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EFFECTIVENESS OF MODIFIED POSTERIOR SHOULDER STRETCHING EXERCISES IN POSTERIOR SHOULDER TIGHTNESS AND GLENOHUMERAL INTERNAL ROTATION DEFICIT: A SYSTEMATIC REVIEW

ORIGINAL ARTICLE

ABSTRACT

Purpose: Posterior shoulder tightness (PST) and Glenohumeral internal rotation deficit (GIRD) can impact shoulder biomechanics and damage shoulder function. Posterior shoulder stretching exercises (PSSEs) are often performed in traditional positions to improve posterior shoulder inflexibility. However, these traditional positions can cause inadequate control of the scapula and glenohumeral rotation. The modified PSSEs through scapular stabilization are preferred as current trends to effective management of the GIRD and PST. However, there is a lack of consensus regarding which type of modified PSSE is more effective on PST and GIRD improvement. Therefore, we aimed to describe the efficacy of modified PSSEs on PST and GIRD in symptomatic and asymptomatic populations to aid clinicians when making decisions for these populations.

Methods: A literature search was conducted for a systematic review. Relevant studies were searched from appropriate electronic databases (CINAHL, Cochrane Review, Pubmed (MEDLINE), Web of Science as well as Google Scholar©), and selected the eligible studies for inclusion.

Results: The present systematic literature search generated 127 relevant citations and 17 articles were included in the final review. As an outcome measure GIRD was assessed in all included studies, whereas PST was assessed in 10 studies.There was high evidence related to the positive effects of both modified cross-body and sleeper stretch to improve GIRD and PST.

Conclusion: According to this systematic literature review, both modified cross-body and sleeper stretch are effective in the improvement of GIRD and PST. Future research should focus on other specific shoulder diseases and should also recruit specific participants to address the effectiveness of modified PSSEs on GIRD and PST.

Keywords: Injuries, Mobility, Physical Therapy

MODİFİYE POSTERİOR OMUZ GERME EGZERSİZLERİNİN POSTERİOR OMUZ GERGİNLİĞİ VE GLENOHUMERAL İNTERNAL ROTASYON DEFİSİTİNDEKİ ETKİNLİĞİ: BİR SİSTEMATİK DERLEME

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Glenohumeral internal rotasyon defisiti (GİRD) ve posterior omuz gerginliği (POG), omuz biyomekaniğini etkileyebilir ve omuz fonksiyonuna zarar verebilir. GİRD ve POG tedavisinde posterior omuz germe egzersizleri (POGE) sıklıkla geleneksel pozisyonlarda uygulanmaktadır. Ancak bu geleneksel pozisyonlar skapulanın ve glenohumeral rotasyonun yetersiz kontrolüne neden olabilmektedir. GİRD ve POG'un etkin tedavisi için güncel yaklaşımlar olarak skapular stabilizasyon ile gerçekleştirilen modifiye POGE tercih edilmektedir. Ancak hangi modifiye germe egzersizinin GİRD ve POG'un iyileşmesinde daha etkili olduğuna dair bir fikir birliği bulunmamaktadır. Bu nedenle, klinisyenlere semptomatik ve asemptomatik popülasyonlar için karar vermede yardımcı olmak için modifiye POGE'nin bu popülasyonlarda POG ve GİRD üzerindeki etkinliğini tanımlamayı amaçladık.

Yöntem: Sistematik bir literatür taraması gerçekleştirdik. İlgili çalışmalar dahil edilmek üzere değerlendirildi ve seçilen çalışmalar uygun elektronik veri tabanlarından (CINAHL, Cochrane Review, Pubmed (MEDLINE), Web of Science ve Google Scholar©) araştırıldı.

Sonuçlar: Sistematik literatür araştırması 127 ilgili makale ile sonuçlandı ve final incelemeye 17 makale dahil edildi. Sonuç ölçümü olarak GİRD dahil edilen tüm çalışmalarda değerlendirilirken, POG 10 çalışmada değerlendirildi.

Tartışma: Bu sistematik literatür derlemesine göre, hem modifiye cross-body germe hem de modifiye sleeper germe GİRD ve POG'u iyileştirmede etkilidir. Gelecekteki araştırmalar POGE'nin GİRD ve POG üzerindeki etkinliğini belirlemek için diğer spesifik omuz hastalıklarına da odaklanmalı ve ayrıca spesifik katılımcıları çalışmalara almalıdır.

Anahtar Kelimeler: Yaralanmalar, Mobilite, Fizik Tedavi

INTRODUCTION

Shoulder pain is a common musculoskeletal complaint affecting up to 67% of adults at some point in their lifetime. Shoulder pain etiology is multifactorial and includes multiple impairments, including also the biomechanical consequences of decreased mobility (1).

Posterior shoulder tightness (PST) is defined as the restriction of the posterior shoulder soft tissues, including contractile (infraspinatus, teres minor, and posterior deltoid muscles) and non-contractile structures (posterior glenohumeral capsule) as well as osseous changes (increased humeral retroversion) (1). Glenohumeral internal rotation deficit (GIRD) is defined as a loss of shoulder IR of the dominant side compared to the non-dominant side (2). PST has been associated with restricted glenohumeral internal rotation (IR) and horizontal adduction (HA) range of motion (ROM) (3,4). From a biomechanical point of view, evidence suggests that PST and GIRD, causing anterosuperior migration of the humeral head, lead to increased subacromial contact pressures (5,6,7) that are sources of subacromial and internal impingement (8), rotator cuff (RC) tendinopathy (9), collectively termed as subacromial pain syndrome (SPS) (10).

PST and GIRD are well documented in overhead athletes (7) as well as the general population (11). In the management of PST and GIRD, researchers focus on posterior shoulder stretching exercises (PSSEs), the most common PSSE types are sleeper and cross-body stretches, to reduce subacromial contact pressure and contribute to prevention as well as treatment for SPS in clinical practice (12,13). Although these traditional PSSEs are effective to improve GIRD and PST, they may have some disadvantages. The most important disadvantage is the lack of scapular stabilization. This leads to prevent isolating the intended stretch to the posteroinferior aspect of the glenohumeral joint and increased the risk of impingement during stretching.

The traditional sleeper PSSE is performed while the person is side-lying on the affected side, arm at 90° shoulder flexion, using the opposite hand to internally rotate the shoulder at 45°-90° flexion by grasping the distal forearm and moving the arm toward the treatment table (14). This traditional position usually causes aggravation of the pain and could not provide enough scapular stabilization to stretch the isolated posterior RC and inferior capsule of the glenohumeral ligament. The traditional cross-body PSSE is performed while the person is in the standing position, sitting position, and rarely in the supine position. The opposite hand horizontally adducts the shoulder. Because of the insufficient scapular stabilization, while the humerus is horizontally adducted, undesired accessory abduction of the scapula, as well as excessive humerus external rotation, occurs.

