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Research Article

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Effects of Two Scapular Stabilization Rehabilitative Approaches on Passive Proprioception, Range of Motion, and Function in Overhead Athletes with Scapular Dyskinesis: A Randomized Controlled Trial

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Abstract

Purpose: Scapular dyskinesis is common in overhead athletes and is linked to impaired joint position sense, restricted mobility and shoulder disability. This trial compared local scapular-focused exercise (SFE) with global kinetic-chain exercise (KCE) for passive proprioception, passive range of motion (ROM) and self-reported function.

Methods: Sixty overhead athletes with scapular dyskinesis were randomized to SFE, KCE or non-exercise control (n = 20 each). Exercise groups trained three times weekly for six weeks. Passive repositioning error, passive ROM (flexion, abduction, external and internal rotation) and the Shoulder Pain and Disability Index (SPADI) were measured before and after the intervention by a blinded assessor. Post-test values were compared by ANCOVA adjusted for pretest, with Bonferroni-adjusted comparisons.

Results: Groups were comparable at baseline. Group effects were significant for repositioning error ($F_{2,56} = 18.47$, $P < .001$, $\eta p^2 = .398$) and SPADI ($F_{2,56} = 22.31$, $P < .001$, $\eta p^2 = .443$). KCE produced lower error and SPADI than SFE ($P = .021$, $P = .034$) and control (both $P < .001$); SFE outperformed control ($P = .006$, $P = .002$). Both exercise groups improved ROM in all movements, with no clear SFE–KCE difference for most.

Conclusion: Six weeks of either program improved passive proprioception, ROM and function versus control. Kinetic-chain training added short-term benefit for proprioception and function; ROM gains were comparable.

Trial registration: IRCT20241202063918N1, Iranian Registry of Clinical Trials,

Keywords

Scapular dyskinesis; Shoulder rehabilitation; Proprioception; Range of motion; Overhead athletes; Kinetic chain

Introduction

Overhead sports such as throwing, serving, spiking and swimming place repetitive, high-velocity demands on the shoulder complex. Over time these demands can alter the position and motion of the scapula, a condition termed scapular dyskinesis, defined as a visible alteration in scapular position or motion during arm movement. A systematic review reported dyskinesis in roughly one-third to more than half of competitive overhead athletes, with a higher prevalence in overhead than in non-overhead athletes [1]. Dyskinesis is not merely a visual finding. A meta-analysis of prospective studies concluded that abnormal scapular movement increased the risk of future shoulder pain by as much as 43% in athletes who were initially asymptomatic [2]. Dyskinesis is therefore regarded as a clinically relevant risk marker and a legitimate target for rehabilitation and injury-prevention programs.

The scapula contributes to shoulder function in several ways. It provides a stable, mobile base for glenohumeral rotation, positions the glenoid beneath the humeral head during elevation, elevates the acromion to preserve subacromial clearance, and acts as a link that transfers energy from the trunk and legs to the arm during overhead activity [3, 4]. When scapular upward rotation, posterior tilt or external rotation is reduced, or when muscle activation is imbalanced, the mechanical demand on the glenohumeral joint and subacromial tissues increases [5, 6]. Imbalance between the upper trapezius and the serratus anterior and lower trapezius is a frequently described feature of this pattern. These mechanisms are the basis of the clinical classification and examination framework proposed in the 2013 Scapular Summit consensus statement, which recommends treating dyskinesis as an impairment to be addressed within the whole kinetic chain rather than as a stand-alone diagnosis [7].

A second consequence of dyskinesis that has received less attention is its possible effect on sensorimotor control. Proprioception comprises the sense of joint position, movement and force, and arises from mechanoreceptors in the joint capsule, ligaments, muscle and skin. It contributes to dynamic joint stability and to feed-forward and feedback control of movement [8, 9]. In the shoulder, which depends heavily on dynamic rather than osseous stability, proprioceptive acuity is considered particularly important for athletes whose sport requires precise limb positioning at high speed [10]. Proprioception is commonly quantified as the error made when reproducing or identifying a target joint angle. Tests can be performed actively, in which the participant moves the limb and muscle activity contributes to the afferent signal, or passively, in which the examiner moves the limb and the contribution of voluntary muscle contraction is minimized. Passive testing is therefore often preferred when the aim is to isolate the contribution of joint and capsuloligamentous afferents [11, 12].

Range of motion (ROM) is a third outcome of interest. Repetitive overhead loading is associated with adaptive changes in the posterior capsule and posterior shoulder musculature, resulting in glenohumeral internal rotation deficit and altered total rotational motion. These changes have been related to shoulder

injury in throwing athletes [13, 14]. Because scapular position influences the available glenohumeral and humerothoracic motion, restoring ROM is a common rehabilitation goal. Finally, patient-reported outcomes complement laboratory measures by capturing the pain and disability that matter to the athlete. The Shoulder Pain and Disability Index (SPADI) is a region-specific, 13-item questionnaire that assesses both pain and disability [15].

Two broad exercise philosophies are used to treat dyskinesis. Scapular-focused exercise (SFE) targets the scapulothoracic muscles directly. Programs aim to restore balance between the serratus anterior and lower trapezius and the upper trapezius, and progress from motor control to loaded strengthening. Electromyographic and kinematic studies have identified exercises that preferentially activate the lower trapezius and serratus anterior while limiting upper trapezius activity [16, 17], and biofeedback and exercise-based protocols have been shown to alter scapular muscle activation and kinematics [18, 19]. Evidence-based reviews support the use of scapular and rotator cuff exercise in the rehabilitation of shoulder impingement-related pain [20].

