



# Scapular Kinematic During Arm Elevation in Shoulder Impingement Syndrome Using Motion Analysis System: A Systematic Review and Meta-analysis

Arghavan Hajibashi<sup>1</sup>, Ali Amiri<sup>1</sup>, Javad Sarrafzadeh<sup>1\*</sup>, Reza Salehi<sup>1</sup> and Sanaz Shanbehzadeh<sup>1</sup>

<sup>1</sup>Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

\*Corresponding author: Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran. Email: sarrafzadeh.j@iums.ac.ir

Received 2022 June 01; Revised 2022 July 27; Accepted 2022 August 06.

## Abstract

**Context:** With a key role in normal shoulder function, scapular kinematics have been investigated in shoulder impingement syndrome (SIS).

**Objectives:** This systematic review aimed at determining scapular kinematic patterns in patients with SIS compared to in asymptomatic individuals.

**Data Sources:** Databases such as PubMed, Scopus, Web of Science, Ovid, Embase and PEDRO were searched from January 1995 to June 2021.

**Study Selection:** Articles in English published in peer-reviewed journals and using motion analysis systems to compare scapular kinematics between patients with SIS and asymptomatic subjects during arm elevation were included.

**Data Extraction:** A modified Downs and Black checklist was used to assess the risk of bias of the included studies. A random-effects model was employed to perform a meta-analysis.

**Results:** Nine out of 1650 screened abstracts were included for data extraction. Scapular upward rotation significantly decreased during arm elevation in SIS (SMD = -0.13, 95% CI = -0.23 to -0.02) with a low effect size ( $I^2 = 46%$ ). No differences were observed in scapular posterior tilt (SMD = -0.07, 95% CI = -0.18 to 0.03) and external rotation (SMD = 0.02, 95% CI = -0.06 to 0.09) between patients with SIS and asymptomatic subjects.

**Conclusions:** This review revealed that except for scapular upward rotation, scapular movement was generally insignificantly different between the subjects with and without SIS during arm elevation. Between-group differences might have been overlooked as a result of the high risk of bias in the included studies. The high-quality studies addressing confounders are required to provide a definitive conclusion on the relationship between SIS and scapular kinematics.

**Keywords:** Shoulder Impingement Syndrome, Scapula, Kinematics, Systematic Review, Meta-analysis, Motion Analysis

## 1. Context

Shoulder pain is a musculoskeletal problem and a common cause of presenting to clinics (1). Shoulder pain interferes with occupation and daily activities by limiting the range of motion and causing shoulder impairment (2). Neer defined shoulder impingement syndrome (SIS) as pressure on the rotator cuff tendons and associated tissues in the subacromial space (3). As the most prevalent diagnosis in shoulder pain (4), SIS causes disability and degrades quality of life (5). SIS can seriously damage the rotator cuff and joints (6). Different anatomical and biomechanical factors have been reported for the multifactorial etiology of SIS (7). Normal shoulder function depends on the cou-

pled and coordinated movement of the glenohumeral and scapulothoracic joints and requires the proper orientation and control of scapular movements on the thorax, which is crucial for the optimal scapular and rotator cuff muscular activity and humeral movements (8, 9). Changes in a component of the shoulder girdle affect the kinematics of the entire chain and cause shoulder malfunction (10). Normal scapulothoracic motions during upper limb elevation include upward rotation, posterior tilting and external rotation (11). Impaired scapular kinematics can decrease the rotator cuff strength and subacromial space and increase the risk of SIS (12).

Despite the numerous studies conducted on scapular kinematics in SIS, the findings were inconsistent in terms

of differences in scapular kinematics between patients with SIS and asymptomatic subjects (13,14). A systematic review conducted in September 2015 on the effect of musculoskeletal shoulder conditions on scapular kinematics did not include meta-analyses and revealed increases in scapular posterior tilt and external rotation during abduction and decreases in scapular upward rotation during scapular plane elevation in SIS (13). This review included studies recruiting athletes or non-athletes and those evaluating scapular kinematics in a static position or dynamic movements. According to sport-specific adaptations in athletes and dynamic nature of arm movements (15, 16), reviewing articles on non-athlete patients with SIS and evaluating scapular kinematics during dynamic arm elevation are crucial. Given the growing body of literature on scapular kinematics, conducting a systematic review and meta-analyzing the data for a decisive conclusion appeared essential.

## 2. Objectives

This systematic review and meta-analysis aimed to compare scapular kinematic patterns between patients with SIS and asymptomatic individuals during arm elevation.

## 3. Data Sources

This review was performed based on the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) (17). The protocol of this study was registered at the International Prospective Register of Systematic Review (PROSPRO) (CRD42020177286) (18).

### 3.1. Information Sources

A.H. searched databases such as PubMed, Scopus, Web of Science, Ovid, Embase and PEDRO from January 1995 to June 2021. Hand-searching was also conducted through the references of the included articles.

### 3.2. Search Strategy

The keywords used included “subacromial pain syndrome” and “scapular kinematic”, and their synonyms were obtained using medical subject heading (MeSH) terms, free text word and expert comments. Appendix 1 provides The PubMed search syntax. Appropriate changes were made in the basic search syntax to optimize the search strategy for the other databases.

## 4. Study Selection

### 4.1. Selection Process

The inclusion criteria for selecting the articles comprised being observational and written in English, recruiting asymptomatic subjects and patients with SIS, diagnosing SIS based on the clinical evaluations performed by professionals and physicians, comparing scapular kinematics during arm elevation between patients with SIS and healthy individuals, outcomes such as scapular kinematics, i.e. upward rotation, external rotation and posterior tilt, measured using a motion analysis system (electromagnetic, marker-based or inertial sensors) during dynamic arm elevation in at least one plane of movement (sagittal, frontal, or scapular). The excluded articles consisted of those addressing nonspecific shoulder pain, rotator cuff rupture or scapular kinematics in a static position or during daily activities such as reaching, grasping and hair combing or recruiting non-adults, athletes or cadavers.

After completing the search, the articles were imported into EndNote and duplicates were removed. Two reviewers, i.e. A.H. and S.SH. screened the titles and abstracts to determine eligible studies for the next stage. A.H. and S.SH. then confirmed the eligibility criteria by reviewing the full text of the articles.

### 4.2. Study Risk of Bias Assessment

Two of the authors assessed the risk of bias in the included articles using the modified Downs and Black checklist, which helps have moderate-to-good interpreter reliability (19). The maximum total score of this checklist is 15 and every item is scored as 1: good description or 0: unclear or no description. The articles receiving a score of at least 12 were considered high quality, 10 - 11 moderate quality and at most 9 low quality (20). Any disagreements between the two authors in the selection and risk of bias assessment were resolved through discussion. A third reviewer resolved the conflict in case the two reviewers did not reach agreement.