There is increasing evidence that modification of these PSSEs can provide isolated posterior capsule stretching by preventing accessory abduction of the scapula and restricting the external rotation range of motion of the humerus without the aggravation of the pain. It is assumed that posterior glenohumeral joint soft tissues are greater isolated by stabilizing the scapula (14). For the first time, Johansen et al. recommended the modified PSSE by manually stabilizing the scapula in the prone position when the shoulder was abducted 90° and 90°-120° of IR with the forearm in pronation (15). Wilk et al. recommended the modified sleeper stretch and modified cross-body stretch rather than the traditional ones to better isolate stretching for the posterior glenohumeral soft tissues (14). A systematic review conducted by Mine et al. was related to the effectiveness of PSSEs on PST and GIRD without distinguishing the modified and traditional PSSE (4). The authors concluded that there was moderate evidence to support the immediate and short-term effects of cross-body PSSE to improve PST and GIRD. For the active sleeper PSSE, moderate evidence was concluded that the sleeper PSSE is not more effective than no intervention in improvement of PST and GIRD in the short-term (4). Although many studies have investigated the effects of traditional and modified PSSEs on PST and GIRD (16,17,18,19,20,21) no literature synthesis has been published to determine the efficacy of modified PSSEs in improving PST and GIRD. Therefore, the purpose of the present study was to perform a systematic review of the literature that has investigated the effectiveness of modified PSSEs on PST and GIRD.

METHOD

Eligibility Criteria for Studies

A clinical question was developed according to the PICOS (P: participant, I: intervention, C: comparator, O: outcome, and S: study design) format for the present systematic review (Table 1). PICOS includes the population characteristics, treatments given, comparative treatments, primary and secondary outcomes, and data collection settings. This systematic review included Turkish-language and English-language studies. As a result of literature research, no Turkish-language study was found related to this topic. Available relevant peer-reviewed English-language randomized controlled trials (RCTs), prospective cohort, and controlled laboratory studies investigating the effects of modified PSSEs on GIRD and/or PST were included. Studies with living human participants with symptomatic and asymptomatic shoulders were accepted for inclusion. Stretching interventions included only modified stretching (i.e. with scapular stabilization); active or passive techniques. Interventions that are composed of a combination of traditional and modified PSSEs were excluded. We did not set a limitation on the timeframe of stretching or types of comparator interventions. Eligible studies determined shoulder HAROM or IRROM (active or passive) as outcome measures (12,13,15-30).

Data Sources and Literature Search Strategy

A systematic search was conducted using English databases (CINAHL, Cochrane Review, Pubmed [MEDLINE], and Web of Science) as well as Google Scholar© to identify peer reviewed articles about the effectiveness of modified PSSEs on PST as well as GIRD according to PRISMA statement (32). The following keywords were used to identify eligible studies: Glenohumeral internal rotation deficit, posterior shoulder tightness, posterior shoulder stretching, posterior shoulder stretch, posterior capsule stretch, modified posterior capsule stretch, modified cross-body stretch, modified sleeper stretch, modified posterior shoulder stretching. We used both 'and' as well as 'or' to combine these keywords. To determine eligible studies using keywords, abstracts were scanned firstly, and then the full texts were investigated. Additionally, reference lists of included articles were searched manually. Databases were searched from inception 1995 to October 2021.

Study Characteristics

A summary of included studies as well as detailed information related to modified PSSEs methods is shown in Table 2.

The risk of bias in included studies was assessed with Physiotherapy Evidence Database (PEDro) scale in Table 3. The quality of each study was

Table 1. PICOS Format and Search Keywords

	Definition	Search Key Words
Participants	Any participants	Not set
Intervention	Any form of modified stretching	Modified posterior shoulder stretch, modified cross-body stretch, Or modified sleeper stretch
Comparison	Any interventions	Not set
Outcome	PST or GIRD	(Posterior shoulder tightness) Or PST Or (glenohumeral internal rotation deficit) Or GIRD
Study Design	RCTs, prospective cohort studies, controlled laboratory study	Not set

GIRD: Glenohumeral internal rotation deficit; PST: Posterior shoulder tightness; RCTs: Randomized controlled trials

Table 2. Summary of Included Studies

Study	Participants	Intervention	Outcome measure	Results	Study Design
Guney et al. (2015)	Asymptomatic non-athletic women with GIRD (n = 74) Age: 24.0 ± 1.5 (Modified CBS group), 24.2 ± 4.1 years (Traditional CBS group) and 23.8 ± 1.7 years (Traditional SS group)	The following interventions were performed everyday over 1 week. ***Modified CBS group** (n = 25): passive static stretching was performed in supine position with scapular stabilization, 30 seconds, 3 repetitions * **Traditional CBS group** (n = 25): static stretching, 30 seconds, 3 repetitions * **Traditional SS grou**p (n = 24): static stretching, 30 seconds, 3 repetitions	The following were assessed for the dominant side before and after interventions. * Passive HA ROM (PST) * Passive IR and ER ROM at 90° abduction	Improvements in passive HA and IRROM were significantly higher in the modified CBS group compared to traditional CBS and SS groups (*P* < 0.001). Passive HA and IRROM improved after interventions in all three groups (*P* < 0.05).	A randomized controlled trial
Hammons et al. (2015)	Asymptomatic young athletes with GIRD (n = 34, 19 men and 15 women) Age: 21.1 ± 1.6 (Traditional CBS group) and 21.6 ± 3.3 years (Modified PPPS group) Sports: Baseball, softball, and swimming	The following interventions were performed three times per week over 4 weeks. ***Traditional CBS group** (n = 17): active, static stretching were performed in standing position, 30 seconds, 5 repetitions ***Modified PPST group** (n = 17): passive IR at 90° abduction with the scapula stabilized in prone, performing static stretching, 30 seconds, 5 repetitions	The following were assessed for the dominant side before and after interventions. *Passive IR and ER ROM at 90° abduction *GIRD * Total arc of motion	Passive IRROM increased and GIRD improved after interventions in both groups (*P* < 0.01). However, there was no significant difference between the two groups. There was no significant improvement in ER ROM in the two groups.	A randomized controlled trial
Salamh et al. (2015)	Asymptomatic elite female volleyball players with GIRD (n = 60) Age: 16.1 ± 1.2 (Modified CBS group) and 16.5 ± 1.5 years (Traditional CBS group)	Single session of PSSE was performed. Passive static CBS with or without passive scapular stabilization was performed for the dominant shoulder in supine. ***Modified CBS group** (n = 30): passive stretching with scapular stabilization in the supine position, 30 seconds, 3 repetitions * **Traditional CBS group** (n = 30): passive stretching in supine position without stabilization, 30 seconds, 3 repetitions	The following were assessed before and immediately after interventions. * Passive HA ROM in side-lying PST) * Passive IRROM at 90° abduction	Baseline data for horizontal adduction and IRROM were not different between the two groups. Both post-intervention horizontal adduction and IRROM were greater in the Modified CBS group compared to the Traditional CBS group (*P* < 0.01).	A randomized controlled trial
Cools et al. (2012)	Overhead athletes (n=60, 31 men and 29 women) with GIRD, including 30 athletes with impingement symptoms and 30 asymptomatic athletes Age: 25.0 ± 7.2 years Sports: Volleyball, tennis, squash, and badminton	The following interventions were performed during 3 weeks * **Symptomatic, modified CBS + SS group** (n=15): passive static modified CBS performed with scapular stabilization in the supine position, passive static modified SS performed with scapular stabilization in the side-lying position, each stretching technique sustained 30 secs, repeated until the end of 15-minute sessions * **Symptomatic, Joint Mobilization group** (n=15): dorsal and caudal glide, high grade, 30 seconds, 30-second rest, repeated until the end of 15-minute sessions * **Asymptomatic, modified CBS + SS group** (n=15): the same implementation as above * **Asymptomatic, Joint Mobilization group** (n=15): the same implementation as above	The following were assessed for both sides before and after 3-week interventions and at 6-week follow-up. *Pain (VAS) *Modified Rowe Score *Passive IRROM at 90° abduction	There was an increase in ROM (*P*<0.05) in both treatment groups, in symptomatic groups as well as in asymptomatic groups. Symptomatic athletes showed a significant improvement in pain and Modified Rowe Score There was no significant difference between the two treatment techniques.	A randomized controlled trial
Oyama et al. (2010)	Asymptomatic male collegiate baseball pitchers (n=15) Age: 20.4 ± 1.35 years	A single session of PSSE was performed. ***Modified SS at 90° group** In standing position, the dominant shoulder was placed against the wall, and the scapula pressed the wall to maintain scapular stabilization. The shoulder flexed to 90° with the elbow in 90° of flexion and internally rotated using contralateral arm ***Modified SS at 45° group** The same position as above, the dominant shoulder flexed to 45° with elbow in 90° of flexion, and internally rotated using contralateral arm ***Modified CBS g**roup The same position as above, the dominant shoulder flexed to 90° and passively horizontally adducted to end range using the contralateral arm *Each stretch repeated 3 times, sustained 30 seconds, with 30 seconds of rest	The following were assessed immediately before and after interventions. * Passive HA ROM in supine (PST) * Passive IR and ER ROM at 90° abduction and 90° of elbow flexion.	There was no significant stretch by session (prestretch versus post stretch) interaction for IR (P=.919), ER (P=.494), or HA ROM (P =.536). There were significant session main effects for IRROM (P< 001) and horizontal adduction ROM (P<.001). There was a significant increase in IRROM (< .001) and HA ROM (< .001) following all modified PSSEs, while no significant session main effect for external rotation ROM (P=.971).	Prospective cohort study

