Effect of an Exercise Program on Glenohumeral Rotator Cuff Muscles Strength in Overhead Athletes with Scapular Dyskinesis

Abstract

Aims: Scapula Dyskinesis (SD) and reduction the strength of glenohumeral External rotator muscles (ER) are shoulder risk factors. While performing high-intensity repetitive throwing movements in overhead athletes can gradually affect the stabilizing mechanisms of the shoulder joint, which are mainly the glenohumeral rotator muscles. This can cause a decrease in the strength of the ER, imbalance of the rotator cuff muscles and SD. Therefore, the purpose of this study was to investigate the effect of an exercise program on SD and the strength of glenohumeral rotator cuff muscles in overhead athletes.

Materials & Methods: The present quazi experimental study with control group and pre and post-test plan was conducted on 62 female handball players (club-level, 18-25 years old) with SD from 2021 to 2022 in Hamadan city. The Lateral scapular slide test and Hand dynamometers were used to measure SD and the strength of Glenohumeral rotator cuff muscles, respectively. The participants in the intervention group participated in eight weeks of three sessions of exercise program. Data Were measured before and after the intervention and were analyzed using Mann-Whitney U test.

Findings: According to this test, there is a significant difference between the strength of ER ($p<0.001$) in the intervention and control groups after exercises, So that the strength of ER and the strength of External rotator muscles to Internal rotator muscles ratio (ER:IR; $p<0.001$) has increased after exercises. Also, SD ($p=0.013$) after exercises has decreased significantly.

Conclusion: Exercises program can increase the strength of ER and ER:IR ratio, and improves SD in overhead athletes.

Keywords

Shoulder [Mesh Link??];
Exercises [Mesh Link??];
Scapular [Mesh Link??];
Dyskinesia [Mesh Link??]

Introduction

Overhead sports require substantial kinetic energy transference through the shoulder at rapid speeds through large ranges of motion with high precision [1]. Scapular dyskinesis (SD) refers to altered position and motion of the scapula [2]. SD has a higher prevalence (61%) in overhead athletes compared with nonoverhead athletes (33%) [3]. SD is present in as many as 67% to 100% of athletes with shoulder injuries. However, it is also present in many asymptomatic individuals [4]. SD has been associated with shoulder pain, specifically shoulder impingement syndrome (SIS), rotator cuff tendinopathy, and multidirectional impairments [2, 5]. It is reported that the athletes with SD have 43% greater risk of developing shoulder pain than those without SD [6]. In overhead athletes during throwing, scapular joint experience increased stress as they act as the ‘‘funnel'' or bridge that transfers power from the lower extremities and trunk to the arm [2, 7, 8]. Alterations in this transfer of power lead to increased stress on the glenohumeral and scapular-thoracic joints, thus increasing the theoretical risk of injury [7, 9]. therefore scapula position in both static and dynamic states is important risk factor of shoulder injuries in overhead sports [10]. On the other hand, in overhead athletes, the high repetition of the movement pattern may cause adaptive changes in the structure and musculoskeletal function of the shoulder girdle [11]. This situation, may gradually affect the stabilizing mechanisms of the shoulder joint, which are mainly rotator cuff muscles [12]. It can cause weakness in the glenohumeral external rotator muscles (ER) and muscle imbalance in rotator cuff [13, 14]. Rotator cuff weakness and imbalance may impair motor control, resulting in superior translation of the humeral head and further mechanical abrasion of the structures of the subacromial space [6]. It is accepted that a low concentric external/internal strength ratio (ER:IR) may lead to excessive humeral head anterior displacement and increase the loading on the biceps long head tendon. Furthermore, the eccentric strength of the external rotator is not only important for acceleration in the cocking phase of throwing and the entering phase of swimming but also for deceleration and control in the follow-through and the recovery phase [15]. It is also believed that it is necessary for eccentric strength to be as strong as concentric internal rotation to maintain normal shoulder function [10, 16]. SD and ER muscles weakness are a causative factor of shoulder injuries in overhead athletes [2, 10, 16-18]. ER weakness [19], lower ER:IR and SD may be risk factors that identify elite handball players at higher risk of injury and require preventive intervention [16, 18, 20-22].

Exercises therapy is frequently recommended to overhead athletes with shoulder injurie who are diagnosed with SD and scapular muscle imbalance to correct the faulty scapular position and to improve function [23, 24]. Therefore, many authors have emphasized the need to correct SD and increasing ER muscles strength and endurance during rehabilitation programs [2, 13].