## 5. Data Extraction

The standard data extraction was performed by describing the article's characteristics, i.e. first author's name, publication date and sample size, describing the participants in terms of BMI, dominant hand, gender and mean age, determining the diagnostic criteria for SIS, test procedure and kinematic outcome measures and explaining the significant results and mean degree

of scapular upward/downward rotation, scapular anterior/posterior tilting and scapular internal/external rotation during arm elevation (flexion, extension and scapulation). The two authors independently extracted the data. Efforts were made to obtain missing data from the corresponding authors and unavailable mean and standard deviation values were calculated using the other available data. The data were manually extracted by digitizing the diagrams using the WebPlotDigitizer application (<https://automeris.io/WebPlotDigitizer/>) for the articles that did not report numerical data.

### 5.1. Synthesis Method

The random-effect model was used to evaluate 95% confidence intervals and to calculate pooled effect sizes (ES) reported as standardized mean difference. Cohen's *d* ES was used and interpreted as follow, small (0.2 - 0.5), moderate (0.5 - 0.8), and large (> 0.8). The presence of heterogeneity was assessed by  $I^2$  statistics. The heterogeneity considered very high if  $I^2 \geq 75\%$ , high  $I^2 \geq 50\%$ , moderate  $25 < I^2 < 50$  and low  $I^2 \leq 25\%$ . In case of high heterogeneity across studies to find the source of heterogeneity, sensitivity analyses including leave-one-out approach by omitting each study and subgroup analyses based on direction of movement (flexion, abduction and scapulation) and degree of arm elevation (30, 60, 90, 120) was performed.

A symmetric funnel plot was used to assess the publication bias and Egger's regression test to examine funnel plot asymmetry at a one-tailed significance level of  $P > 0.05$ . The trim-and-fill method was employed to adjust for missing studies in case of publication bias.

## 6. Results

After eliminating the duplicates, 1650 out of 2203 retrieved articles remained for screening their title and abstract. Eighteen articles underwent a full text review and nine ineligible ones were excluded. Manual search did not include any studies and nine eligible articles were ultimately included in this systematic review as per [Figure 1](#).

### 6.1. Risk of Bias Assessment

[Table 1](#) presents the risk of bias summary of the included articles. High quality was assigned to 11% of the included studies, moderate quality to 33% and low quality to 56%. A high risk of bias was observed in the majority of the articles in sampling and controlling confounders such as arm dominance and type of activity. Some of the included study did not report the time/location of recruitment and some recruited their subjects from a local health center or hospital that did not represent the entire population.

### 6.2. Overview of Participant Characteristic and Methodology Consideration

According to the summary in [Table 2](#), most of the studies defined SIS as pain in the lateral area of the shoulder with painful arch and at least three positive impingement signs (the painful arch tests in flexion or abduction, Neer or Jobe test, Hawkins-kennedy test, and painful resisted lateral rotation). Kolk et al. performed MRI to exclude participants with other diagnoses such as complete rotator cuff tear, calcific tendonitis and labrum pathology (25). The SIS symptoms in the articles were found to last one or six weeks, or at least three months. The majority of the studies failed to provide information on the dominance distribution or reported mismatch between the two groups in this regard. McClure et al. (22) and Rossi et al. (27), however, reported matched limb dominance between groups. Range of motion of over  $130^\circ$  in arm elevation was considered an inclusion criterion in four of the studies (21, 26, 28, 30). The other studies did not report the minimum range of elevation for inclusion.

### 6.3. Meta-analysis

#### 6.3.1. Upward Rotation

A low effect size and moderate heterogeneity were obtained from a meta-analysis of scapular upward rotation [SMD = -0.13, 95% CI = -0.23 to -0.02 ( $I^2 = 46\%$ )] ([Figure 2](#)). The subgroup analysis of the arm movement direction showed a lower upward rotation in the sagittal plane and a low effect size [SMD = -0.15, 95% CI = -0.30 to 0.00 ( $I^2 = 46.5\%$ )] in the patients with SIS than in the healthy subjects. No differences were observed between the groups in the abduction (SMD = -0.09, 95% CI = -0.26 to 0.08) and scapulation (SMD = -0.15, 95% CI = -0.39 to 0.09) and low heterogeneity was obtained in the abduction and scapulation among the studies [ $I^2 = 33.3\%$ ,  $I^2 = 58.3\%$ ]. The Funnel plot and Egger's test revealed potential publication bias ( $P = 0.005$ ). The trim-and-fill analysis also showed no missing studies.

#### 6.3.2. Posterior Tilt

The overall effect size estimated for scapular posterior tilt with moderate heterogeneity showed no differences between the patients with SIS and healthy subjects during arm elevation (SMD = -0.07, 95% CI = -0.18 to 0.03  $I^2 = 44.9\%$ ) ([Figure 3](#)). The subgroup analysis of the arm elevation direction revealed no significant differences in the posterior tilt between the patients with SIS and asymptomatic subjects during flexion (SMD = -0.00, 95% CI = -0.17 to 0.17  $I^2 = 57.8\%$ ), abduction (SMD = -0.15, 95% CI = -0.30 to 0.01  $I^2 = 13.3\%$ ) and scapulation (SMD = -0.15, 95% CI = -0.34 to 0.04  $I^2 = 37\%$ ). The Egger's test also showed no publication bias ( $P = 0.896$ ).