Brown et al. (2015)	Asymptomatic collegiate baseball players (n=40) Age between 18 and 21 years Traditional CBS group (n=20) age= 18.9 ±.94 years Modified CBS group (n=20) age= 19.9 ± 1.3 years	A single session of PSSE was performed ***Traditional CBS group** (n=20) In upright standing position CBS was performed without scapular stabilization ***Modified CBS group** (n=20) In side-lying position, the participant pulled the throwing arm across the body using the non-throwing arm while maintaining 90° of shoulder and elbow flexion with scapular stabilization. Scapular stabilization ensured using a standard foam roller (ıt placed horizontally under the participant's lateral scapular border to provide external stabilization while the stretch was performed) Each stretch was repeated 5 times, sustained 30 seconds, with 15 seconds of rest	The following were assessed at three different intervals: 1) after their initial warm-up but before throwing 2) after throwing, and 3) after stretching intervention *Passive HA ROM in supine (PST) * Passive IR and ER ROM at 90° abduction and 90° of elbow flexion. *TR ROM (IR+ER ROM)	There was no significant difference for IR, ER, HAD, and TROM when the two groups compared across the various time points (p>.05). Both the modified CBS and Traditional CBS improved the passive shoulder IR, HA, and TR ROM in the overhead athlete after an acute bout of throwing (P<.05).	A double-blind randomized controlled trial
Bailey et al. (2017)	Asymptomatic male baseball players (n=60) with GIRD,	A single session of treatment was performed. *** Instrumented manual therapy plus modified SS and CBS group (n=30)** In the prone position, instrumented manual therapy was performed targeting the infraspinatus and teres minor muscles for 2 minutes. In the side-lying position, the dominant shoulder flexed at 90° with the elbow flexed to 90°; the shoulder was then rotated internally using the opposite hand. The scapula was retracted and stabilized using a towel roll during modified SS. The modified CBS was performed in the same starting position described above. The athlete grasped the dominant elbow with the opposite hand placed beneath the arm and pull across the front of the body. Each stretch repeated 2 times, sustained 60seconds, with 30 seconds of rest ***Modified SS and CBS groups (n=30)** The same stretching techniques, as above, was performed	The following were assessed immediately before and after a single treatment session. *Passive HA ROM in supine (PST) * Passive IR and ER ROM at 90° abduction and 90° of elbow flexion. *TR ROM *Humeral Torsion	There was a significant improvements in ROM in both groups after the intervention. The instrumented manual therapy plus modified SS and CBS stretching group was significantly greater increases in internal rotation, TR ROM and HA ROM compared with modified CBS and SS group (p<.05).	Controlled laboratory study
Mine et al. (2017)	Young healthy individuals n=12, 9 men and 3 women) Age 20.9 ± 0.3 years	A single session of PSSE was performed. Each subject completed the stretching interventions for 48 hours. Two testing sessions were separated by a minimum of 48 hours, to minimize potential carry-over effects of stretching. ***Modified SS group (n=6)** Participants performed modified SS by rotating their upper trunk posteriorly 20-30° in side-lying, and rotating the dominant shoulder internally at 90° shoulder flexion and 90° elbow flexion using the non-dominant hand ***Traditional CBS gr**oup (n=6) Participants performed the traditional cross-body stretch in a sitting position. Each stretch repeated 5 times, sustained 20 seconds, with 10 seconds of rest	The following were assessed at two separate sessions. In the first experimental sessions, anthropometric measurements were taken, and body mass index was calculated accordingly. In both intervention sessions, the baseline data for ER, IR, and HA ROM on the dominant side was collected in this order. *Passive HA ROM in supine (PST) * Passive IR and ER ROM at 90° abduction and 90° of elbow flexion.	There was a significant immediate improvement in IR and HA ROM in both stretching interventions (p<0.01). There was no significant difference between the two intervention groups in terms of ROM changes (p>.05).	A crossover randomized controlled trial.

