantly fewer SIS subjects than No-SIS achieved selective activation ($p = 0.02–0.03$).

In 2013, a randomized study was performed by Struyf et al. [25], on motor retraining of the scapula muscles in individuals with SIS. The research involved 22 people diagnosed with SIS, of which 12 were included in the control group. For the diagnosis of the syndrome, participants underwent clinical tests of which they had to show positive 2 out of 3 between the Hawkins test, Jobe's test, Neer's test. Main outcome measures were the shoulder disability questionnaire, diagnostic tests for shoulder impingement syndrome, clinical tests for scapular positioning, shoulder pain (visual analog scale; VAS), and muscle strength. A large clinically important treatment effect in favor of scapular motor control training was found in self-reported disability (Cohen’s d00.93, p00.025), and a moderate to large clinically important improvement in pain during the Neer test, Hawkins test, and empty can test (Cohen’s d 0.76, 1.04, and 0.92, respectively). The experimental group demonstrated a moderate (Cohen’s d00.67) improvement in self-experienced pain at rest (VAS), whereas the control group did not change. The effects were maintained at three months follow-up.

In 2012, a study was published by Yuang et al. [26] on the short-term retraining of neuromuscular control of the

scapulothoracic muscles in subjects with SIS using biofeedback. Thirteen people with SIS as well as 12 healthy people, aged 18 to 40, participated in this research. This research was conducted to investigate the effect of electromyography (EMG) biofeedback training on muscle balance ratios and scapular kinematics in healthy adults and subjects with SIS, and to investigate whether the effects of EMG biofeedback on muscle balance ratios are different between groups. For the subjects with SIS, muscle balance ratios were lower during forward flexion with EMG biofeedback than during exercise only (UT/SA: 70.3–45.2; UT/LT: 124.8–94.6). Additionally, similar results were found during side-lying external rotation (UT/MT: 58.5–36.4). For the scapular upward rotation and tipping in both groups, there were no significant differences with and without EMG biofeedback.

In 2009, Roy et al. [27], conducted a study on the retraining of motor control and muscle strength of the shoulder girdle region of individuals with SIS. The research lasted 9 weeks and was divided into 3 parts: A1 part (2 weeks), B part (4 weeks) and A2 part (3 weeks). During part A (pre-intervention part), the examinees performed every day submaximal isometric contractions leaning against a wall, of the abductors as well as the internal and external rotators of the shoulder with a total duration of 2 weeks. Part B (intervention part) included 6 phases of scapular motor control (correct kinematics) exercises. Measures taken during the intervention and post-intervention phases were compared to pre-intervention values. All subjects showed significant improvement in the SPADI at the end of the study. A disappearance of a painful arc of motion in flexion and abduction (n ¼ 6), an increase in isometric peak torque in lateral rotation (n ¼ 3) and abduction (n ¼ 2), and changes in the scapular kinematics, mainly in the sagittal plane, were also observed. The present results provide preliminary evidence to support the use of shoulder control exercises to reduce pain and improve function of persons with shoulder impingement.

In 2010, a study was published by Roy et al. [28], regarding the retraining of motor control of the shoulder girdle in individuals with SIS. A total of 33 people diagnosed with SIS by an orthopedic surgeon took part in the research. Participants presented with 1 of the following from each category: (1) painful arch on shoulder abduction or flexion, (2) positive Neer or Hawkins-Kennedy test, (3) shoulder pain on resisted external rotation or abduction the positive Jobe test. Kinematic patterns of the upper limb were evaluated once during the first visit, immediately after supervised training; they were evaluated twice during the second visit, before and immediately after unsupervised training. Kinematic patterns were characterized by total excursion and final position during reaching. Unsupervised training consisted of reaching movements performed in front of a mirror. The day after supervised training, subjects with SIS used significantly larger trunk rotation and finished reaching with the trunk more rotated as compared to immediately after supervised training. Following unsupervised training, kinematics of the trunk was back to the level observed immediately after supervised training. Subjects who presented the largest kinematic deficits also significantly improved their shoulder and clavicular movements. Unsupervised training appears to be a good complement to supervised training in order to normalize the kinematic impairments of persons with SIS as compared to healthy subjects.

Table 1. The studies presented in this review.