Kinetic-chain exercise (KCE) is grounded in the principle that the shoulder functions as one link in a sequence that transfers force from the legs and pelvis, through the trunk and scapula, to the hand. Within this framework, deficits in hip, trunk or scapular control can alter the loads placed on the glenohumeral joint, so rehabilitation should integrate the whole chain rather than isolate the scapula [21, 22]. Descriptions of the throwing shoulder and of kinetic-chain rehabilitation propose that whole-body, sequential and closed-chain activities improve force transfer, reduce compensatory loading of the shoulder and may enhance sensorimotor integration [23–25]. Much of this literature is conceptual or biomechanical, and the relative merit of a kinetic-chain program compared with a scapula-specific program has seldom been tested in the same cohort of athletes.

Direct comparative evidence is therefore limited. Previous work has tended to assess a single approach, to rely on active joint position sense or generic upper-extremity disability scales, or to examine muscle activation and kinematics rather than the outcomes athletes and clinicians use to judge recovery. To our knowledge, few randomized trials have compared a scapular-focused with a kinetic-chain program on passive proprioception, passive ROM and shoulder-specific function within one cohort of overhead athletes with confirmed dyskinesis. This gap matters clinically, because practitioners must choose how to allocate limited rehabilitation time between local scapular retraining and global kinetic-chain integration.

The purpose of this randomized controlled trial was to compare the effects of a 6-week SFE program and a 6-week KCE program with a non-exercise control condition on passive shoulder proprioception, passive ROM (flexion, abduction, external rotation and internal rotation) and self-reported shoulder function (SPADI) in overhead athletes with scapular dyskinesis. We hypothesized that both programs would improve all outcomes relative to control, and that the two programs would differ in the size of

their effects because they target different levels of the movement system. The direction of any between-program difference was not specified in advance.

Methods

Study design and reporting

This study was a three-arm, parallel-group randomized controlled trial with a pretest–posttest design, conducted in a university human-movement and biomechanics laboratory. Eligible athletes were allocated in a 1:1:1 ratio to scapular-focused exercise (SFE), kinetic-chain exercise (KCE) or a non-exercise control group (CON). The trial is reported in accordance with the CONSORT statement for randomized trials, and the participant flow is shown in Fig. 1.

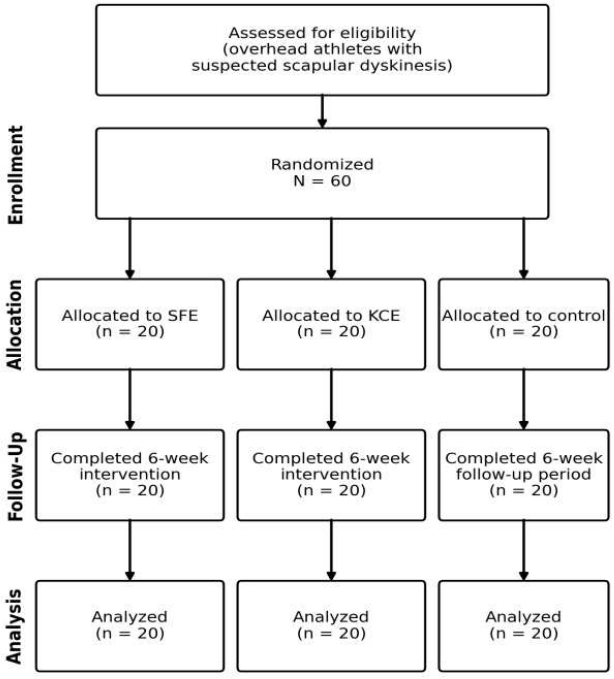


Fig. 1 Participant flow through recruitment, randomization and analysis. SFE scapular-focused exercise group; KCE kinetic-chain exercise group

Participants

Participants were recruited from local sports clubs. They were overhead athletes aged 18–30 years with at least three years of regular participation in an overhead sport (for example volleyball, handball, tennis, baseball/softball or swimming) who had scapular dyskinesis of the dominant, sport-specific overhead limb. Dyskinesis was identified by a licensed physiotherapist, blinded to later group allocation, who combined visual observation of abnormal prominence of the scapular bony landmarks (inferior angle, medial border or superior angle) with a positive Kibler lateral scapular slide test (LSST) (Fig. 2d). The dyskinesis pattern was classified according to the Kibler system as Type I (inferior-angle

prominence), Type II (medial-border prominence/winging) or Type III (excessive early elevation and superior rotation) [7].

Inclusion criteria were age 18–30 years, a minimum of three years of regular overhead-sport participation, a positive LSST and shoulder pain intensity of 3–7 on a 10-point visual analog scale (VAS). Exclusion criteria were body mass index outside 18–25 kg/m²; a history of shoulder trauma, fracture or dislocation; upper-limb surgery within the previous two years; structural spinal deformity (for example scoliosis or hyperkyphosis); and any neurological or systemic musculoskeletal condition affecting movement.

Sample size

A priori sample size was estimated with G*Power *(version 3.1.7) using α = .05, power (1−β) = .95 and an effect size of 0.40, which indicated a minimum of 20 participants per group. All 60 athletes (20 per group) completed the study and were included in the final analysis.*

Ethics approval, consent and trial registration

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the authors' institutional Ethics Committee (approval no. IR.KHU.REC.1404.066), and the protocol was prospectively registered in the Iranian Registry of Clinical Trials (IRCT20241202063918N1). Before participation, the objectives and procedures were explained to every athlete, and written informed consent was obtained. Participants were assured of confidentiality and of their right to withdraw at any stage without penalty.

Randomization and blinding

After baseline (pretest) assessment and confirmation of eligibility, participants were allocated to groups using a computer-generated random sequence prepared by an investigator who was not involved in testing or in delivering the interventions. Because of the nature of exercise interventions, blinding of participants and of the exercise instructor was not feasible. The outcome assessor and the statistician who performed the analysis were blinded to group allocation.