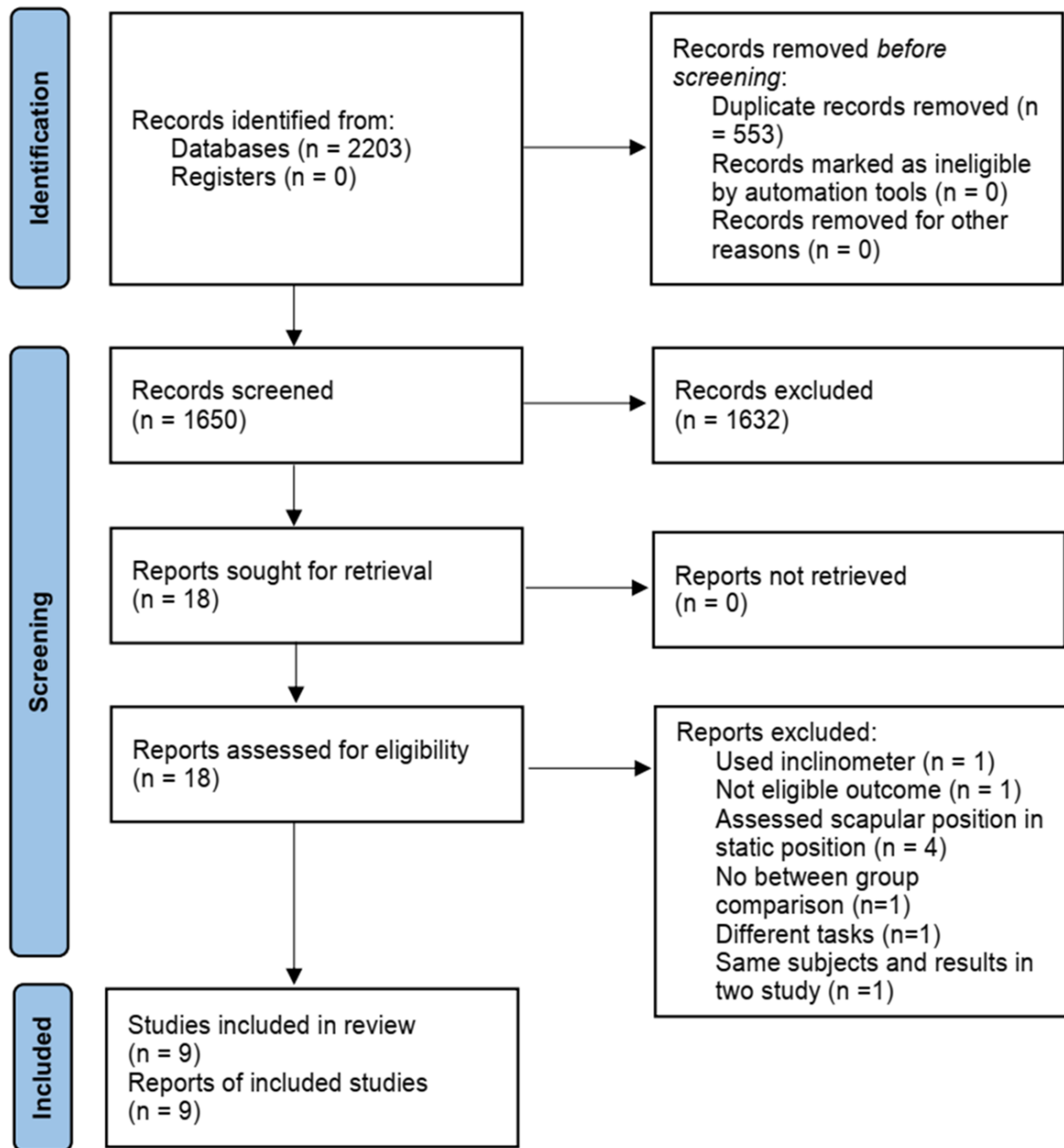


Figure 1. PRISMA flow diagram

### 6.3.3. External Rotation

No significant differences were found between the healthy subjects and patients with SIS in terms of scapular external rotation during arm elevation (SMD=0.02, 95% CI= -0.06 to 0.09) (Figure 4). The subgroups analysis of each direction showed no significant differences in the

flexion (SMD = 0.01, 95% CI= -0.09 to 0.12,  $I^2=0\%$ ), abduction (SMD= 0.12, 95% CI= -0.01 to 0.25) and scaption (SMD= -0.13, 95% CI= -0.29 to 0.04). A low heterogeneity among the studies was obtained in scapular external rotation in three planes of arm elevation ( $I^2 = 0\%$ ). The funnel plot and the Egger's test showed publication bias ( $P < 0.001$ ). The