Moura *et al.* also found that amateur athletes with subacromial pain syndrome associated with SD responded well to a rehabilitation program [13]. The training program of Tang *et al.* also emphasized shoulder stabilization exercises and improved shoulder function and SD in patients with shoulder arthritis and SD [25]. Based on a systematic review of the literature that was conducted to evaluate the role of exercise in the treatment of rotator cuff impingement and synthesis of a standard evidence-based rehabilitation protocol. Although many of the articles had methodological concerns, the data showed that exercise had a statistically and clinically significant effect on reducing pain and improving function, but not on range of motion or strength [26]. According to the study of Yuksel and yesilyaprak, Scapular stabilization exercises added to the shoulder mobilization, stretching, and strengthening exercises are effective in improving SD, reducing pain, increasing muscle strength and shoulder function in patients with Subacromial pain syndrome (SAPS) accompanied by SD [27]. But Hotta *et al.* found that the inclusion of the isolated scapular stabilization exercises, emphasizing retraction and depression of the scapula, to a progressive general periscapular strengthening protocol did not add benefits to shoulder pain and disability, muscle strength, and ROM in patients with SAPS [28].

Some exercise programs emphasized scapular control, correction of muscular imbalance, and sensory motor training [13] or shoulder stabilization exercise [28]. Some others focus on shoulder mobilization exercises, Scapular stabilization, stretching [29], and strengthening exercises [27]. As mentioned, there is no consensus on the type of exercises effective in correcting scapular position (SD) and reducing rotator cuff muscle imbalance. Also, in most studies, exercises have been presented for individuals with shoulder pain, and clinical disorders such as impingement syndrome. There is a lack of studies that investigate the mentioned factors in asymptomatic overhead athletes. Therefore, the purpose of this study was to investigate the effect of an exercise program on SD and the strength of glenohumeral rotator cuff muscles in overhead athletes.

Materials and Methods

Design

This study is quazi experimental method with control group and pre and post-test plan was conducted from 2021 to 2022 in Hamadan city, Iran.

The population of this study is female handball players (club-level, 18–25 years old) with SD in Hamadan city, Iran. A total of 221 handball players were identified and evaluated by an experienced physiotherapist and according to the inclusion and exclusion criteria, 62 subjects with SD were selected using convenience sampling method. A block randomization method with a block size of four was used to randomize participants. For this purpose, four sheets of paper were prepared. The letter I (under treatment with exercise program) was written on two sheets and the letter C (control group) was written on the other two sheets. The sheets were mixed and randomly drawn out one at a time for each participant without replacement until all four sheets were drawn. This method was repeated until all participants were randomized (each group 31).

Inclusion and exclusion criteria

The study's inclusion criteria consisted of the female gender, having at least three years of regular sports experience in handball, and the presence of SD. the exclusion criteria consisted of pain in the shoulder girdle and neck in the normal and practice conditions, history of fracture or dislocation in each shoulder girdle bones, complete rupture of shoulder girdle muscles, positive Neer impingement test or Hawkins impingement test; and history of surgery in the shoulder girdle.

Measurement and Data gathering

Scapular Dyskinesis: To assess SD, the scapula lateral sliding test provided by Kibler was used [10]. In this test, the distance of the lower angle of each scapula from the adjacent vertebra was measured with a tape measure in three positions of 0.45 and 90 degrees of arm abduction. Each of the measurements was repeated three times in both hands and then their average was calculated. If there is a difference of 1.5cm or more between the two shoulders, the test is positive. Kibler has reported the intra-group reliability of this test from 0.84 to 0.88 and its out-group reliability from 0.77 to 0.85 in different angles [30].

Internal and external rotation strength of the shoulder: To measure the isometric IR and ER strength, a handheld dynamometer (Lafayette Instruments, Lafayette, USA) was used. The subject was placed in the supine position by adopting 90 degrees of shoulder abduction and 90 degrees of elbow flexion (while the forearm was perpendicular to the ground). Shoulder stabilized by an assistant, then the subject maximally resisted against the dynamometer placed 2 cm below the styloid process in the ventral face of the wrist (for IR) and dorsal face (for ER). The maximum isometric force of the individual was recorded in kilograms on the digital screen of the device [31]. Each test was repeated three times with a one-minute break between them, and then their average was recorded. At the same time, the measurements were performed on the dominant hand of the subjects.