Outcome measures

Three outcome domains were assessed: passive shoulder proprioception, passive shoulder ROM and shoulder-specific pain and disability. All outcomes were measured on the dominant, sport-specific overhead limb at baseline and again 48–72 hours after the final training session, under standardized laboratory conditions and by the same assessor, who was blinded to group allocation (Fig. 2). Participants were instructed to avoid strenuous upper-limb exercise on the day of testing. The SPADI was completed first, followed by ROM and then proprioception testing. Demographic and anthropometric data (age, height, body mass, years of overhead-sport experience) were recorded at baseline.

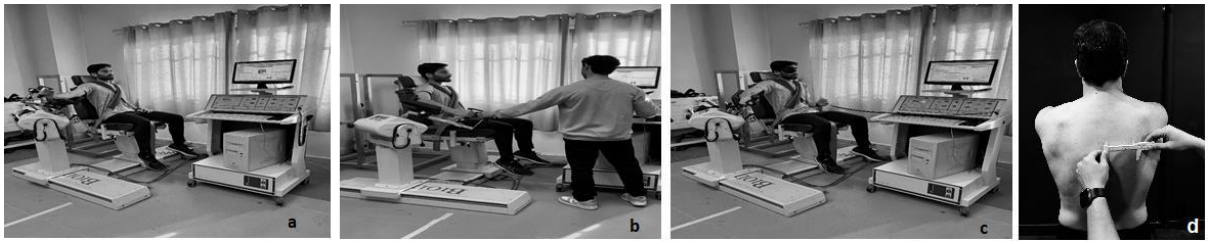


Fig. 2 Outcome assessment setup. a–c Passive shoulder proprioception testing on an isokinetic dynamometer, with the examiner passively guiding the limb toward the target angle; d lateral scapular slide test (LSST) used to confirm scapular dyskinesis

Screening: scapular dyskinesis and the lateral scapular slide test

Scapular dyskinesis was confirmed during screening by a licensed physiotherapist using visual observation of the scapula during active arm elevation and lowering, supplemented by the Kibler lateral scapular slide test (LSST) [3, 7]. In the LSST, the distance from the inferior angle of the scapula to the nearest spinous process of the thoracic spine was measured bilaterally with a tape measure in three standardized positions: arms relaxed at the sides; hands on the hips with isometric contraction of the shoulder girdle muscles; and arms at approximately 90° of abduction with maximal internal rotation. A side-to-side difference of 1.5 cm or more in at least one position was considered positive. Dyskinesis type was recorded using the Kibler classification (Type I, II or III). Pain intensity at screening was recorded on a 10-point visual analog scale (VAS), and only athletes scoring 3–7 were included.

Passive shoulder proprioception (joint position sense)

Passive joint position sense (JPS) was measured as the passive repositioning error with an isokinetic dynamometer Biodex Isokinetic 3 which provided a controlled passive movement and an accurate angular read-out. The participant was seated upright with the trunk, pelvis and scapula stabilized by straps to limit compensatory movement The tested arm was positioned in the scapular plane with 45° of shoulder abduction, 30° of horizontal flexion and 90° of elbow flexion, with the forearm supported by the dynamometer attachment. The axis of rotation of the dynamometer was aligned with the long axis of the humerus Dynamometer calibration was performed before each testing session according to the manufacturer's instructions.

To reduce visual cues, participants kept their eyes closed during all trials; no additional sensory-occlusion device was used. From the neutral starting position, the examiner passively moved the arm into internal or external rotation at a slow, controlled velocity toward a target angle of 30° from neutral. Participants were instructed to say "stop" when they perceived that the arm had reached the target angle. The angle at that moment was recorded, and absolute angular error (°), defined as the absolute difference between the target angle (30°) and the angle at which the participant indicated arrival, was used as the measure of proprioceptive acuity. Each direction was tested in three trials, with a brief rest and return to neutral between trials. The mean of the three trials was calculated for each direction, and internal- and external-rotation errors were averaged to obtain a single repositioning-error score. Participants

completed practice trials before data collection. Lower values indicate better proprioceptive acuity [11, 12].

Passive range of motion

Passive ROM of shoulder flexion, abduction, external rotation and internal rotation was measured with a standard universal goniometer, with the participant supine on a firm examination table and the scapula manually stabilized by the examiner to limit scapular compensation [13, 14]. For flexion and abduction, the fulcrum was placed over the acromion process, the stationary arm was aligned with the midaxillary line of the trunk, and the moving arm was aligned with the lateral epicondyle of the humerus. For external and internal rotation, the shoulder was positioned in 90° of abduction with the elbow flexed to 90° and the forearm perpendicular to the floor; the fulcrum was placed over the olecranon process, the stationary arm was aligned vertically, and the moving arm followed the ulna toward the ulnar styloid process. The examiner moved the limb slowly to the end of the available range, defined by a firm end-feel, the onset of scapular movement or the athlete's report of stretch or pain, and the angle was read from the goniometer. Two measurements were taken for each movement, and their mean (in degrees) was used for analysis.

Shoulder pain and disability (SPADI)

Shoulder-specific pain and disability were assessed with the Shoulder Pain and Disability Index (SPADI), a 13-item self-administered, region-specific questionnaire [15]. It contains a 5-item pain subscale and an 8-item disability subscale. Each item is scored from 0 (no pain/no difficulty) to 10 (worst pain imaginable/so difficult that help is required) for the previous week. Each subscale is converted to a percentage (0–100), and the total score is the mean of the two subscale percentages, with higher scores indicating greater pain and disability. The total SPADI score, expressed as a percentage, was analyzed. The manuscript should identify the language version actually administered and cite its validation study before submission.

Interventions

Both exercise programs were delivered over six weeks, with three non-consecutive sessions per week of about 45 minutes, under the direct supervision of a licensed physiotherapist. The control group continued habitual training and sport participation without a structured corrective exercise program during the study period. Attendance, adherence, adverse events and the continuation of sport-specific training should be reported from the study records; no counts are supplied in the current manuscript.