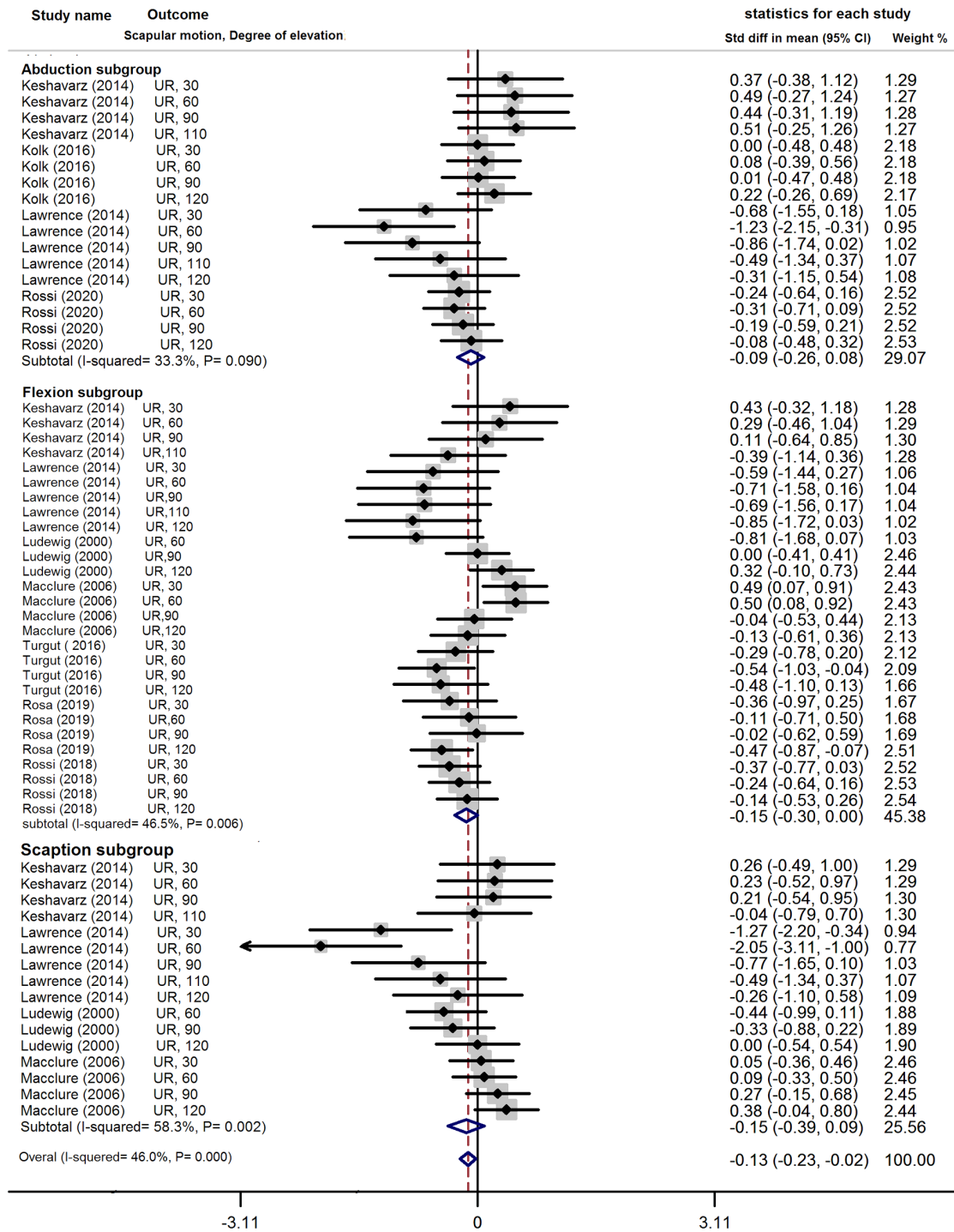


Figure 2. Upward rotation forest plot

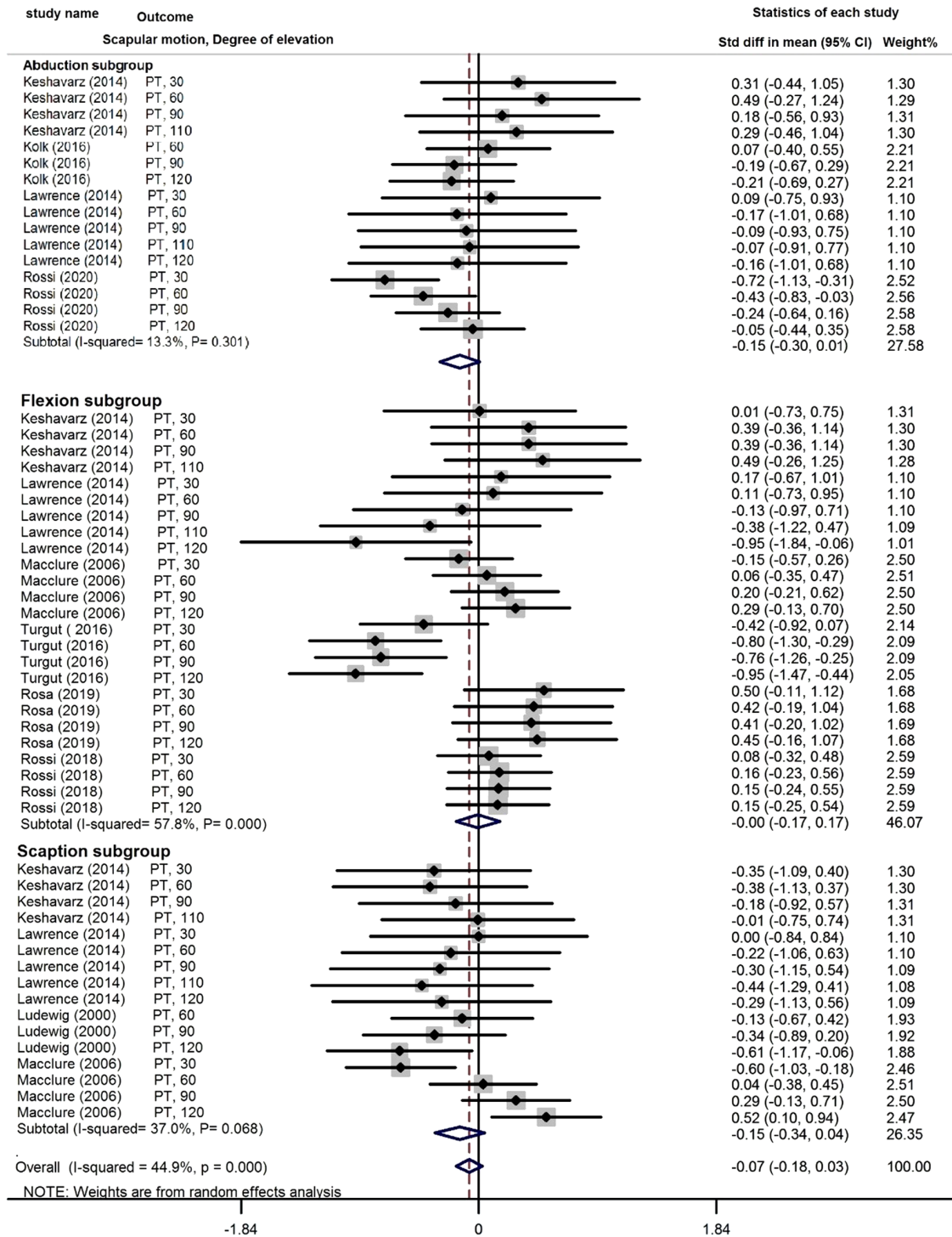


Figure 3. Posterior tilt forest plot

**Table 1.** A Summary of Risk of Bias Assessment of the Included Studies

Study	1 <sup>a</sup>	2 <sup>b</sup>	3 <sup>c</sup>	5 <sup>d</sup>	6 <sup>e</sup>	7 <sup>f</sup>	10 <sup>g</sup>	11 <sup>h</sup>	12 <sup>i</sup>	16 <sup>j</sup>	18 <sup>k</sup>	20 <sup>l</sup>	21 <sup>m</sup>	22 <sup>n</sup>	25 <sup>o</sup>	Total
Ludewig and Cook (21)	1	1	1	0	1	1	0	0	0	1	1	1	1	0	1	10
McClure et al. (22)	1	1	1	0	1	1	1	0	0	1	1	1	1	0	0	10
Lawrence et al. (23)	1	1	1	0	1	1	1	0	0	1	1	1	1	0	0	10
Keshavarz et al. (24)	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	9
Kolk et al. (25)	1	1	1	0	1	1	1	1	0	1	1	1	1	1	0	12
Turgut et al. (26)	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	9
Rossi et al. (27)	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	9
Rosa et al. (28)	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	9
Rossi et al. (29)	1	1	1	0	1	1	1	0	0	1	1	1	0	0	0	9

<sup>a</sup> Presented the objective clearly.

<sup>b</sup> Main outcomes presented.

<sup>c</sup> Participants presented.

<sup>d</sup> Distribution of confounders in each groups presented.

<sup>e</sup> Findings presented clearly.

<sup>f</sup> Estimate of random variability.

<sup>g</sup> Probability value presented.

<sup>h</sup> Subjects asked represent population.

<sup>i</sup> Included subjects represent population.

<sup>j</sup> Planned data analysis.

<sup>k</sup> Accurate statistics.

<sup>l</sup> Accurate outcome measures.

<sup>m</sup> Participants included from same population.

<sup>n</sup> Participants recruited in same time period.

<sup>o</sup> Adjustment for confounding in analysis.