Intervention

In this study, the intervention is modified exercise protocol of Moura *et al*. The intervention group received the exercise protocol of Moura *et al*. [13].

The program used included the modified exercise protocol of Moura *et al*. (Table 1) [13], which was repeated by the experimental group three sessions per week with moderate intensity for a period of eight weeks. The exercise program consisted of three phases, the first phase focusing on scapular control and increasing the range of motion, the second phase on increasing the strength of the scapular muscles and sensorimotor exercises, and the third phase on advanced sensorimotor exercises. All exercises were performed in 3 sets with 15 repetitions. The rest between each set was gradually reduced until the end of the period. Data Were measured within a week before and after the intervention. Also, the subjects of control group were advised to continue their usual exercise routine. Control group received only routine exercises

Blinding

In this protocol, we attempted to minimize biases by randomizing subjects, blinding the assessor (who did not know the subjects' allocation). However, the researcher responsible for the intervention was not blinded due to the characteristics of the intervention.

Statistical analysis

The data were analyzed using SPSS software (International Business Machines Corporation, New York State, USA). The normality of variables was investigated using Shapiro-Wilk test. Mann-Whitney U test was used to compare the demographic variables between the two groups. In addition, Mann-Whitney U test was used to compare the mean strength of IR, ER and SD, as divided by the time intervals before and after the intervention between the two groups. All statistical analyses were performed at P<0.05 significant levels

Table 1. Selected corrective exercise protocol

Phase 1 (week 1&2)	Phase 2 (week 3&5)	Phase 3 (week 6&8)
Sleeper stretch (60, 90, 120)	Sleeper stretch (60, 90, 120)	
Sitting, arms in neutral position, pull their shoulder blades back and down	Punch with dumbbells	Standard push-up plus with the Swiss ball
Punch exercise	One-hand push-up plus exercise	Modified prone Cobra on Swiss ball with dumbbells
Wall push-up plus exercise	Modified prone Cobra with dumbbells	Prone horizontal abduction exercise on the Swiss ball with dumbbells
Modified prone Cobra	Prone horizontal abduction exercise Prone V-raise exercise Prone row Rotator cuff exercise	Prone V-raise exercise on the Swiss ball with dumbbells Low row exercise with theraband Rotator cuff exercise with theraband

Finding

In this study 62 participants participated in the study and remained until the end of the study. There was no statistically significant differences between intervention and control groups in mean age (P=0.056), height (P=0.241), weight (P=0.735), and SD of participants (P=0.525; Table 2).

There is a significant difference between the strength of ER in intervention and control groups (p<0.001) after exercises, so that the strength of ER and the strength of ER:IR has increased after exercises in intervention group (p<0.001). Also, SD after exercises has decreased significantly (p=0.013; Table 3).

Table 2. Demographic Characteristics of the Intervention and Control Group

Variable	Group		P-value
	Intervention (N=31)	Control (N=31)	
Age (Y)	21.67±2.57	22.87±2.09	0.056
Height (cm)	165.83±3.62	164.70±4.06	0.241
Weight (kg)	63.06±7.07	62.62±5.08	0.735

the Mann–Whitney U test

Table3. Comparison of the mean score of strength of the ER and SD between the two groups

Variable	Time	Intervention	Control	P-value
Glenohumeral Internal Rotators Strength (kg)	Pre	12.19±0.87	12.41±0.95	0.421
	Post	13.00±0.77	12.83±0.86	0.438
Glenohumeral External Rotators Strength (kg)	Pre	9.03±0.70	9.35±0.75	0.116
	Post	13.03±0.75	9.35±0.79	<0.001*
External Rotators Strength/ Internal Rotators Strength	Pre	0.74±0.06	0.75±0.06	0.455
	Post	1.00±0.04	0.73±0.08	<0.001*
Scapular Dyskinesis (cm)	Pre	1.83±0.34	1.73±0.22	0.525
	Post	1.64±0.29	1.73±0.21	0.013*

Mann–Whitney U test

Discussion

The purpose of this study was to investigate the effect of of exercise program on SD, ER strength and rotator cuff balance (ER:IR strength) in female handball players. SD is characterized by reduced scapular upward rotation, increased scapular internal rotation and anterior tilt, and reduced range of motion. These positions create scapular protraction and decreases demonstrated rotator cuff strength [32]. The results of the study showed that the exercise program caused significant decrease the SD, and increase of ER and ER:IR strength in handball players.