Joung et al. (2019)	Asymptomatic participants (n=26, 14 males, 12 females) with limited shoulder HA ROM (<115°), GIRD (>10°) when compared dominant and non-dominant side Age for traditional CBS group 21.0 ± 1.5 years Age for modified CBS group 21.5 ± 1.3 years	The following interventions were performed four times per week over 4 weeks. ***Traditional CBS group** In the side-lying position, the dominant shoulder flexed at 90° with the elbow flexed to 90°; the participant grasped the dominant elbow with the opposite hand placed beneath the arm and pulled the elbow as possible as on the transverse plane without scapular stabilization. ***Modified CBS group** Modified CBS performed with scapular stabilization. For scapular stabilization participants used a non-elastic orthopedic manual therapy belt. When the participant retracted the scapula, the belt was applied just under the participant's axilla with a tension of 2 to 3 kg stabilization force for allowing a normal breath pattern. A towel was applied between both scapulae. The same stretching position as mentioned above, modified CBS performed with scapular stabilization. Each stretch repeated 10 times, sustained 30 seconds, with 10 seconds of rest	The following were assessed for both sides before and after 4-week interventions *Passive HA ROM (PST) * Passive IRROM at 90° abduction and 90° of elbow flexion. *Horizontal adductor strength	There were significant improvements in IR and HA ROM in both stretching interventions (p<0.01). There was a significant increase for HA ROM in the modified CBS group when compared to the traditional CBS group (p<.05). There was no significant difference between the two intervention groups in terms of IRROM changes as well as shoulder horizontal adductor strength (p>.05).	A randomized controlled trial.
Rao et al. (2016)	Asymptomatic Overhead Athletes (n=45) There was no information related to sex, age as well as the type of overhead sports	The following interventions were performed five repetitions daily, for 4 weeks. ***Modified SS group (n=15)** The athlete performed modified SS by rotating their upper trunk posteriorly 20-30° in side-lying, and rotating the dominant shoulder internally at 90° shoulder flexion and 90° elbow flexion using the non-dominant hand ***Modified CBS group (n=15)** In a side-lying position on the involved side, the trunk rolled posteriorly 20-30°, and both knees semi-flexed. The shoulder is elevated to 90° and then aligned the forearm that to be stretched with the opposite forearm on the top. During stretching the athlete stabilized the scapula against the treatment table as the shoulder was horizontally adducted, while external rotation was restricted via counterpressure of the opposite forearm, and a therapist stood behind the athlete, supported the back to prevent further trunk rotation to maintain scapular stabilization. ***Traditional CBS group (n=15)**) Participants performed the traditional cross-body stretch in upright standing position. Each stretch repeated 5 times, sustained 20 seconds, with 10 seconds of rest	The following interventions were assessed before and after 4-week interventions. * Passive IRROM at 90° abduction and 90° of elbow flexion * Thumb-up-the back * Penn Shoulder Score	There were significant improvements in IRROM, Thumb-up-the back, and Penn Score (Decrease in shoulder disability) in three stretching interventions (p<0.05). There was a significant improvement for IRROM and disability level in the modified CBS group when compared to modified SS as well as traditional CBS group (p<.001).	A randomized controlled trial.
Pandya et al. (2018)	Asymptomatic overhead throwers (n=60) Modified SS group age= 32.20±8.9 years and Modified SS with kinesio taping group age=24.96 ±4.9 years. There was no information related to sex as well as the type of overhead sports	The following interventions were performed five times a week for 4 weeks. ***Modified SS group** (n=30) The athlete was positioned in the side-lying on the throwing side to stabilize the scapula against the treatment table, and both the shoulder and elbow flexed to 90°. In this position, the dominant arm passively internally rotated by using the opposite hand. ***Modified SS with Kinesio taping group** (n=30) Stretching performed as mentioned above. Before stretching, kinesio tape was applied from the anterior aspect of the humeral head, just lateral to the acromion process to finish at the inferior angle of the scapulae, as well as the second piece of tape commenced on the anterior aspect of the humeral head over the acromion in sitting position. The opposite hand lifted the humeral head up and back during the application of the tape. Each stretch was repeated 3 times, sustained 30 seconds, with 30 seconds of rest. The tape was changed on an alternate day.	The following were assessed for both sides before treatment (1st day), 1st week, 2nd week, 3rd week, and after 4-week interventions. *IRROM deficit (GIRD)	There was a significant improvement in IRROM in the dominant side of the shoulder in the modified SS group after 1st, 2nd, 3rd and 4 weeks of treatment (p<.05) There was a significant improvement in IRROM in the dominant side of the shoulder in modified SS with kinesio taping group (p<.05) except for 3rd and 4 weeks conclusion, where there was no significant improvement (p>.05). For IRROM improvement, the short-term effect of modified SS with kinesio taping was significantly greater than modified SS (p<.05). However, the effectiveness of kinesio taping on long-term effect was less as compared to 1st day and there was no significant difference between groups on 3rd week to 4th week (P>.05).	A randomized controlled trial.

Salamh et al. (2017)	Patients who underwent arthroscopic shoulder surgery (all participants having undergone subacromial decompression, distal clavicle excision, and RC debridement) within 2 weeks preceding data collection (n=63) Age=51 ±12 years	The following interventions were performed two times per day with a mean of 2 days at home (48–72 h between baseline and follow-up) ***Traditional SS group (n=21)** In the supine position, The patient was abducted to the operative shoulder approximately 45° and flexed the elbow at 90° with neutral rotation of the glenohumeral joint. The patient placed the other hand on the wrist of the involved extremity, and then passively internally rotated without scapular stabilization. ***Modified CBS group (n=21)** In an upright standing position, the patient stabilized the operative scapula against a wall. The opposite hand is placed on the elbow of the involved extremity and assists the operative shoulder into horizontal adduction. In addition to stretching, pendulum exercises were performed. ***Control Group (n=2**1) The patients performed only pendulum exercises twice a day. No stretching was performed. Each stretch was repeated 3 times, sustained 30 seconds, twice a day.	The following interventions were assessed before treatment and 48–72 h follow-up. *Passive HA ROM (PST) in the side-lying position * Passive IRROM at 90° abduction and 90° of elbow flexion *QuickDASH *Pain	There was a statistically significant difference for PST improvement between both the modified CBS group and the traditional SS group (p = 0.01) as well as between the modified CBS group and the control group (p < 0.01), favoring greater improvement in the modified CBS group in both instances at 48–72 h. There were no significant differences acutely with regards to IRROM (p>.05), average pain scores (p>.05) and QuickDASH scores (p>.05) between groups	A single-blinded randomized control trial
Tahran et al. (2020)	Patients with subacromial impingement syndrome and GIRD (n=67, 45 male, 22 female) Age=52.94 ± 11.05 years	The following interventions were performed five times a week for 4 weeks (5 days under physical therapist supervision and 2 days at home). ***Modified SS group (n=22)** They received a standard treatment program with modified SS. Modified SS was performed in a side-lying position; the body was rolled 20° to 30° posteriorly to reduce symptoms of pain, and the humerus was moved into IR using the opposite arm ***Modified CBS Group (n=22**) They received a standard treatment program with modified CBS. Modified CBS was performed in a side-lying position to limit scapular abduction. The forearms were aligned, with the opposite arm on top to limit the ER of the humerus, and the humerus was moved into horizontal adduction using the opposite arm. ***Control Group (n=2**3) Standart treatment program consisting of modalities, ROM, and strength training but no PSSE. Each stretch was repeated 5 times, sustained 30 seconds, once a day for 4 weeks.	The following interventions were assessed before and after 4-week interventions. *Passive HA ROM (PST) * IRROM *ER ROM *TR ROM (IR+ER ROM) *Pain at rest *Pain during activity *CMS score *QuickDASH score	There was a significant improvement in pain, PST, shoulder rotation ROM, function, and disability in all groups after treatment (P<.05). The modified stretching groups were superior to the control group in improving pain with activity, IRROM, function, and disability (P<.05). There was no significant difference between modified stretching groups (p>.05).	A randomized controlled trial.
Yamauchi et al. (2016)	Asymptomatic college baseball players (n=24) with GIRD Modified CBS group age=21.4 ± 1.2, Modified SS group age= 20.3 ± 0.9 There was no information related to sex.	The following interventions were performed once daily after practice or before going to bed for 4 weeks. ***Modified CBS group (n=12)**Modified CBS was performed with the subjects in the side-lying position on the throwing side to stabilize the scapula; the forearms were aligned, with the opposite forearm on top to restrict ER of the stretched shoulder; and the humerus of the throwing side was moved into HA using the opposite arm. ***Modified SS group (n=12**) Modified SS was performed with the subjects in the side-lying position on the throwing side; the trunk was rolled 30° posteriorly on the throwing side to decrease the pressure at the glenohumeral joint; a towel was placed under the subject's humerus to increase the amount of glenohumeral HA; and the humerus of the throwing side was moved into IR using the opposite arm. Each stretch was repeated 3 times, sustained 30 seconds, for 4 weeks.	The following interventions were assessed before and after 4-week interventions. *IRROM *ER ROM *TR ROM (IR + ER ROM) *HA ROM *Muscle stiffness for infraspinatus, teres minor, and posterior deltoid	There was a significant improvement in IRROM and HA ROM in both modified stretching groups (P<.05). After 4-week intervention muscle stiffness of the teres minor significantly decreased in the modified CBS group (P<.05), while muscle stiffness of the infraspinatus significantly decreased in the modified SS group (P<.05).	A randomized controlled trial.