**Table 2.** Summary of the Included Studies

Study's Characteristics	Participants' Characteristics	Task and Test Procedure	Outcomes Measures	Reliability	Significant Results
Ludewig and Cook (21) (USA)	26 healthy, 26 SIS	Test position: standing Task: scaption in 3 condition no external load, 2.3 and 4.6 kg load	Scapular muscle EMG activity, 3D motion of scapula and humerus	ICC between day: 0.93 - 0.98	Decrease UR in 60° arm elevation and PT in 120°. Decrease ER in loaded elevation. Increase UT and LT EMG activity in 61°-90° and 91°-120°.
McClure et al. (22) (USA)	45 healthy, 45 SIS	Test position: standing Task: scaption, flex, ER with the arm at 90 degrees of elevation in the frontal plane	Shoulder ROM and muscle force, thoracic posture, shoulder kinematic	NR	Increase UR in 90° - 120° flexion and 90° scaption. Increase PT in 120° scaption. Increase clavicular elevation in 90° - 120° flexion. Increase clavicular retraction in 120° scaption.
Lawrence et al. (23) (USA)	12 healthy, 10 SIS	Test position: standing Task: scaption, flexion, abduction	Kinematic of Scapulothoracic, acromioclavicular and sternoclavicular joints	ICC Within day Control: 0.83 - 0.98 SIS: 0.76 - 0.96	Decrease UR in 30° and 60° of elevation in frontal and scapular plans. Decrease Sternoclavicular protraction in all phase planes and angles. Decrease Sternoclavicular elevation in 30° scaption.
Keshavarz et al. (24) (Iran)	13 healthy, 15 SIS	Test position: sitting Task: scaption, flexion, abduction with 1 kg external load.	scapular translation and ROT	ICC intra-rater reliability 0.64 - 0.94 SEM: 3.2 - 5.7 mm and 2.9° - 8.8°	Decrease UR in 30° - 90° abduction and 30° scaption. Decrease PT at 30° flexion Decrease scapular lateral translation in 90° and 110° abduction
Kolk et al. (25) (Netherlands)	34 unilateral SIS	Test position: sitting Task: bilateral abduction	scapular kinematic in affected and non-affected side and in affected side after sub-acromial anesthetic	NR	Increase IR in 110°-120° abduction. Increase IR and decrease PT in 110° - 120° abduction after anesthetic
Turgut et al. (26) (Turkey)	37 healthy, 29 unilateral SIS	Test position: standing Task: bilateral Flexion	scapular kinematic in control and SIS group in both side	ICC Within day without removal of sensor 0.88-0.97	Decrease UR in 120° and PT in 60°, 90° and 120° compare to control and in all angle compare to asymptomatic side. Decrease ER and UR in dominant side of control group. scapular movement was more asymmetrical for IR and UR in individuals with SIS when compared with healthy controls
Rossi et al. (27) (Brazil)	25 No pain, 25 No pain + SD, 25 SIS, 25 SIS + SD	Test position: standing Task: Flexion	scapular kinematics in SIS and in asymptomatic participants with and without SD	NR	Pain and no pain (no SD) had less PT throughout the elevation in comparison to the No Pain + SD group. Pain + SD group had less PT throughout the arm-lowering phase than the No Pain + SD group. During the arm-lowering phase asymptomatic participants with SD had different scapular motion and showed increased PT compared to symptomatic participants with SD
Rosa et al. (28) (Brazil)	28 No pain, 27 No pain + PCT, 25 SIS, 25 SIS + PCT	Test position: standing Task: Flexion	Scapular kinematics and humeral translations Shoulder IR and ER ROM, ER strength, and pain and SPADI	ICC Within day for humeral translation: 0.85	Decrease scapular ER. Increase PT in comparison with PCT. Decrease humeral ant translation than the other group. Groups without PCT had greater IR ROM.
Rossi et al. (29) (Brazil)	50 healthy, 47 SIS	Test position: standing Task: bilateral abduction	Scapular kinematic (3 ROT and 3 translation and angular velocity)	Between day ICC: control: 0.58 - 0.88 SIS: 0.54 - 0.85 SEM: Control: 3.37° - 6.79° SIS: 3.62° - 7.44°	Decrease PT in elevation and lowering phase. Increase forward/backward translation in lowering phase. Change anterior tilt angular velocity.

Abbreviations: SIS, shoulder impingement syndrome; SD, scapular dyskinesia; NR, not reported; UR, upward rotation; PT, posterior tilt; ER, external rotation; IR, internal rotation; PCT, posterior capsule tightness.

trim-and-fill method used to retrieve five missing studies changed the effect size to -0.075 (95% CI -0.14, -0.004) after adjustment for publication bias.

Sensitivity analyses and the subgroup analysis based on degree of arm elevation did not decrease heterogeneity. Standardized mean differences were also insignificant

along all directions of arm elevation for these groups.

## 7. Discussion

Except for scapular upward rotation, scapular movement was generally insignificantly different between the subjects with and without SIS during arm elevation as the meta-analysis conducted. The two groups were not different in scapular external rotation and posterior tilt in all directions and degrees of arm elevation. The low scapular upward rotation obtained was in line with the reports by Keshavarz et al. (13) and Timmons et al. (31). In contrast, Keshavarz et al. (13) reported a high scapular posterior tilt in SIS, and Timmons et al. (31) reported a lower scapular external rotation in patients with SIS than in asymptomatic subjects. The inconsistency among the results of different studies can be attributed to differences in the type of motion, i.e. static or dynamic, and study population, i.e. athletes or non-athletes. Given differences in scapular kinematics between athletes and non-athletes and between static positions and dynamic movement (15, 16), the present systematic review addressed non-athletes and included articles that evaluated scapular kinematics during dynamic arm elevation for a decisive conclusion. Moreover, the results revealed that differences in the scapular upward rotation between the patients with SIS and asymptomatic individuals can be affected by the plane of arm elevation. Previous studies showed that dyskinesia is more obvious during arm elevation in sagittal plane and symptomatic individuals represent dyskinesia in this plane of movement (32, 33).

According to theoretical knowledge, scapular kinematic alterations such as decreased scapular upward rotation, posterior tilt and external rotation cause subacromial compression (12, 34). This review, however, found differences between the patients with SIS and asymptomatic individuals only in terms of upward rotation of the scapula. Given SIS as a multifactorial condition that is not exclusively caused by biomechanical factors (35), different methodological factors can mask scapular kinematic differences between two groups. The results of most of the included articles could have been affected by their high risk of bias in controlling confounders such as matching the groups based on type of activity, arm dominance and BMI. Given differences in scapular kinematics between the two sides, research suggests a lower scapular upward rotation and posterior tilt on the non-dominant than the dominant side (36, 37). The results of comparing patients with SIS and asymptomatic subjects can be therefore affected by the dominant side, which was not controlled in most of the studies. A significantly higher scapular upward rotation during arm elevation was reported in individuals with BMI

> 27 kg/m<sup>2</sup> compared to in those with BMI ≤ 23 kg/m<sup>2</sup> (38). In contrast, the majority of the included articles failed to address the potential effects of BMI on the results.