Moura *et al*. by presenting an exercise program similar to the present study, found that SD decreased, and ER strength and ER/IR ratio increased in athletes with subacromial pain syndrome [13]. These results agree with the findings of our study. In the present study, exercise program included three phases. The focus of the first phase was on controlling the scapula and increasing the range of motion, in the second phase on increasing the strength of the scapular muscles and sensorimotor exercises, and in the third phase on advanced sensorimotor exercises [13]. The study of Hotta *et al*. revealed Motor control and muscular strengthening training lasting for 8 weeks influenced the resting position (SD) and scapular movement pattern of subjects with shoulder impingement syndrome [34]. Various authors have suggested that neuromuscular control and strengthening of the periscapular muscles is important in the treatment of SD in patients with shoulder injuries [13]. Scapular-focused treatment includes a variety of interventions directed at the soft tissues functionally related to the scapula, such as periscapular strengthening, stretching, mobilization [33], stability/stabilization, motor control of the scapula [33-35]. A study by Baskurt *et al.* on patients with subacromial impingement syndrome showed the efficacy of proprioceptive neuromuscular facilitation exercises for scapular muscles [35].

Activation sequencing patterns and strength of the muscles that stabilize the scapula are altered in patients with SD [2]. Increased upper trapezius activity, imbalance of upper trapezius/lower trapezius activation and decreased serratus anterior activity have been reported in this patients [32]. The serratus anterior is most important as an external rotator of the scapula, and the lower trapezius acts as a stabilizer of the acquired scapular position [1]. Scapular stabilization protocols should focus on re-educating these muscles to act as dynamic scapula stabilizers first via the implementation of short lever, kinetic chain assisted exercises then progress to long lever movements [32], And this is an issue that has been done in all three phases of the exercise program of the current study, by including exercises such as push-up plus, punch exercise, prone Cobra, prone horizontal abduction. It seems that, Scapular stabilization exercises added to the shoulder mobilization, stretching, and strengthening are effective in improving SD, reducing pain, increasing muscle strength and shoulder function in patients with Subacromial pain syndrome accompanied by SD [25, 27]. Although Hotta *et al*. mentioned that the inclusion of the isolated scapular stabilization exercises to a progressive periscapular strengthening protocol did not add benefits to disability, muscle strength, and range of motion in patients with subacromial pain syndrome. The reason for the difference in the results of the mentioned study can be related to the type of selected exercises. Also, the samples were not athletes [28]. There are some inconsistencies in the results for efficacy of therapeutic exercises on SD and strength of ER. Methodologic heterogeneity could be a reason for the conflicting results.

Another finding of the study was the increase of ER and ER:IR strength (rotator cuff balance) after exercise program. The scapular position in which it provides a stable base of support for the rotator cuff muscles is that of retraction and external rotation. On the opposite, in SD when the scapula is protracted, the maximal rotator cuff strength decrease because of reduced force-generating capabilities for the internal and external rotators [36]. This situation creates conditions for rotator cuff muscle imbalance [2]. merolla *et al*. reported the weakness of supraspinatus and infraspinatus due to SD, and explained that the first step in the rehabilitation program is to strengthen the periscapular muscles [36]. Therefore, the inclusion of all the exercises from the present study, such as push-up plus, punch, prone horizontal abduction and prone cobra, which strengthen the periscapular muscles and improve SD [13], are also considered as the first stage of rotator cuff muscle imbalance rehabilitation [36]. Rotator cuff emphasis in rehabilitation should be after scapular control is achieved. A logical progression of exercises focused on strengthening the lower trapezius and serratus anterior while minimizing upper trapezius activation has been described in the literature [32]. Stabilization exercises, which include stretching and strengthening exercises with emphasis on the position and movement of the scapula, allow the scapula to act as basis for muscle activity, as well as the role of the link in the proximal to distal transfer of energy for the appropriate shoulder positioning [37].

In present study, performing rotator cuff strengthening exercises included external rotation with and without theraband, in the second and third phases of exercise program is associated with the increase ER and ER:IR strength [13, 36]. Similar results were obtained by Moura *et al*. They found that ER and ER:IR strength increased after performing an exercise program similar to our study [13].

One of the strengths of the study was its preventive approach to injury. Also, to eliminate some nuisance variables, such as the difference in the movement pattern of different sports, the samples were selected from only one sport (handball). The limitation of the present study was the low number of studies that were used non-pathological athletes. The majority of studies were conducted on athletes with subacromial pain syndrome. Also, other variables related to SD such as glenohumeral rotation range of motion and electromyographic of periscapular muscles were not measured.