Gharisa et al. (2021)	Asymptomatic and symptomatic overhead athletes (n=42, 22 female, 20 male) having GIRD (IRROM deficiency >10°) Age= 25.9 ± 2.6 years Sports: Baseball, volleyball, tennis, water polo, squash, and swimming	The following interventions were performed 3 times a week for 4 weeks ***Novel SS with Clam Shell Bridging Group (n=20)** In a supine position, a resistance band was placed around the participant's knees, and then he/her opened knees. After, the participant was a bridge as high as possible, with the elbow flexed to 90° and shoulder abducted to 90° . The bridging maneuver shifts the body weight superiorly and stabilized the medial border of the scapula against the thorax without directly compressing or restricting posterior shoulder structures. While maintaining this position, participants were asked to contract their gluteal muscles and perform the stretching by actively internally rotating their shoulder to the end of ROM using the opposite hand. ***Modified SS Group (n=22**) In a side-lying position; the body was rolled 20° to 30° posteriorly to reduce symptoms of pain, and the elbow flexed to 90°, the shoulder elevated to 90. In the side-lying position, on the affected side, with the elbow flexed to 90°, scapula was stabilized with the participant's body weight. Passive IR stretching was performed using the opposite hand. Each stretch repeated 3 times a week with 3 repetitions, sustained 30 seconds, with 30 s rest between repetitions for 4weeks	The following interventions were assessed baseline, immediately after and after 4-week post interventions for IRROM, baseline, and after 4-week post interventions for pain. *IRROM *Pain	There was a significant increase in IRROM from baseline to immediate and week 4, and from immediate to week 4 in both groups (p < .001). There was no significant difference between groups (p>.05) There was a significant reduction in pain intensity over time in the novel SS with Clam Shell Bridging Group p<.05), but not in the modified SS group (p>.05).	A parallel-design 2-arm, assessor-blinded randomized controlled clinical trial.
John et al. (2010)	Asymptomatic male bowlers athletes with GIRD (n=45, age between 16-24 years) There was no information related to mean age.	The following interventions were performed 6 times a week for 3 weeks ***Modified SS and CBS Group (n=15)** -For modified SS, the athlete is in a side-lying position, with the humerus flexed 90° and the elbow flexed 90°. The practitioner was placed one hand on the proximal humerus to assist the body weight in stabilizing the scapula, and placed the other hand on the posterior aspect of the distal ulna. A downward motion at the distal ulna internally rotated the humerus. After IR, the trunk was rotated toward the humerus to enhance the stretch. -For modified CBS, in a supine position, the practitioner was stabilized the scapula with the help of the hip and the shoulder was stretched in the direction of the horizontal adduction. ***Posterior glide mobilization group (n=15)** In the supine position, the athlete's arm flexed to 90° internally rotated, and with elbow flexed. The practitioner used to place padding under the scapula for stabilization. The practitioner placed one hand across the proximal surface of the humerus and the other hand over the athlete's elbow, the humeral head was glided posteriorly by pushing down at the elbow through the long axis of the humerus. ***Combination of modified SS and CBS, as well as posterior glide mobilization group (n=1**5) The combination of the same implementations as mentioned above. Each stretch was repeated 6 times a week with 5 repetitions, sustained 30 seconds, with 30 s rest between repetitions for 3 weeks. Posterior glide mobilization performed 3 times a week for 10 repetitions per session maintaining end position for one minute for 3 weeks	The following interventions were assessed baseline, weekly and at the end of 3-week post interventions for IRROM, baseline and after 3 week past interventions for HA distance *IRROM *HA distance	There was a significant improvement for IRROM and HA distance in all groups at the end of the weeks (p<.05) At the different intervals (1 week, 2 weeks) as well as at the end of 3 weeks interventions, IRROM and HA distance were significantly improved in combination of modified SS and CBS plus posterior glide mobilization group when compared to the modified SS and CBS group and the posterior glide mobilization group (p<.05). There was no significant difference between the modified SS and CBS group and the posterior glide mobilization group for IRROM ROM outcome, whereas for HA distance outcome, modified SS and CBS group significantly greater decreased when compared to the posterior glide mobilization group (p<.05)	A randomized controlled trial

Lo, et al. (2021)	Asymptomatic baseball pitchers with GIRD (n=31) Modified SS group (n=10, 20.5 ± 2.6 1.2years) Kinezio Tape Group (n=11, age=20.4± 1.9 years) Control group (n=10, 20.9 ± 1.5 years)	A single session of treatment was performed. *Modified SS group (n=10) Each participant laid on the dominant shoulder, the shoulder abducted to 90, and elbows flexed to 90. The scapula was stabilized using the participant's body weight to avoid movement of the scapula. Each participant was required to grab the wrist of his or her dominant side with the non-dominant hand and slowly press the wrists in the direction of IR until feeling that the shoulder tissue was being pulled without any pain. Modified SS was repeated five times, each lasting 30 s *Kinesio Tape Group (n=11) Four I-shaped strips of Kinesio tape were used on the posterior deltoid fibers, infraspinatus, and teres minor. Each participant sat down, and taping was applied from the endpoints to the starting points of the relevant muscles to help the muscles relax. No tensile force was applied during the tape application.	The following were assessed immediately before and after a single intervention. *Active IRROM * Active ER ROM * TR ROM (IR+ER ROM) *Active HA ROM *IR, ER, and HA strength *AHD	There were significant changes between the pretest and post-test values concerning the measurement of shoulder IR, ER, HA, and TR ROM in the Kinesio tape group and the modified SS group increased (p<.05), whereas shoulder ER exhibited reduced ROM in these two groups when compared to the control group. ER strength significantly increased followingkKinesio tape application, but significantly decreased after modified SS (p<.05). There was no change in the control group (p>.05) There was no significant change on the sub-acromial space after intervention and among the groups (p>.05).	A randomized controlled trial

AHD: Acromio-humeral distance, CBS: Cross-body stretching, SS: Sleeper stretching, PPST: Prone-passive stretching technique, GIRD: Glenohumeral Internal Rotation Deficit, HA: Horizontal adduction, IR: Internal rotation, ROM: Range of Motion, TR ROM: Total rotational range of motion, PST: Posterior shoulder tightness, JM: Joint mobilization. Values are described as mean ± standard deviation.