A systematic review showed changes in scapular kinematics in the rotator cuff tear and found more tissue damage to cause more scapular dysfunction (39). The majority of the studies included in the present review used clinical tests to diagnose SIS. These tests only ruled out glenohumeral instability, cervical referral pain and frozen shoulder and failed to identify the exact tissues involved and differentiate between rotator cuff tendinopathy and tear (12), which might have affected the results. Failing to investigate postural alignment, especially spinal thoracic curvature and rounded shoulder, and pectoralis muscle length in any of the studies might have also changed scapular motions and orientation in the healthy individuals (40). Moreover, selection bias associated with the sampling method might have influenced the results.

The scapular kinematic alterations reported in asymptomatic individuals with normal arm movements might have caused negligible between-group differences (41). The other limitations comprised inherent between-individual variations and including patients with SIS and without shoulder range of motion limitations.

Several articles were found to have identified the effect of fatigue on scapular kinematic alterations during repeated movements (42, 43); nevertheless, none of the studies compared scapular kinematics between patients with SIS and asymptomatic subjects under these circumstances. Repeated movement and examining the kinematics of the scapula in fatigue conditions may present the between-group differences obviously, which is suggested for future studies. The present findings can assist clinicians in gaining knowledge of scapular kinematic alterations during arm elevation in patients with SIS. These patients should be treated by considering numerous effective factors in scapular kinematics.

The limitations of the present systematic review included retrieving only articles published in English and peer-reviewed journals, which can cause publication bias. The subjects of the included studies were non-athlete, however, some of the studies did not exclude overhead workers. Therefore, the results might have been also affected by the population type. Sample size was not justified by power analysis in most of the included studies. As a result, the external validity of the finding compromised.

## 8. Conclusions

According to the present review, scapular upward rotation between the patients with SIS and asymptomatic individuals was significantly different and can be affected by



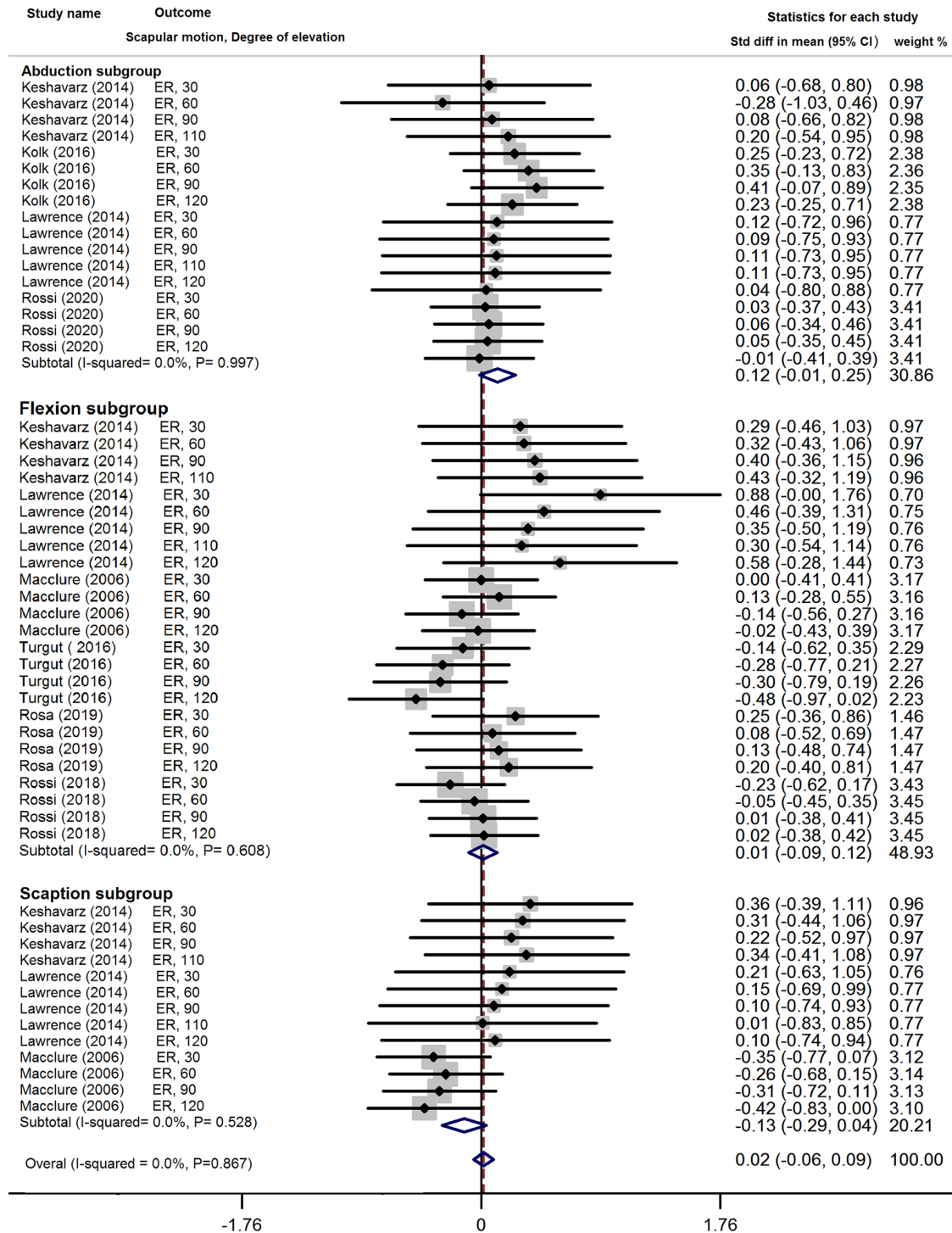


Figure 4. External rotation forest plot

the plane of arm elevation. No differences in scapular external rotation and posterior tilt were observed along any directions and degrees of arm elevation between the two groups. Between-group differences might have been overlooked as a result of the high risk of bias in the included studies. The high-quality studies addressing confounders were required to provide a definitive conclusion on the relationship between SIS and scapular kinematics.

### Supplementary Material

Supplementary material(s) is available [here](#) [To read supplementary materials, please refer to the journal website and open PDF/HTML].

### Acknowledgments

We would also like to show our gratitude to Denise Martineli Rossi (Departamento de Fisioterapia Aplicada Universidade Federal do Triângulo Mineiro [UFTM]) and Dayana Patricia Rosa (PT, Postdoc Position at Laval University) for providing their articles data that greatly improved the manuscript.

### Footnotes

**Authors' Contribution:** Study concept and design, A. H., J. S. R. S., A. A. and S. Sh.; Acquisition of data, A. A. and S. Sh.; Analysis and interpretation of data, A. H., S. Sh.; Drafting of the manuscript, A. H., A. A., J. S., S. Sh., and R. S.; Critical revision of the manuscript for important intellectual content, A. H., J. S., R. S., A. A. and S. Sh.; Statistical analysis, S. Sh.; Study supervision, J. S. and A. A., final approval of the submitted version, A. H., J. S. R. S., A. A. and S. Sh.