Authors	Participants	Evaluation Tools	Results
Worsley et al. 2013	N= 32 Age ≈ 23 16 control group, 16 SIS group	Electromyography (EMG) and 3-dimensional motion analysis was used to record muscle activation and kinematic data during arm elevation to 90° and lowering in three planes.	Pre-intervention, patients reported pain and reduced function compared to the healthy participants (SPADI in patients 20 ± 9.2; healthy 0±0). Post-intervention the SPADI scores reduced significantly ($p<0.001$) by a mean of 10 points (±4). EMG showed delayed onset and early termination of serratus anterior and lower trapezius muscle activity pre-intervention, which improved significantly post-intervention ($p<0.05$-0.01). Pre-intervention, patients exhibited on average 4.6-7.4° less posterior tilt, which was significantly less in two arm elevation planes ($p<0.05$) than healthy participants. Post-intervention, upward rotation and posterior tilt increased significantly ($p<0.05$) during two arm movements, approaching the healthy values.
Larsen et al. 2014	N= 30 N1= 8 female, 7 male SIS group N2= 8 female, 7 male control group	Bipolar circular surface electromyographical (sEMG) electrodes, Visual Analog Scale,	Without the use of biofeedback, fewer subjects in the SBP group were able to selectively contract as well as reach activation levels above 95% for each part of the trapezius muscle. With the use of biofeedback, however, there were no significant statistical differences between the control group and the group with SBP.
Struyf et al. 2012	N= 22 N1= 10 SIS group N2= 12 control group	Shoulder Disability Questionnaire, verbal numeric rating scale, Visual analog scale, inclinometry, kinetic medial rotation test, Jobe's test position, acromial distance, Visual observation for tilting and winging	A large clinically important treatment effect in favor of scapular motor control training was found in self-reported disability (Cohen's d00.93, p00.025), and a moderate to large clinically important improvement in pain during the Neer test, Hawkins test, and empty can test (Cohen's d 0.76, 1.04, and 0.92, respectively). In addition, the experimental group demonstrated a moderate (Cohen's d00.67) improvement in self-experienced pain at rest (VAS), whereas the control group did not change
Yuang et al. 2012	N= 25 Age 18-40 N1= 13 SIS group N2= 12 control group	EMG (activity of scapular muscles), and ratios (UT/SA, UT/MT, and UT/LT) during exercises with/without EMG biofeedback	For the subjects with SAIS, muscle balance ratios were lower during forward flexion with EMG biofeedback than during exercise only (UT/SA: 70.3–45.2; UT/LT: 124.8–94.6). Additionally, similar results were found during side-lying external rotation (UT/MT: 58.5–36.4). For the scapular upward rotation and tipping in both groups, there were no significant differences with and without EMG biofeedback
Roy et al. 2009	N= 33	total excursion and final position during reaching	Unsupervised training appears to be a good complement to supervised training in order to normalize the kinematic impairments of persons with SIS as compared to healthy subjects
Roy et al. 2010	N= 8	Shoulder Pain and Disability Index questionnaire, Optotrak Probing System	All subjects showed significant improvement in the SPADI at the end of the study. A disappearance of a painful arc of motion in flexion and abduction (n ¼ 6), an increase in isometric peak torque in lateral rotation (n ¼ 3) and abduction (n ¼ 2), and changes in the scapular kinematics, mainly in the sagittal plane, were also observed. The present results provide preliminary evidence to support the use of shoulder control exercises to reduce pain and improve function of persons with shoulder impingement.

DISCUSSION

All the above results demonstrated that a rehabilitation program based on motor control exercises and strengthening presented reduce pain as well as improve functionality in people with SIS.

Larsen et al. [24] results showed that with the use of biofeedback there were no significant statistical differences between the control group and the group with SIS. This suggests that individuals with this syndrome may have reduced proprioceptive information and thus be more dependent on visual stimuli to perform the same as the control group. Individuals with SIS may benefit from biofeedback training to gain control of the neuromuscular function of the scapular muscle.

According to Worsley et l. study [23] results a decrease in the activation latency of the dentate anterior during raising the upper limb in the frontal plane as well as the lower part of the trapezius in the anteroposterior plane was noted. There was an increase in the contraction of the dentate anterior during downward movement of the upper limb at all three levels as well as the lower trapezius at the anteroposterior level and at the level

of the scapula after the intervention. After the intervention, an increase in upper rotation of the scapula was observed when raising the upper limb in the anteroposterior plane as well as posterior tilt in the frontal plane.

In Struyf et al. study [25] the results indicated that there is a statistically significant difference between group A and group B (control group), as there was a reduction in pain (VAS scale: during movement and Neer's test) as well as an increase in functionality that was more important from the individuals in the control group.

Shoulder flexion exercises from a sitting position as well as shoulder external rotation from a lateral position using biofeedback in the above-mentioned scapulothoracic muscles provide the possibility, in the healthy population as well as in individuals presenting with SBP, to improve the motor control of the scapulothoracic muscles was proved by Yuang et al study [26].

Roy et al. conducted two researches examining the SIS. The first study [27] demonstrated that a 4-week rehabilitation program based on motor control exercises and strengthening can reduce pain as well as improve function in individuals with SCI. While the second's [28] short-term results show that the subjects improved greatly from the intervention as they show a more normal movement pattern, specifically a reduction in compensatory movements: scapula elevation and lateral trunk flexion.

CONCLUSION

The reported research on restoring neuromuscular control of the scapulothoracic muscles in individuals with SIS appears to be very encouraging as their findings show an increase in the individual's ability to voluntarily and involuntarily control their scapula kinematics through better activation of the scapulothoracic muscles. A rehabilitation program with motor control exercises showed significant improvement in function, range of motion and pain intensity.

Further research: It is noted that further research is needed as there are not enough studies regarding the restoration of the neuromuscular control of the scapulothoracic muscles in SIS as the retraining of the motor control of the scapula through feedback is only a part of these exercises. It is recalled that neuromuscular control consists of preparatory motor control as well as reflex motor control, and that exercises using feedback belong to preparatory motor control exercises. So the other area of neuromuscular control should be investigated. With regard to motor control exercises of the scapula with the use of feedback, the effects of the interventions over time should be further investigated, the ideal periodicity of these exercises should also be determined as well as the time period of their application in order to have the best result possible. Additionally, larger sampling should be done because it is noted that a key limitation of the above research is the small sample size. It is also proposed to categorize the examinees according to their age, their profession as well as their activities, especially for athletes who have greater demands on their bodies so that the findings can be effectively applied to each population category. Finally, in any case the findings of the above investigations should be taken into account with caution and critical thinking as there can always be a deviation of the results in relation to reality.

Conflict of Interest: None

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