Scapular-focused exercise (SFE)

The SFE program comprised neuromuscular re-education and progressive strengthening of the scapular stabilizing muscles (serratus anterior and lower trapezius). It included wall slides, low rows, prone horizontal abduction and scapular retraction/protraction drills, with resistance progressing from 60% to 80% of one-repetition maximum (1RM) [16, 17]. Neuromuscular drills emphasized motor control

without shrugging, and an inferior glide exercise was included to correct inferior scapular winging and elevation dominance. The protocol and its progression are given in Table 1 and Fig. 3.

Table 1 Scapular-focused exercise (SFE) protocol and progression

Week	Phase	Exercise	Sets × reps	Intensity
1–2	Neuromuscular	Towel slide / scapular clock — scapular retraction/depression and multidirectional patterns without shrugging	3 × 10	Motor control, no external load
1–2	Strengthening	Push-up plus / full can / horizontal rowing	3 × 10	60% 1RM
3–4	Neuromuscular	PNF scapular / towel slide — therapist-resisted diagonal patterns	3 × 12	Increased motor accuracy
3–4	Strengthening	Scapular punch / diagonal D1 / side-lying external rotation	3 × 12	60–70% 1RM
5–6	Neuromuscular	Scapular clock / towel slide, advanced multidirectional control at higher volume	3 × 15	Advanced motor control
5–6	Strengthening	Diagonal D1 / push-up plus / prone horizontal abduction with external rotation	3 × 15	70–80% 1RM

SFE scapular-focused exercise; 1RM one-repetition maximum; PNF proprioceptive neuromuscular facilitation



Fig. 3 Representative exercises from the scapular-focused exercise (SFE) protocol, illustrating the progression of neuromuscular control and strengthening drills described in Table 1

Kinetic-chain exercise (KCE)

The KCE program emphasized force transfer from the lower extremities through the trunk to the shoulder girdle. It used closed-chain and diagonal-pattern exercises (for example kinetic-chain rows, sternal lifts, internal/external diagonal rotation patterns and step-and-reach drills) that progressively integrated lower-limb, trunk and scapular activation [21, 23, 24]. Each exercise was performed at 4×10, 4×12 and 5×10 repetitions across the three weekly sessions (Table 2, Fig. 4). The KCE program also included a wall-wash drill intended to target proprioception.

Table 2 Kinetic-chain exercise (KCE) protocol and progression

Exercise	Brief description	Sets × reps (session 1/2/3)
Lateral stride punch	Lateral step with weight shift while punching the opposite arm forward, transferring force from the lower limb through the trunk to the shoulder	4×10 / 4×12 / 5×10
Fencing / shoulder flexion with anterior step-up	Forward step paired with shoulder flexion of the opposite arm (fencing-lunge posture)	4×10 / 4×12 / 5×10

Exercise	Brief description	Sets × reps (session 1/2/3)
Power position / step back	Controlled backward step from an athletic power position	4×10 / 4×12 / 5×10
Shoulder punch	Forward arm punch with visible terminal scapular protraction and no shrug	4×10 / 4×12 / 5×10
Short-lever lawnmower	Half-bent posture, short-lever pull-and-rotate motion coordinated with hip/trunk rotation	4×10 / 4×12 / 5×10
External/internal diagonal rotation	Diagonal shoulder rotation patterns (D1/D2) with trunk involvement and weight shift	4×10 / 4×12 / 5×10
Sternal lift	Lift the sternum up/forward with gentle thoracic extension, avoiding excess lumbar lordosis	4×10 / 4×12 / 5×10
Kinetic-chain row	Standing row initiated by weight transfer from the legs, scapulae retracted at end range	4×10 / 4×12 / 5×10
Low row	Lower-level rowing motion with a stable trunk, emphasizing pelvic and scapular control	4×10 / 4×12 / 5×10
Wall wash	Palm on wall, slow controlled circular/directional hand movements targeting proprioception	4×10 / 4×12 / 5×10

KCE kinetic-chain exercise. Exercises were rotated across a 6-exercise weekly schedule over the 6-week program; each exercise was trained at 4×10, 4×12 and 5×10 across its three weekly sessions



Fig. 4 Representative exercises from the kinetic-chain exercise (KCE) protocol, illustrating progressive whole-body force-transfer drills described in Table 2

Statistical analysis

Data were analyzed with IBM SPSS Statistics (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation (SD). Normality was assessed with the Kolmogorov–Smirnov test, and homogeneity of variance with Levene's test. Baseline differences among groups in demographic and outcome variables were examined with one-way analysis of variance. The primary analysis was a one-way analysis of covariance (ANCOVA) comparing post-test values among the three groups for each outcome, with the pretest value of the same outcome entered as the covariate. The group-by-baseline-covariate interaction was examined to assess homogeneity of regression slopes before interpreting each ANCOVA. When the omnibus test was significant, Bonferroni-adjusted pairwise comparisons were performed. Effect sizes are reported as partial eta-squared (ηp^2), interpreted as small (≥ 0.01), medium (≥ 0.06) and large (≥ 0.14). Percentage change was calculated as (post-test −

pretest) / pretest × 100 from group means. The significance level was set at $P < .05$. All 60 randomized participants were included in the final analysis because none was lost to follow-up.

Results

Participant characteristics

Sixty overhead athletes with scapular dyskinesis were randomized, 20 to each of the SFE, KCE and CON groups, and all completed the intervention period and were analyzed (Fig. 1). The groups did not differ significantly at baseline in age, height, body mass, training experience, proprioceptive error or SPADI score (Table 3; all $P > .05$). Baseline ROM values were also similar (Table 4, pretest values).