**Conflict of Interests:** All authors except one (A. H.) are faculty member of Iran university and medical sciences. A. H. is a PhD candidate of Iran University and medical sciences. The authors have no conflict of interest and financial interest. There is no consultation fees and patent. The authors have no stock or shares in companies. A. H. is the member of the board of the cardiopulmonary branch of Iranian physiotherapy association. We declared that one of the authors (S. SH.) is one of the editorial board of this journal from about two week ago. This journal confirmed that the mentioned author completely excluded from all review processes. We also introduced this author during the submission as an opposed reviewer.

**Data Reproducibility:** This study is a review article, so the primary data of this study provide from included study.

**Funding/Support:** This study has no funding and support.

### References

- Mitchell C, Adebajo A, Hay E, Carr A. Shoulder pain: diagnosis and management in primary care. *BMJ*. 2005;**331**(7525):1124–8. [PubMed ID: 16282408]. [PubMed Central ID: PMC1283277]. <https://doi.org/10.1136/bmj.331.7525.1124>.
- Kuijpers T, van der Windt D, van der Heijden G, Bouter LM. Systematic review of prognostic cohort studies on shoulder disorders. *Pain*. 2004;**109**(3):420–31. [PubMed ID: 15157703]. <https://doi.org/10.1016/j.pain.2004.02.017>.
- Neer CS. Impingement Lesions. *Clinical Orthopaedics and Related Research*. 1983;**173**:70–7. [PubMed ID: 00003086-198303000-00010].
- Harrison AK, Flatow EL. Subacromial impingement syndrome. *J Am Acad Orthop Surg*. 2011;**19**(11):701–8. [PubMed ID: 22052646]. <https://doi.org/10.5435/00124635-201110000-00006>.
- Aceituno-Gomez J, Garcia-Madero VM, Blazquez-Gamallo R, Harto-Martinez AM, Mohedano A, Vinuela A, et al. [Health-related quality of life in patients diagnosed with subacromial syndrome in the Talavera Integrated Area]. *Rev Esp Salud Publica*. 2019;**93**. Spanish. e201910094. [PubMed ID: 31621693].
- Yamamoto A, Takagishi K, Osawa T, Yanagawa T, Nakajima D, Shitara H, et al. Prevalence and risk factors of a rotator cuff tear in the general population. *J Shoulder Elbow Surg*. 2010;**19**(1):116–20. [PubMed ID: 19540777]. <https://doi.org/10.1016/j.jse.2009.04.006>.
- Garving C, Jakob S, Bauer I, Nadjar R, Brunner UH. Impingement Syndrome of the Shoulder. *Dtsch Arztebl Int*. 2017;**114**(45):765–76. [PubMed ID: 29202926]. [PubMed Central ID: PMC5729225]. <https://doi.org/10.3238/arztebl.2017.0765>.
- Leong HT, Ng GY, Chan SC, Fu SN. Rotator cuff tendinopathy alters the muscle activity onset and kinematics of scapula. *J Electromyogr Kinesiol*. 2017;**35**:40–6. [PubMed ID: 28595162]. <https://doi.org/10.1016/j.jelekin.2017.05.009>.
- Ludewig PM, Braman JP. Shoulder impingement: biomechanical considerations in rehabilitation. *Man Ther*. 2011;**16**(1):33–9. [PubMed ID: 20888284]. [PubMed Central ID: PMC3010321]. <https://doi.org/10.1016/j.math.2010.08.004>.
- Lefevre-Colau MM, Nguyen C, Palazzo C, Srouf F, Paris G, Vuillemin V, et al. Kinematic patterns in normal and degenerative shoulders. Part II: Review of 3-D scapular kinematic patterns in patients with shoulder pain, and clinical implications. *Ann Phys Rehabil Med*. 2018;**61**(1):46–53. [PubMed ID: 28987866]. <https://doi.org/10.1016/j.rehab.2017.09.002>.
- Lefevre-Colau MM, Nguyen C, Palazzo C, Srouf F, Paris G, Vuillemin V, et al. Recent advances in kinematics of the shoulder complex in healthy people. *Ann Phys Rehabil Med*. 2018;**61**(1):56–9. [PubMed ID: 28964876]. <https://doi.org/10.1016/j.rehab.2017.09.001>.
- 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. [PubMed ID: 23580420]. <https://doi.org/10.1136/bjsports-2013-092425>.
- Keshavarz R, Bashardoust Tajali S, Mir SM, Ashrafi H. The role of scapular kinematics in patients with different shoulder musculoskeletal disorders: A systematic review approach. *J Bodyw Mov Ther*. 2017;**21**(2):386–400. [PubMed ID: 28532884]. <https://doi.org/10.1016/j.jbmt.2016.09.002>.
- Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther*. 2009;**39**(2):90–104. [PubMed ID: 19194022]. [PubMed Central ID: PMC2730194]. <https://doi.org/10.2519/jospt.2009.2808>.
- Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Scapular position and orientation in throwing athletes. *Am J Sports Med*. 2005;**33**(2):263–71. [PubMed ID: 15701613]. <https://doi.org/10.1177/0363546504268138>.