Conclusion

The present exercises program can increase the strength of ER and ER:IR ratio, and improve SD in overhead athletes. Therefore, it is suggested to overhead athletes and their coaches to include the mentioned exercises as part of their regular sports training. However, future studies with standard, reliable, and valid measurement techniques with more participants with more following time are recommended.

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Ethical Permissions: This study was approved by the Research Ethic Committee (REC) of Hamadan University of Medical Sciences with ID code; IR.UMSHA.REC.1401.244. The written informant consent form was completed by participants. The study was conducted following the Declaration of Helsinki.

Conflicts of Interests: There is no conflict of interest between the authors.

References

1- Kibler WB, Wilkes T, Sciascia A. Mechanics and pathomechanics in the overhead athlete. Clin Sports Med. 2013;32(4):637-51.
2- 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.
3- Burn MB, McCulloch PC, Lintner DM, Liberman SR, Harris JD. Prevalence of scapular dyskinesis in overhead and nonoverhead athletes: A systematic review. Orthop J Sports Med. 2016;4(2):2325967115627608.
4- Pluim BM. Scapular dyskinesis: Practical applications. Br J Sports Med. 2013;47(14):875-6.
5- Timmons MK, Thigpen CA, Seitz AL, Karduna AR, Arnold BL, Michener LA. Scapular kinematics and subacromial-impingement syndrome: A meta-analysis. J Sport Rehabil. 2012;21(4):354-70.
6- Hickey D, Solvig V, Cavalheri V, Harrold M, Mckenna L. Scapular dyskinesis increases the risk of future shoulder pain by 43% in asymptomatic athletes: A systematic review and meta-analysis. Br J Sports Med. 2018;52(2):102-10.
7- Cools AMJ, Struyf F, De Mey K, Maenhout A, Castelein B, Cagnie B. Rehabilitation of scapular dyskinesis: From the office worker to the elite overhead athlete. Br J Sports Med. 2014;48(8):692-7.
8- Myers JB, Oyama S, Hibberd EE. Scapular dysfunction in high school baseball players sustaining throwing-related upper extremity injury: A prospective study. J Shoulder Elbow Surg. 2013;22(9):1154-9.
9- Struyf F, Nijs J, Meeus M, Roussel NA, Mottram S, Truijen S, *et al*. Does scapular positioning predict shoulder pain in recreational overhead athletes?. Int J Sports Med. 2014;35(1):75-82.
10- Kibler WB, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg. 2012;20(6):364-72.
11- Ramsi M, Swanik KA, Swanik CB, Straub S, Mattacola C. Shoulder-rotator strength of high school swimmers over the course of a competitive season. J Sport Rehabil. 2004;13(1):9-18.
12- Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. J Orthop Sports Phys Ther. 2009;39(2):90-104.
13- Moura KF, Monteiro RL, Lucareli PRG, Fukuda TY. Rehabilitation of subacromial pain syndrome emphasizing scapular dyskinesis in amateur athletes: A case series. Int J Sports Phys Ther. 2016;11(4):552-63.
14- Cools AM, Johansson FR, Borms D, Maenhout A. Prevention of shoulder injuries in overhead athletes: A science-based approach. Braz J Phys Ther. 2015;19(5):331-9.
15- Wang HK, Cochrane T. Mobility impairment, muscle imbalance, muscle weakness, scapular asymmetry and shoulder injury in elite volleyball athletes. J Sports Med Phys Fitness. 2001;41(3):403-10.
16- Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: A prospective cohort study. Br J Sports Med. 2014;48(17):1327-33.
17- Uga D, Nakazawa R, Sakamoto M. Strength and muscle activity of shoulder external rotation of subjects with and without scapular dyskinesis. J Phys Ther Sci. 2016;28(4):1100-5.
18- Andersson SH, Bahr R, Clarsen B, Myklebust G. Preventing overuse shoulder injuries among throwing athletes: A cluster-randomised controlled trial in 660 elite handball players. Br J Sports Med. 2017;51(14):1073-80.
19- Fredriksen H, Cools A, Myklebust G. Development of a short and effective shoulder external rotation strength program in handball: A delphi study. Phys Ther Sport. 2020;44:92-8.
20- Ghanbari L, Alizadeh MH, Minoonejad H, Hosseini SH. Predictive relationship of strength and glenohumeral rotation range of motion with scapular dyskinesis in female athletes with overhead-throwing pattern. Res Sport Med Technol. 2019;17(17):83-92. [Persian]
21- Ghanbari L, Alizadeh MH, Minoonejad H, Hosseini SH. Prediction of scapular dyskinesis through electromyographic indices of scapulothoracic muscles in female overhead athletes. J Rehabil Sci Res. 2018;5(3):74-80.