Table 3 Baseline characteristics of participants (mean ± SD)

Variable	SFE (n = 20)	KCE (n = 20)	CON (n = 20)	P
Age (years)	23.8 ± 2.7	24.1 ± 2.9	23.6 ± 2.8	.84
Height (cm)	179.4 ± 6.1	180.2 ± 5.8	179.0 ± 6.4	.82
Body mass (kg)	75.8 ± 8.2	76.5 ± 7.7	74.9 ± 8.6	.83
Training experience (years)	5.8 ± 1.7	6.0 ± 1.8	5.7 ± 1.6	.88
Proprioceptive error (°)	7.2 ± 1.5	7.3 ± 1.6	7.1 ± 1.4	.91
SPADI (%)	31.0 ± 7.1	30.6 ± 7.5	30.8 ± 6.9	.97

SFE scapular-focused exercise; KCE kinetic-chain exercise; CON control; SPADI Shoulder Pain and Disability Index

Effects of the interventions on all outcomes

All outcome data are summarized in Table 4, which gives pretest and post-test values, change, ANCOVA results and Bonferroni-adjusted pairwise comparisons for every outcome, and in Fig. 5. Significant group effects were found for all six outcomes, with large effects for proprioceptive error, flexion, abduction, external rotation and SPADI, and a moderate effect for internal rotation (Fig. 6).

Table 4 Pretest and post-test values, change, ANCOVA and pairwise comparisons for all outcomes

Outcome	Group	Pretest	Posttest	Change	Change (%)	ANCOVA (group effect)	Bonferroni pairwise comparisons
Proprioceptive error (°)	SFE	7.2 ± 1.5	4.6 ± 1.2	−2.6	−36.2	$F_{2,56} = 18.47$; $P < .001$; $\eta p^2 = .398$ (large)	KCE vs SFE: P = .021; KCE vs CON: P < .001; SFE vs CON: P = .006
	KCE	7.3 ± 1.6	3.8 ± 1.0	−3.5	−47.8		
	CON	7.1 ± 1.4	6.8 ± 1.5	−0.3	−4.2		
SPADI (%)	SFE	31.0 ± 7.1	20.3 ± 6.0	−10.7	−34.5	$F_{2,56} = 22.31$; $P < .001$; $\eta p^2 = .443$ (large)	KCE vs SFE: P = .034; KCE vs CON: P < .001; SFE vs CON: P = .002
	KCE	30.6 ± 7.5	16.6 ± 5.4	−14.0	−45.8		
	CON	30.8 ± 6.9	29.5 ± 7.1	−1.3	−4.2		
Flexion ROM (°)	SFE	165.2 ± 8.7	172.8 ± 7.0	+7.6	+4.6	$F_{2,56} = 7.82$; $P = .001$; $\eta p^2 = .218$ (large)	SFE vs KCE: P = .99; SFE vs CON: P = .08; KCE vs CON: P = .02
	KCE	164.7 ± 9.1	173.9 ± 6.8	+9.2	+5.6		
	CON	165.8 ± 8.9	166.9 ± 8.8	+1.1	+0.7		
Abduction ROM (°)	SFE	163.4 ± 9.2	170.2 ± 7.5	+6.8	+4.2	$F_{2,56} = 6.41$; $P = .003$; $\eta p^2 = .186$ (large)	SFE vs KCE: P = .99; SFE vs CON: P = .13; KCE vs CON: P = .04
	KCE	164.1 ± 8.7	172.0 ± 7.1	+7.9	+4.8		
	CON	164.0 ± 8.8	165.2 ± 8.7	+1.2	+0.7		
External rotation ROM (°)	SFE	82.1 ± 7.3	89.5 ± 6.4	+7.4	+9.0	$F_{2,56} = 8.17$; $P = .001$; $\eta p^2 = .226$ (large)	SFE vs KCE: P = .99; SFE vs CON: P = .04; KCE vs CON: P = .01
	KCE	81.7 ± 7.5	90.8 ± 6.1	+9.1	+11.1		
	CON	82.3 ± 7.1	82.9 ± 7.2	+0.6	+0.7		
Internal rotation ROM (°)	SFE	61.8 ± 6.4	67.0 ± 5.7	+5.2	+8.4	$F_{2,56} = 4.02$; $P = .023$; $\eta p^2 = .126$ (moderate)	SFE vs KCE: P = .99; SFE vs CON: P = .12; KCE vs CON: P = .04
	KCE	62.0 ± 6.1	68.2 ± 5.3	+6.2	+10.0		
	CON	61.5 ± 6.3	62.4 ± 6.2	+0.9	+1.5		

Values are mean ± SD. Change = posttest − pretest; % change = (posttest − pretest)/pretest × 100. Lower proprioceptive error and SPADI values indicate better outcomes; higher ROM values indicate greater mobility. ANCOVA used the pretest value as covariate (degrees of freedom 2 and 56). SFE scapular-focused exercise; KCE kinetic-chain exercise; CON control; ηp^2 partial eta-squared; ROM range of motion