16. MacLean KF, Chopp JN, Grewal TJ, Picco BR, Dickerson CR. Three-dimensional comparison of static and dynamic scapular motion tracking techniques. *J Electromyogr Kinesiol.* 2014;**24**(1):65–71. [PubMed ID: 24189397]. <https://doi.org/10.1016/j.jelekin.2013.09.011>.
17. PRISMA. PRISMA. USA: PRISMA; 2021, [cited 2021]. Available from: <https://prisma-statement.org/>.
18. Hajibashi A, Sarrafzadeh J, Amiri A, Salehi R. *Kinematic of the scapula during arm elevation in subacromial pain syndrome.* York, UK: National Institute of Health Research; 2020, [cited 2021]. Available from: [https://www.crd.york.ac.uk/prospero/display\\_record.php?ID=CRD42020177286](https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020177286).
19. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health.* 1998;**52**(6):377–84. [PubMed ID: 9764259]. [PubMed Central ID: PMC1756728]. <https://doi.org/10.1136/jech.52.6.377>.
20. Fu X, Yung PS, Ma CC, Leong HT. Scapular Kinematics in Athletes With and Without Rotator Cuff Tendinopathy: A Systematic Review. *J Sport Rehabil.* 2020;**29**(6):820–9. [PubMed ID: 31869815]. <https://doi.org/10.1123/jsr.2019-0095>.
21. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther.* 2000;**80**(3):276–91. [PubMed ID: 10696154]. <https://doi.org/10.1093/ptj/80.3.276>.
22. McClure PW, Michener LA, Karduna AR. Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Phys Ther.* 2006;**86**(8):1075–90. [PubMed ID: 16879042]. <https://doi.org/10.1093/ptj/86.8.1075>.
23. Lawrence RL, Braman JP, LaPrade RF, Ludewig PM. Comparison of 3-dimensional shoulder complex kinematics in individuals with and without shoulder pain, part 1: sternoclavicular, acromioclavicular, and scapulothoracic joints. *J Orthop Sports Phys Ther.* 2014;**44**(9):636–45. <https://doi.org/10.2519/jospt.2014.5339>.
24. Keshavarz R, Shakeri H, Arab AM, Ashrafi H, Talim Khani A. Scapular position and orientation during abduction, flexion and scapular plane elevation phase. *Iran Rehabil J.* 2014;**12**(1):22–30.
25. Kolk A, Henseler JF, de Witte PB, van Arkel ERA, Visser CPJ, Nagels J, et al. Subacromial anaesthetics increase asymmetry of scapular kinematics in patients with subacromial pain syndrome. *Man Ther.* 2016;**26**:31–7. [PubMed ID: 27469585]. <https://doi.org/10.1016/j.math.2016.07.002>.
26. Turgut E, Duzgun I, Baltaci G. Scapular asymmetry in participants with and without shoulder impingement syndrome; a three-dimensional motion analysis. *Clin Biomech (Bristol, Avon).* 2016;**39**:1–8. [PubMed ID: 27614041]. <https://doi.org/10.1016/j.clinbiomech.2016.09.001>.
27. Rossi DM, Resende RA, da Fonseca ST, de Oliveira AS. Scapulothoracic kinematic pattern in the shoulder pain and scapular dyskinesia: A principal component analysis approach. *J Biomech.* 2018;**77**:138–45. [PubMed ID: 30037581]. <https://doi.org/10.1016/j.jbiomech.2018.07.010>.
28. Rosa DP, Borstad JD, Ferreira JK, Camargo PR. The Influence of Glenohumeral Joint Posterior Capsule Tightness and Impingement Symptoms on Shoulder Impairments and Kinematics. *Phys Ther.* 2019;**99**(7):870–81. [PubMed ID: 30921461]. <https://doi.org/10.1093/ptj/pzz052>.
29. Rossi DM, Resende RA, Hotta GH, da Fonseca ST, de Oliveira AS. Altered Scapular Time Series in Individuals With Subacromial Pain Syndrome. *J Appl Biomech.* 2020:1–9. [PubMed ID: 32101790]. <https://doi.org/10.1123/jab.2019-0247>.
30. Borstad JD, Ludewig PM. Comparison of scapular kinematics between elevation and lowering of the arm in the scapular plane. *Clin Biomech (Bristol, Avon).* 2002;**17**(9-10):650–9. [PubMed ID: 12446161]. [https://doi.org/10.1016/s0268-0033\(02\)00136-5](https://doi.org/10.1016/s0268-0033(02)00136-5).
31. 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. [PubMed ID: 22388171]. <https://doi.org/10.1123/jsr.21.4.354>.
32. Lopes AD, Timmons MK, Grover M, Ciconelli RM, Michener LA. Visual scapular dyskinesia: kinematics and muscle activity alterations in patients with subacromial impingement syndrome. *Arch Phys Med Rehabil.* 2015;**96**(2):298–306. [PubMed ID: 25449194]. <https://doi.org/10.1016/j.apmr.2014.09.029>.
33. Uhl TL, Kibler WB, Gecewich B, Tripp BL. Evaluation of clinical assessment methods for scapular dyskinesia. *Arthroscopy.* 2009;**25**(11):1240–8. [PubMed ID: 19896045]. <https://doi.org/10.1016/j.arthro.2009.06.007>.
34. Lawrence RL, Braman JP, Ludewig PM. The Impact of Decreased Scapulothoracic Upward Rotation on Subacromial Proximities. *J Orthop Sports Phys Ther.* 2019;**49**(3):180–91. [PubMed ID: 30658048]. [PubMed Central ID: PMC7112160]. <https://doi.org/10.2519/jospt.2019.8590>.
35. Umer M, Qadir I, Azam M. Subacromial impingement syndrome. *Orthop Rev (Pavia).* 2012;**4**(2). e18. [PubMed ID: 22802986]. [PubMed Central ID: PMC3395987]. <https://doi.org/10.4081/or.2012.e18>.
36. Lee SK, Yang DS, Kim HY, Choy WS. A comparison of 3D scapular kinematics between dominant and nondominant shoulders during multiplanar arm motion. *Indian J Orthop.* 2013;**47**(2):135–42. [PubMed ID: 23682174]. [PubMed Central ID: PMC3654462]. <https://doi.org/10.4103/0019-5413.108882>.
37. Matsuki K, Matsuki KO, Mu S, Kenmoku T, Yamaguchi S, Ochiai N, et al. In vivo 3D analysis of clavicular kinematics during scapular plane abduction: comparison of dominant and non-dominant shoulders. *Gait Posture.* 2014;**39**(1):625–7. [PubMed ID: 23871318]. <https://doi.org/10.1016/j.gaitpost.2013.06.021>.
38. Gupta M, Dashottar A, Borstad JD. Scapula kinematics differ by body mass index. *J Appl Biomech.* 2013;**29**(4):380–5. [PubMed ID: 22923369]. <https://doi.org/10.1123/jab.29.4.380>.
39. Barcia AM, Makovicka JL, Mrab Study Group, Spenciner DB, Chamberlain AM, Jacofsky MC, et al. Scapular motion in the presence of rotator cuff tears: a systematic review. *J Shoulder Elbow Surg.* 2021;**30**(7):1679–92. [PubMed ID: 33540119]. <https://doi.org/10.1016/j.jse.2020.12.012>.
40. Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *J Orthop Sports Phys Ther.* 2005;**35**(2):72–87. [PubMed ID: 15773565]. <https://doi.org/10.2519/jospt.2005.35.2.72>.
41. McQuade KJ, Borstad J, de Oliveira AS. Critical and Theoretical Perspective on Scapular Stabilization: What Does It Really Mean, and Are We on the Right Track? *Phys Ther.* 2016;**96**(8):1162–9. [PubMed ID: 26847012]. <https://doi.org/10.2522/ptj.2014.0230>.
42. Andres J, Painter PJ, McIlvain G, Timmons MK. The Effect of Repeated Shoulder Motion on Scapular Dyskinesia in Army ROTC Cadets. *Mil Med.* 2020;**185**(5-6):e811–7. [PubMed ID: 31783408]. <https://doi.org/10.1093/milmed/usz408>.
43. Umehara J, Kusano K, Nakamura M, Morishita K, Nishishita S, Tanaka H, et al. Scapular kinematic and shoulder muscle activity alterations after serratus anterior muscle fatigue. *J Shoulder Elbow Surg.* 2018;**27**(7):1205–13. [PubMed ID: 29478944]. <https://doi.org/10.1016/j.jse.2018.01.009>.