Table 3. Risk of Bias Assessment in the Included Studies

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Guney et al. (2015)	1	1	1	1	0	0	1	1	1	1	1	8/10
Hammons et al. (2015)	1	1	1	1	0	0	1	0	0	1	1	6/10
Salamh et al. (2015)	1	1	0	1	0	0	1	0	0	1	1	5/10
Cools et al. (2012)	1	1	0	1	0	0	0	0	0	1	1	4/10
Oyama et al. (2010)	1	0	0	0	0	0	0	1	1	1	1	4/10
Brown et al. (2015)	1	1	1	1	0	0	1	1	0	1	1	8/10
Bailey et al. (2017)	1	1	0	0	0	0	1	1	1	1	1	7/10
Mine et al. (2017)	1	1	1	1	0	0	1	1	1	1	1	8/10
Joung et al. (2019)	1	1	0	1	0	0	0	1	1	1	1	6/10
Rao et al. (2016)	0	1	0	0	0	0	0	1	1	1	1	5/10
Pandya et al. (2018)	1	1	0	0	0	0	0	1	1	1	1	5/10
Salamh et al. (2017)	1	1	1	1	1	0	1	1	1	1	1	9/10
Tahran et al. (2020)	1	1	0	1	0	0	1	1	1	1	1	7/10
Yamauchi et al. (2016)	1	1	0	1	0	0	1	1	1	1	1	7/10
Gharisa et al. (2021)	1	1	1	1	1	0	1	1	1	1	1	9/10
John et al. (2010)	1	1	0	1	0	0	0	1	1	1	1	6/10
Lo et al. (2021)	1	1	0	1	0	0	0	1	1	1	1	6/10

PEDro scale: 1, eligibility criteria 2, random allocation; 3, concealed allocation; 4, similarity at baseline; 5, blinding of participants; 6, blinding of therapists; 7, blinding of assessors; 8, measures of at least one key outcome from at least 85% of participants initially allocated to groups; 9, intention to treat analysis; 10, between-group comparison; 11, point measures and measures of variability. 1: Yes (1 point), 0: No (0 point), maximum score: 10 (criterion 1 is not included in scores)

classified as “high” (≥7/10), “moderate” (5/10, 6/10), or “poor” (≤4/10) considering total scores. The effect size was assessed for data extraction and synthesis as follows; small (0.20 to 0.49), moderate (0.50 to 0.79), and large (0.80 or greater) (33).

RESULTS

Study Selection

The literature search generated 127 relevant papers. Following duplicates and irrelevant articles were excluded through screening in title and abstract, and then full-text assessment. According to the examination of eligibility criteria, 69 articles underwent title and abstract screening. Subsequently, 35 articles underwent full-text review, ultimately producing 17 articles that met the inclusion criteria for the present systematic review (Figure 1).The presence of GIRD or PST was in the inclusion criteria of twelve studies, although GIRD and PST definitions were somewhat different among studies. GIRD was defined as >10° restriction in IRROM at 90° shoulder abduction in the dominant side compared to the non-dominant side, in five studies (16,19,20,24,25,26). Two studies defined GIRD as more than 15° decrease (23,27), one study as more than or equal to 18° (28) decrease, and the other one as more than 20° decrease (12) in IRROM. Apart from these studies, one study defined GIRD as more than 10% of the total shoulder ROM [sum of the IR and external rotation (ER)ROM] (29).

***Study Designs*:** Fourteen RCTs used parallel designs, whereas one RCT used a cross-over design (16). Oyama et al. conducted a prospective cohort study (22). Only one study conducted by Bailey et al. was a controlled laboratory study (23).

Participants: PSSEs were generally performed in overhead athletes performing baseball, volleyball, softball, swimming, badminton, tennis, water polo, softball, basketball, and squash sports (12,16,19,20,24,25,26). On the other hand, PSSE was also performed in the non-athletic population with shoulder pain syndrome (18,27). Sample sizes ranged between 15-65. The total sam-

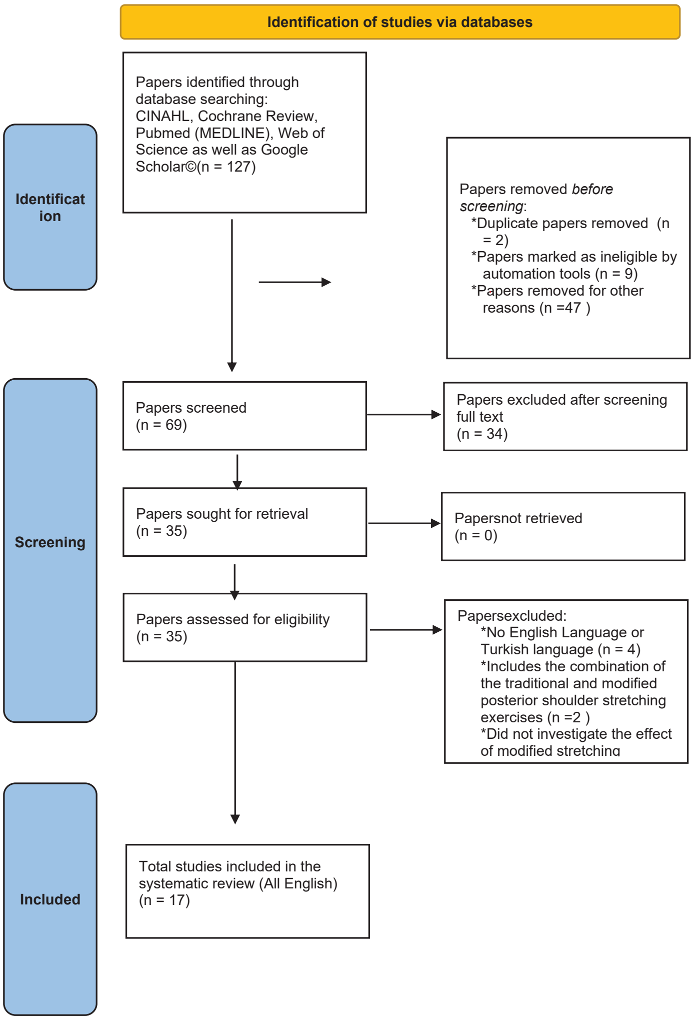

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Diagram of the Literature Search Used

ple size for the present review was 758 subjects (390 male and 263 female, no given information related to sex in 105 subjects (21,30).

Interventions: Isolated modified cross-body stretch was used in eight studies (17,18, 19,20,21,22,25,28), whilst isolated modified sleeper stretch was used in eight studies (16,21,22,24,25,27,29,30). One study used the passive stretching technique in the prone position, where the examiner stretched the participants' shoulder into IR at 90° abduction passively whilst stabilizing the scapula (26). The combination of the modified cross-body and modified sleeper stretch was examined in three studies (12,23,31). Other interventions utilized in the included studies were traditional cross-body stretch (16,17,19,20,21,26), traditional sleeper stretch (18,28) kinesio taping (29,30) joint mobilization (12,31), prone passive IR stretching with manual scapular stabilization (26), instrumented manual therapy with combination of modified modified cross-body and modified sleeper stretch (23), sleeper stretch with clamshell bridging (24). Control groups without any stretching intervention were used in three studies (18,27,29).

Outcome Measures: All studies included in the present review measured either or both active/ passive IRROM at 90° abduction (12,15-31), and active/passive HAROM (16,17,18,20,22,24,25,27,28,31).

Effectiveness of Modified Cross-body Stretch on PST and GIRD

In the literature, the effects of modified cross-body stretch and its variations were investigated. In studies investigating the effects of modified cross-body stretch and its variations (12,17,18,19,20,21,22,25,27,28) single-session (immediate effect) modified active static cross-body stretch was found to have similar positive effects with active static traditional cross-body stretch (18) and passive static modified sleeper stretch (22) on PST and GIRD. Salamh et al. demonstrated that two sessions of passive static modified cross-body stretch, performed in standing position with scapular stabilization improved PST in 48–72 hours compared to passive static traditional sleeper stretch and no-stretch in postoperative population, but GIRD improvements were similar among groups (18). In asymptomatic non-athletic women, one week of passive static modified cross-body stretch program performed in supine position with manual scapular stabilization improved PST and GIRD compared to the passive static traditional cross-body stretch and sleeper stretch (28). In short term (4-weeks stretching period), both passive static and active static modified cross-body stretch were found to be more effective to improve PST (20) and GIRD (21) when compared to passive static traditional cross-body stretch. 4 weeks of Wilk's Modified active static cross-body stretch was found to be beneficial in improving PST and GIRD similar to Wilk's modified sleeper stretch.