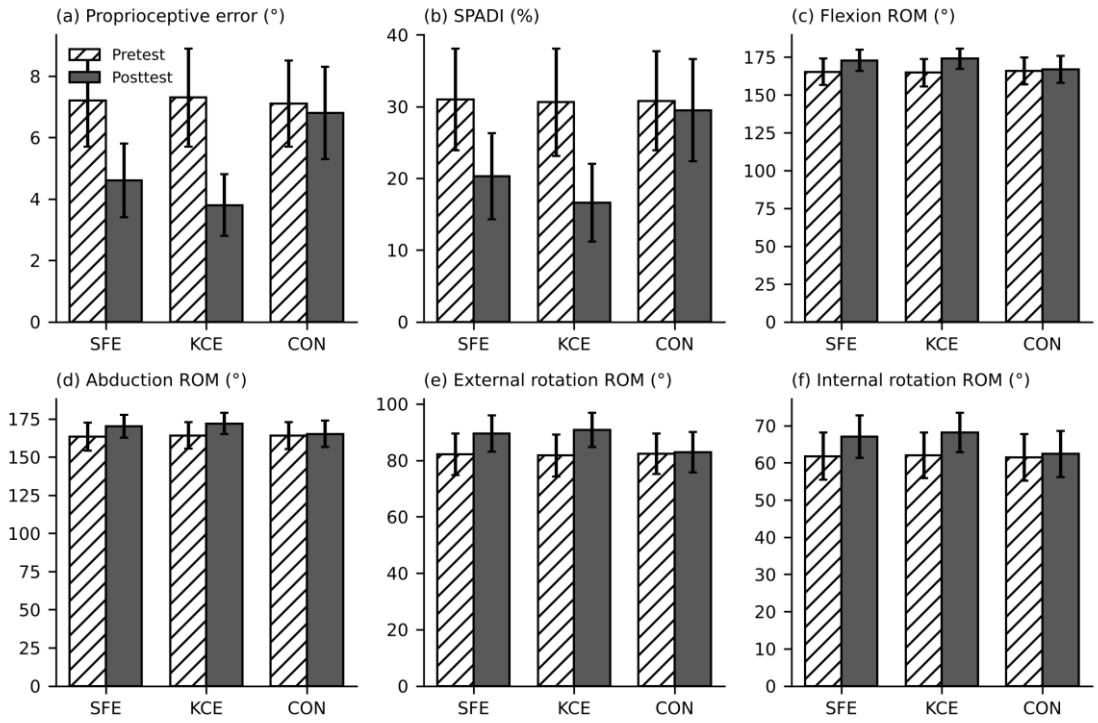


Fig. 5 Pretest and post-test values (mean ± SD) for all outcome measures, by group. a Proprioceptive repositioning error; b SPADI; c flexion ROM; d abduction ROM; e external rotation ROM; f internal rotation ROM. SFE scapular-focused exercise group; KCE kinetic-chain exercise group; CON control group

Shoulder proprioception

Both exercise groups reduced their absolute passive repositioning error from pretest to post-test. The SFE group decreased from 7.2 ± 1.5° to 4.6 ± 1.2° (approximately 36%) and the KCE group from 7.3 ± 1.6° to 3.8 ± 1.0° (approximately 48%), whereas the control group changed minimally (7.1 ± 1.4° to 6.8 ± 1.5°). After adjusting for baseline proprioception, the group effect was significant ($F_{2,56} = 18.47$, $P < .001$, $\eta p^2 = .398$). KCE produced significantly lower post-test error than CON ($P < .001$) and SFE ($P = .021$), and SFE was also significantly lower than CON ($P = .006$).

Shoulder range of motion

Both exercise groups improved passive shoulder ROM in all four movements, whereas the control group changed by about one degree or less. The largest improvements were for flexion and external rotation (+7.6° and +7.4° for SFE; +9.2° and +9.1° for KCE). ANCOVA showed significant group effects for flexion, abduction, external rotation and internal rotation (Table 4). Pairwise comparisons between SFE and KCE were not statistically significant for most ROM variables, so the two programs influenced mobility similarly, and the advantage of kinetic-chain training was more evident for proprioceptive and functional outcomes than for ROM.

Shoulder function (SPADI)

SPADI scores improved substantially in both exercise groups. The SFE group decreased from 31.0 ± 7.1 to 20.3 ± 6.0 points (−10.7 points) and the KCE group from 30.6 ± 7.5 to 16.6 ± 5.4 points (−14.0 points), whereas the control group changed by only 1.3 points. The group effect was significant ($F_{2,56}$

= 22.31, P < .001, ηp^2 = .443). KCE had significantly lower post-test SPADI scores than SFE (P = .034) and CON (P < .001), and SFE was also lower than CON (P = .002).

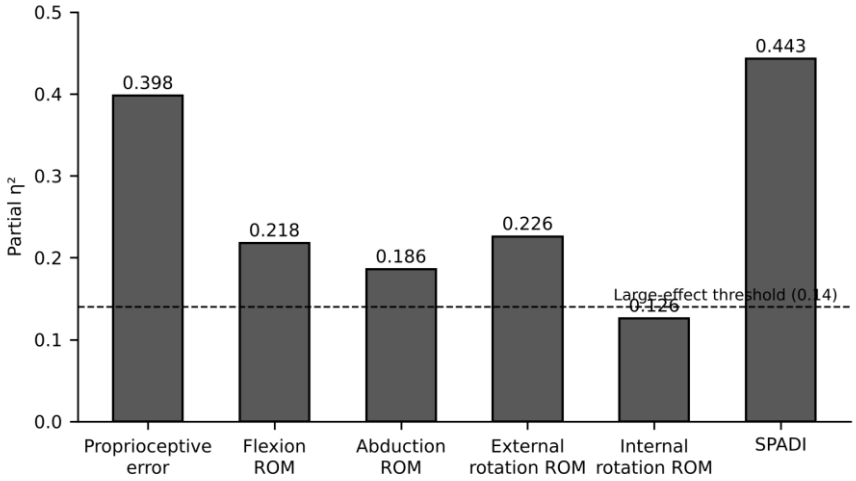


Fig. 6 Partial η^2 effect sizes from the ANCOVA models for each outcome. The dashed line marks 0.14, above which values are conventionally interpreted as large effects

Discussion

Summary of principal findings

This randomized controlled trial compared a scapular-focused and a kinetic-chain exercise program with no structured exercise in overhead athletes with scapular dyskinesis. Three main findings emerged. First, both programs improved passive proprioception, passive ROM and self-reported function relative to control, with large effect sizes for most outcomes. Second, kinetic-chain training produced a further reduction in repositioning error (3.8° versus 4.6° after SFE) and in SPADI score (16.6 versus 20.3 points) than scapular-focused training. Third, ROM gains of about 5–9° were similar with both programs, and between-program differences were not statistically significant for most ROM variables. Taken together, the results indicate that both approaches are effective over six weeks, but that they do not produce identical profiles of change, which is consistent with the idea that local scapular retraining and whole-chain integration act through partly different pathways.