22- Ghanbari L, Alizadeh MH, Minoonejad H, Hosseini H. Prediction of scapular dyskinesis through electromyographic index of scapulothoracic muscles and glenohumeral internal rotation range of motion in female overhead athletes. Tabari Biomed Stu Res J. 2019;1(3):1-8.
23- Camargo PR, Alburquerque-Sendín F, Avila MA, Haik MN, Vieira A, Salvini TF. Effects of stretching and strengthening exercises, with and without manual therapy, on scapular kinematics, function, and pain in individuals with shoulder impingement: A randomized controlled trial. J Orthop Sports Phys Ther. 2015;45(12):984-97.
24- Nodehi Moghadam A, Rahnama L, Noorizadeh Dehkordi S, 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.
25- Tang L, Chen K, Ma Y, Huang L, Liang J, Ma Y. Scapular stabilization exercise based on the type of scapular dyskinesis versus traditional rehabilitation training in the treatment of periarthritis of the shoulder: Study protocol for a randomized controlled trial. Trials. 2021;22:713.
26- Kuhn JE. Exercise in the treatment of rotator cuff impingement: A systematic review and a synthesized evidence-based rehabilitation protocol. J Shoulder Elbow Surg. 2009;18(1):138-60.
27- Yuksel E, Yesilyaprak SS. Scapular stabilization exercise training improves treatment effectiveness on shoulder pain, scapular dyskinesis, muscle strength, and function in patients with subacromial pain syndrome: A randomized controlled trial. J Bodyw Mov Ther. 2024;37:101-8.
28- Hotta GH, Gomes de Assis Couto A, Cools AM, McQuade KJ, Siriani de Oliveira A. Effects of adding scapular stabilization exercises to a periscapular strengthening exercise program in patients with subacromial pain syndrome: A randomized controlled trial. Musculoskelet Sci Pract. 2020;49:102171.
29- Naderifar H, Ghanbari L. Effect of selected corrective exercises on glenohumeral rotation range of motion in overhead athletes with scapular dyskinesis. Studia Sportiva. 2022;16(1):54-62.
30- Lucas KR, Rich PA, Polus BI. Muscle activation patterns in the scapular positioning muscles during loaded scapular plane elevation: The effects of latent myofascial trigger points. Clin Biomech. 2010;25(8):765-70.
31- Seitz AL, McClelland RI, Jones WJ, Jean RA, Kardouni JR. A comparison of change in 3D scapular kinematics with maximal contractions and force production with scapular muscle tests between asymptomatic overhead athletes with and without scapular dyskinesis. Int J Sports Phys Ther. 2015;10(3):309-18.
32- Kibler WB, Sciascia A. Current concepts: Scapular dyskinesis. Br J Sports Med. 2010;44(5):300-5.
33- Saito H, Harrold ME, Cavalheri V, McKenna L. Scapular focused interventions to improve shoulder pain and function in adults with subacromial pain: A systematic review and meta-analysis. Physiother Theory Pract. 2018;34(9):653-70.
34- Hotta GH, Santos AL, McQuade KJ, Oliveira AS. Scapular-focused exercise treatment protocol for shoulder impingement symptoms: Three-dimensional scapular kinematics analysis. Clin Biomech. 2018;51:76-81.
35- Başkurt Z, Başkurt F, Gelecek N, Özkan MH. The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. J Back Musculoskelet Rehabil. 2011;24(3):173-9.
36- Merolla G, De Santis E, Campi F, Paladini P, Porcellini G. Supraspinatus and infraspinatus weakness in overhead athletes with scapular dyskinesis: Strength assessment before and after restoration of scapular musculature balance. Musculoskelet Surg. 2010;94(3):119-25.
37- Cools AM, Dewitte V, Lanszweert F, Notebaert D, Roets A, Soetens B, *et al*.. Rehabilitation of scapular muscle balance: Which exercises to prescribe?. Am J Sports Med. 2007;35(10):1744-51.