Effectiveness of Modified Sleeper Stretch on PST and GIRD

The effectiveness of isolated modified sleeper stretch was performed in eight studies (4,21,22,24,25,27,29,30). After a single session intervention, Oyama et al. (22) demonstrated no difference between passive static modified sleeper stretch (at 45° and at 90° shoulder flexion) and passive static modified cross-body stretch on PST and GIRD in asymptomatic male overhead athletes. Furthermore, Mine et al. (4) concluded no difference between active static modified sleeper stretch and active static traditional cross-body stretch in terms of PST and IRROM improvements in young healthy individuals. Lo et al. (29) showed no difference between the modified sleeper stretch and kinesio taping on GIRD and PST in asymptomatic overhead athletes having GIRD. Pandya et al. (30) concluded that kinesio taping plus passive static modified sleeper stretch provided more improvement in GIRD when compared to only passive static modified sleeper stretch in a short term (1st and 2nd week) in asymptomatic overhead throwers. They found no difference during the 3rd and 4th weeks between groups. After 4 weeks of stretching (21,24,25,27), Rao et al. (21) found significant improvement in GIRD with passive static modified cross-body stretch when compared to passive static modified sleeper stretch and traditional cross-body stretch in asymptomatic overhead athletes. Tahran et al. (27) found no significant difference in PST and GIRD improvements of active static modified cross-body stretch and modified sleeper stretch groups in patients with SPS after 4 weeks of intervention. Yamauchi et al. (25) reported no significant difference in GIRD and PST recovery between active static modified sleeper and cross-body stretch in asymptomatic overhead throwers. Gharisa et al. (24) investigated the effects of novel sleeper stretch with clamshell bridging and the modified sleeper stretch on GIRD in both asymptomatic and symptomatic overhead athletes. They stated no significant difference between stretching techniques in terms of GIRD improvement.

Effectiveness of Combined Modified Stretch Interventions on PST and GIRD

The combination of the modified cross-body and sleeper stretch on GIRD and PST was investigated in three studies. A combination of passive static modified cross-body stretch and passive static sleeper stretch (12,31) was as effective as joint mobilization in improving GIRD in short term. PST improved more after a combination of passive static modified sleeper and cross-body stretch when compared to posterior glide mobilization (31). The addition of the instrumented manual therapy to the active static modified sleeper and cross-body stretch combination for a single session was found to be more effective

Table 4. Comparison of Within-Group Effect Sizes

Study	Outcome measure	Intervention	Effect size [95%CI]
Guney et al. (2015)	IR	Modified CBS group	4.27 [2.58 to 5.96]*
		Traditional SS group	1.44 [-0.40 to 3.28]
		Traditional CBS group	1.95 [0.54 to 3.37]*
	HA	Modified CBS group	1.37 [-0.71 to 3.44]
		Traditional SS group	1.09 [-0.35 to 2.52]
		Traditional CBS group	1.04 [-0.50 to 2.58]
Hammons et al. (2015)	IR	Traditional CBS group	0.96 [-2.00 to 3.92]
		Modified PPST group	1.04 [-3.27 to 5.34]
Salamh et al. (2015)	IR	Modified CBS group	0.93 [-2.07 to 3.93]
		Traditional CBS group	0.48 [-1.64 to 2.60]
	HA	Modified CBS group	1.33 [-2.66 to 5.32]
		Traditional CBS group	0.00 [-3.23 to 3.23]
Cools et al. (2012)	IR	Symptomatic, modified CBS + SS group	1.21 [-1.82 to 4.23]
		Symptomatic, Joint Mobilization group	2.38 [0.48 to 4.27]*
		Asymptomatic, modified CBS + SS group	2.81 [0.20 to 5.42]*
		Asymptomatic, Joint Mobilization group	1.75 [-2.21 to 5.70]
Oyama et al. (2010)	IR	Modified CBS	0.42 [-3.31 to 4.16]
		Modified SS at 90°	0.41 [-2.97 to 3.80]
		Modified SS at 45°	0.41 [-3.56 to 4.39]
	HA	Modified CBS	1.02 [-0.46 to 2.50]
		Modified SS at 90°	0.63 [-1.13 to 2.40]
		Modified SS at 45°	0.56 [-1.29 to 2.41]
Brown et al. (2015)	IR	Modified CBS	0.56 [-2.51 to 3.64]
		Traditional CBS	0,24 [-2,84 to 3,32]
	HA	Modified CBS	-0.37 [-3.82 to 3.08]
		Traditional CBS	-0.29 [-3.56 to 2.97]
Bailey et al. (2017)	IR	Modified SS and CBS groups	0.76 [-1.62 to 3.15]
		Instrumented manual therapy plus modified SS and CBS group	1.15 [-1.51 to 3.81]
	HA	Modified SS and CBS groups	0.69 [-1.83 to 3.22]
		Instrumented manual therapy plus modified SS and CBS group	1.58 [-0.58 to 3.74]
Mine et al. (2017)	IR	Modified SS group	1.23 [-1.11 to 3.57]
		Traditional CBS group	0.89 [-1.76 to 3.54]
	HA	Modified SS group	0.74 [-2.64 to 4.11]
		Tarditional CBS group	0.67 [-2.30 to 3.64]
Joung et al. (2019)	IR	Modified CBS group	0.53 [-2.51 to 3.57]
		Traditional CBS group	0.31 [-2.59 to 3.20]
	HA	Modified CBS group	7.70 [6.60 to 8.80]*
		Traditional CBS group	17.46 [14.97 to 19.94]*
Rao et al. (2016)		The data not available*	
Pandya et al. (2018)	IR	Modified SS group	8.6 [7.59 to 9.61]*
		Modified SS with kinesio taping group	10.98 [10.03 to 11.94]*

Salamh et al. (2017)	**IR**	**Modified CBS group**	0.51 [-3.04 to 4.07]
		Traditional SS group	0.26 [-4.31 to 4.84]
		Control Group	0.0 [-4.0 to 4.0]
	HA	**Modified CBS group**	1.24 [-2.19 to 4.7]
		Traditional SS group	0.39 [-3.50 to 4.27]
		Control Group	0.08 [-3.61 to 3.77]
Tahran et al. (2020)	**IR**	**Modified CBS group**	2.26 [-0.57 to 5.08]
		Modified SS group	1.67 [-2.24 to 5.58]
		Control Group	0.68 [-3.06 to 4.42]
	HA	**Modified CBS group**	2.58 [0.06 to 5.09]*
		Modified SS group	1.57 [-2.60 to 5.75]
		Control Group	0.80 [-2.60 to 4.21]
Yamauchi et al. (2016)	**IR**	**Modified CBS group**	1.28 [-1.22 to 3.78]
		Modified SS group	1.39 [-0.91 to 3.69]
	HA	**Modified CBS group**	0.52 [-3.33 to 4.37]
		Modified SS group	0.39 [-3.67 to 4.46]
Gharisa et al. (2021)	**IR**	**Novel SS with Clam Shell Bridging Group**	2.0 [-1.53 to 5.53]
		Modified SS Group	1.25 [-3.11 to 5.62]
John et al. (2010)		**The date not available***	
Lo et al. (2021)	**IR**	**Modified SS group**	1.42 [-2.76 to 5.59]
		Kinesio Tape Group	1.61 [-0.74 to 3.96]
		Control group	-4.05 [-9.11 to 1.01]
	HA	**Modified SS group**	11.40 [7.09 to 15.70]*
		Kinesio Tape Group	1.19 [-2.92 to 5.29]
		Control group	0.15 [-7.25 to 7.54]

CBS: Cross-body stretching, SS: Sleeper stretching, HA: Horizontal adduction, IR: Internal rotation, PST: Posterior shoulder tightness, JM: Joint mobilisation. CI: Confidence interval.