Proprioception

The most distinctive finding was the greater reduction in passive repositioning error after KCE, which corresponded to a 48% reduction compared with 36% after SFE and 4% in the control group. Several explanations are plausible. Joint position sense depends on afferent input from capsuloligamentous and musculotendinous mechanoreceptors and on its central integration, and it is regarded as an important component of dynamic shoulder stability [8–10]. Training that exposes the system to varied, multi-joint loading and to continual changes in trunk and limb position may provide a richer and more variable afferent stimulus than isolated scapular exercises, and may promote better central integration of that information. The kinetic-chain rationale predicts exactly this kind of benefit, because the scapula and shoulder are assumed to depend on coordinated input and output from the legs and trunk [21, 22]. The

KCE program also contained a wall-wash drill aimed explicitly at proprioception, and its closed-chain, weight-shifting tasks require continuous position monitoring, which could have contributed directly to the gains.

Our findings should be read alongside the literature on strength training and proprioception. Salles et al. discussed evidence that strength training can improve shoulder proprioception [11]. This is consistent with our observation that SFE, which contained loaded strengthening progressing to 70–80% of 1RM as well as neuromuscular re-education, also reduced repositioning error significantly compared with control. In other words, both exercise approaches appear capable of improving proprioceptive acuity, and the question addressed by the present trial is one of degree. Work in patients with chronic mechanical cervical pain has shown that shoulder proprioception can be impaired by dysfunction in an adjacent region [12]. If shoulder position sense is sensitive to the state of neighboring segments, it is biologically reasonable that interventions that engage the trunk and lower limbs, as KCE does, could influence it. We note, however, that this inference is indirect, because our trial did not measure trunk or hip function and cannot identify the mechanism.

Three aspects of the proprioceptive result require caution. First, the absolute difference between the KCE and SFE groups at post-test was less than one degree, and, although statistically significant after Bonferroni adjustment (P = .021), it is smaller than the pre-to-post change in either group. Its practical importance is uncertain, particularly because the measurement error of dynamometer-based passive repositioning in this sample was not quantified. Second, the target angle (30° of rotation at 45° abduction in the scapular plane) lies in the mid-range of motion, where capsular tension and capsuloligamentous afferent input are relatively low. Results may differ near end range, where capsular receptors are more strongly engaged and where throwing athletes are most vulnerable. Third, the test relied on a verbal response, and participants could not be blinded to their allocation, so expectation and learning effects cannot be excluded, although the control group showed little change over the same period.

Previous trials in this area have often used active joint-position-sense testing, which combines afferent input with voluntary muscle activity and is therefore less specific to joint and capsular afferents. By using a passive protocol, the present study isolates, as far as practicable, the sensory component of position sense, and our results therefore extend earlier findings to this specific measure. At the same time, direct numerical comparison with studies that used different joints, target angles, positions or devices is not possible, and we limit our comparison to the direction and relative size of the effects.

Range of motion

Both programs improved passive flexion, abduction, external rotation and internal rotation by roughly 5–9°, while the control group changed by about one degree or less. The improvements were slightly larger for KCE, but between-program comparisons were not significant for most variables, which

supports the interpretation that the two programs act similarly on mobility. A likely explanation is that both programs required repeated, progressively loaded movement through the available range, which may have improved the extensibility of the capsule and myofascial tissue, reduced protective muscle guarding and improved scapular positioning, regardless of whether the emphasis was local or global. A reduction in pain, which fell in both exercise groups, may also have increased tolerance for end-range positioning during passive testing.

The relevance of rotational ROM for overhead athletes is well described. Wilk et al. reported that glenohumeral internal rotation deficit and deficits in total rotational motion were related to shoulder injury in professional baseball pitchers [13], and Manske et al. discussed glenohumeral motion deficits as adaptations that can be either physiologic or pathologic [14]. The gains of 5–6° in internal rotation and 7–9° in external rotation observed here are therefore of potential clinical interest. It is important to recognize, however, that we measured only the dominant limb, did not calculate side-to-side differences or the total rotational arc, and did not include posterior-shoulder stretching in either program. We cannot conclude that exercise alone corrects glenohumeral internal rotation deficit, and future work should include these variables. Flexion and abduction at baseline were already around 164–166°, close to what is usually regarded as normal range, so the scope for improvement was limited and a ceiling effect may have reduced the ability to detect differences between the programs. Finally, the goniometric measurements were passive and performed with manual scapular stabilization, which isolates glenohumeral motion and may not reflect the combined scapulothoracic and glenohumeral motion used in sport.

Shoulder pain and function

Self-reported shoulder pain and disability improved in both exercise groups, by 10.7 SPADI points after SFE and 14.0 points after KCE, compared with 1.3 points in the control group. This is a meaningful improvement in a sample whose baseline mean was about 31%, and it supports the use of both programs for symptomatic athletes. The additional 3.3-point reduction in the KCE group relative to the SFE group (adjusted comparison, P = .034) was statistically significant but modest, and we cannot be sure that it exceeds the threshold at which athletes perceive a difference. The SPADI contains both pain and disability items, and because we analyzed only the total score, we cannot say which component drove the group difference. In addition, the SPADI is a subjective outcome and the athletes knew which program they were following, so a contribution of expectation, attention from the supervising physiotherapist and the training effect of a novel program cannot be excluded.

The scapular-focused literature supports the notion that these programs have a sound physiological basis. Electromyographic studies have identified exercises that activate the lower trapezius and serratus anterior with relatively low upper trapezius activity [16, 17], biofeedback and exercise protocols have altered muscle activation patterns and scapular kinematics [18, 19], and reviews support scapular and rotator cuff exercise in rehabilitation [20]. These studies mostly address mechanisms, however, and

many examined muscle activation or kinematics rather than patient-reported function after a supervised multi-week intervention. Our results complement them by showing that a program built on these principles also improves function and ROM in athletes with confirmed dyskinesis. The SFE group improved on all outcomes, which confirms that local scapular retraining remains clinically valuable.