* The necessary data were lacking in two studies to calculate the effect size. We contacted to corresponding authors by e-mail. However, we could not reach the authors. Because of this reason, the data is not available

in improving GIRD than using the active static modified sleeper stretch and cross-body stretch combination alone (23).

Effectiveness of Modified Prone Passive Stretching Technique on GIRD

In addition to the two most popular arm positions used in modified PSSE in the literature, a different modified stretching position is defined in Hammer et al. (26). The authors compared the effects of modified passive stretching in the prone position with manual scapular stabilization and passive static traditional cross-body stretch on asymptomatic GIRD in young athletes. The authors found similar benefits in terms of the GIRD improvement.

DISCUSSION

To the best of the authors' knowledge, the present systematic review is the first studyon the effectiveness of modified posterior shoulder stretching exercises for PST and GIRD. This systematic literature review demonstrates that there is high evidence related to the positive effects of both modified cross-body and sleeper stretch for GIRD and PST in acute or short-term durations. According to research results, only three studies with different treatment durations and different populations concluded that modified cross-body stretch was more effective than modified sleeper stretch to improve PST (18,20) and GIRD (21). However, the results of the other studies indicated that the effects of the two modified stretching applications were similar (16,22,25,27). In three research, the effects of a single-session stretching intervention on posterior shoulder mobility were evaluated inoverhead athletes as well as postoperative populations. They found no difference between modified and traditional PSSEs (16,17,18). However, the studies comparing the short-term effects of modified and traditional PSSEs on GIRD and PST concluded that modified PSSEs were more effective than traditional PSSEs in terms of GIRD and PST improvement (19,20,21,28).

In the literature, the two most popular arm positions used in modified PSSE (modified cross-body and modified sleeper stretch) have been defined by Wilk et al. (14). and eight studies used these modified PSSEs (16,17,21,23,25,27,30,31). Different modified PSSE positions have been used in three studies (15,24,26). Johansen et al. (15) and Hammons et al. (26) used prone passive stretching with manual stabilization of the scapula. Modified prone passive stretching with manual scapular stabilization and passive static traditional cross-body stretch on GIRD demonstrated similar short-term benefits in terms of the GIRD improvement in asymptomatic young athletes with GIRD (26). Gharise et al. investigated the effect of novel sleeper stretching with clamshell bridging and only modified sleeper stretching on GIRD in overhead athletes and found no difference between interventions for GIRD improvement (24).

Source of Bias and Limitations of Included Studies

Studies without allocation concealment or adequate blinding for participants, therapists as well as assessors showed larger effects of exercises. This suggests Type 1 error (12,20,23,29,30). Furthermore, the four included studies did not perform intention-to-treat analysis even they reported drop-outs (12,17,19,26). These methodological flaws might have resulted in the overestimation of the intervention effects. Therefore, positive findings should be interpreted critically.

Within-group effect sizes were generally found as large in most studies (12,16,18,19,20,23,24,26, 27,28,29,30); however, roughly less then half 95% CIs around effect sizes excluded zero meaning no effect (12,20,27,28,29,30) (Table 4).

In one low-quality prospective cohort study that was conducted by Oyama et al., the authors investigated three different modified PSSEs performing one treatment session in a standing position. IRROM was improved statistically significant in all modified stretch groups (modified cross-body stretch, modified sleeper stretch at 45° or 90°), whereas the effect size was small in all groups. Without allocation concealment, similarity at baseline data, as well as inadequate blinding procedures may probably cause this result (22).

In one high-quality study, the authors investigated the modified cross body and sleeper stretch in asymptomatic college baseball players with GIRD. The participants performed stretching exercises as a home program daily. IRROM and PST were improved in both modified PSSEs groups. However, the effect size was small for the modified sleeper stretch group and moderate for the modified cross-body stretch group in terms of the IRROM improvements. The modified PSSEs were given as a home exercise program in this study and this may affect the results (25).

The necessary data were lacking in two studies to calculate the effect size. We contacted corresponding authors by e-mail. However, we could not reach the authors. Because of this reason, the data is not available (21,31).

Most research was conducted on asymptomatic young overhead athletes or non-overhead population throughout the included studies (17,19,22,23,24,25,28). Two research were conducted with the symptomatic non-overhead population (18,27), whereas the other two research were conducted with the symptomatic overhead athletes (12,24). Due to the heterogeneity of studies, findings cannot be generalized to symptomatic or older people. Furthermore, the six studies investigated the immediate effect of modified stretching exercises(16,17,19,22,23,29), whereas the other studies investigated the short-term effect of modified stretching exercises (12,18,20,21,24,25,26,27,28,30,31). The included studies did not conduct long-term follow-up except for Cools et al.'s study (12) included six-week follow-up period.

Limitations of This Systematic Review

The present systematic review has several limitations. The included studies were potentially limited by the English-language, since language limitation may lead to bias. Furthermore, heterogeneity of included studies such as stretching positions, duration of stretching, repetitions as well as total treatment duration, study populations prevented us from objectively summarising the present review findings.

Clinical Recommendations for Future Research

Future research should focus on other specific shoulder diseasessuch as subacromial pain syndrome, SLAP lesions or other glenohumeralinstability. It is unclear whether the traditional or modified techniques are superior to each other as few studies compare traditional and modified PSSE. Future studies with larger sample sizes to provide better statistical precision and conducting longer treatment durations with follow-ups to determine how long the treatment effect lasts are needed.

This systematic literature review describes the effectiveness of modified PSSEs on PST and GIRD in different populations. There is high evidence to support both the immediate and short-term positive effects of modified cross-body and sleeper stretch on PST and GIRD among symptomatic and asymptomatic subjects. It was found that modified cross-body and modified sleeper stretch have better effects compared to no intervention (18,27,29) or traditional PSSEs (19,20,21,28) in both immediate and short-term interventions. Furthermore, high (18) and moderate (20,21) quality studies with different treatment durations and different populations found that modified cross-body stretch was more effective than modified sleeper stretch to improve PST and IRROM, whereas the other studies, ranging from high to poor quality, reported that the effects of the two methods were similar in acute or short-term durations (12-17,19,23,24,25,26,27,28,29,30,31). Studies demonstrated no difference between the results of different modified stretching types (sleeper and cross-body) in terms of GIRD and PST gains. There is a need for high-quality studies examining the long-term effectiveness of modified PSSEs on PST and GIRD in symptomatic people.

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