The kinetic-chain literature is predominantly conceptual or biomechanical. Reviews and clinical commentaries have argued that deficits in the legs, pelvis, trunk and scapula can alter the demands on the shoulder, and that rehabilitation of the throwing shoulder should therefore incorporate the whole chain [21–25]. The advantage we observed for KCE on function and proprioception is consistent with these proposals and provides trial-based evidence from a controlled comparison. It is plausible that SPADI items, which reflect tasks such as reaching, lifting and overhead activity, depend on coordinated whole-limb and trunk effort, so that training that rehearses force transfer from the legs through the trunk translates more directly into perceived functional gains than isolated scapular exercises. We emphasize, however, that this is an interpretation. We did not measure trunk or hip strength, scapular kinematics or muscle activation, and so cannot confirm that changes in these variables mediated the effects.

Hypothesis and unexpected findings

We hypothesized that both programs would improve outcomes relative to control and that the programs would differ in their effects, without specifying direction. Some conceptual accounts would predict that SFE confers greater local sensorimotor and pain-related benefit, as it targets the dysfunctional scapular muscles directly. This was not what we found: KCE produced larger improvements in proprioception and function, while ROM was similar. One possible reason is that scapular dyskinesis in overhead athletes may be, in part, a consequence of altered proximal control rather than only of local scapular muscle imbalance, so that addressing the whole chain yields more benefit. Another, less theoretical, reason concerns training dose. The KCE program prescribed four to five sets of 10–12 repetitions per exercise, whereas the SFE program used three sets of 10–15 repetitions, and KCE involved large-muscle, multi-joint tasks. Although session duration was matched at about 45 minutes, total workload and metabolic demand were probably not matched, and the greater benefit of KCE may in part reflect a greater training stimulus rather than a specific kinetic-chain mechanism.

The control group changed little on any outcome, which indicates that the improvements in the exercise groups are unlikely to be explained by repeated testing, familiarization or spontaneous recovery over six weeks. However, the control group received no attention or sham intervention, so the trial cannot separate the specific effects of the exercise content from non-specific effects of supervised contact.

Clinical implications

The findings suggest that both programs are viable six-week options for overhead athletes with scapular dyskinesis. SFE remains a logical first step for establishing local scapular control, particularly in athletes with marked winging or pronounced muscle imbalance, whereas KCE appears to be a useful

choice, or a progression, when the clinical priorities are proprioceptive acuity and functional recovery and when the athlete needs to return to sport-specific, whole-body force transfer. Because ROM gains were comparable, clinicians need not choose between the programs on the basis of mobility alone. These observations are consistent with a phase-based approach in which scapular-specific control is established early and kinetic-chain integration is emphasized as the athlete moves toward sport demands [23, 24], and a program combining both elements may offer the most complete framework. This combined approach was not tested in the present trial and should be evaluated directly.

Strengths and limitations

Strengths of the study include its randomized, three-arm design with a no-exercise control, prospective registration, blinded outcome assessment and statistical analysis, supervised delivery of both programs, confirmation of dyskinesis by a licensed physiotherapist using a defined classification, the use of a passive proprioception protocol, and the combination of laboratory, range-of-motion and patient-reported outcomes in a single cohort.

Several limitations should be considered. The intervention lasted six weeks and there was no follow-up, so the durability of the effects and their influence on injury incidence or sports performance are unknown. Participants and instructors could not be blinded, which may have influenced subjective outcomes such as the SPADI and the verbal response used in proprioception testing. The programs were not matched for volume, and the control group received no attention placebo. Passive ROM and proprioception were measured with goniometry and a dynamometer rather than three-dimensional motion analysis or electromyography, so scapular kinematics and muscle activity before and after training were not described, and we cannot say whether dyskinesis itself resolved. The sample consisted of young athletes from a limited set of sports at a single center, and the findings may not generalize to other age groups, female athletes, higher competitive levels or specific sports. Only the dominant limb was examined. Multiple outcomes were analyzed without a global correction across outcomes, although pairwise comparisons within each outcome were Bonferroni-adjusted. Finally, minimal detectable change and minimal clinically important difference thresholds were not applied, and the SPADI pain and disability subscales were not analyzed separately.

Future research should include longer follow-up, matched training volumes, an attention-control or sham condition, and combined or phase-based programs compared with each single approach. Measuring scapular kinematics, muscle activation, trunk and hip performance, active and end-range proprioception, total rotational motion and sport-specific performance would help to clarify mechanisms. Larger and more diverse samples, including female athletes and different overhead sports, would improve generalizability.

Conclusions

Both scapular-focused and kinetic-chain exercise programs improved passive shoulder proprioception, range of motion and self-reported function in overhead athletes with scapular dyskinesis over six weeks, relative to a non-exercise control. Kinetic-chain training conferred an additional advantage for proprioceptive acuity and for function, whereas range-of-motion gains were comparable between the two programs. A phase-based combination of local scapular stabilization and global kinetic-chain training may represent a comprehensive framework for rehabilitation in this population, although this remains to be tested in trials with longer follow-up and matched training volumes.

Statements and Declarations

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Competing interests: The authors have no relevant financial or non-financial interests to disclose.

Ethics approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the institutional Ethics Committee of Kharazmi University (approval no. IR.KHU.REC.1404.066). The protocol was prospectively registered in the Iranian Registry of Clinical Trials (IRCT20241202063918N1).

Consent to participate: Written informed consent was obtained from all individual participants included in the study.

Consent to publish: All participants depicted in the photographs provided separate written consent for the use of de-identified images for research publication. Facial features are obscured in every figure.

Data availability: The data supporting the findings of this study are available from the corresponding author on reasonable request, subject to institutional and ethical restrictions.

Author contributions: Nima Tadbiri: data curation, investigation, formal analysis, writing – original draft preparation. Seyed Sadredin Shojaedin: conceptualization, methodology, supervision. Malihe Hadadnejad: conceptualization, methodology, writing – review and editing.

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