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Scientific/Clinical Article

Effect of rotator cuff strengthening as an adjunct to standard care in subjects with adhesive capsulitis: A randomized controlled trial

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ABSTRACT

Study Design: Randomized controlled trial.
Purpose of the Study: To study the effect of adding rotator cuff (RC) muscles strengthening to joint mobilization and transcutaneous electrical nerve stimulation (TENS) in patients with adhesive capsulitis.
Methods: A prospective, parallel-group, randomised clinical trial was conducted on 42 patients. One group received TENS and joint mobilization and in the other group RC muscles strengthening was added. Treatment was given for 12 sessions within 4 weeks.
Results: When compared between the groups statistically significant changes were seen in all the outcome measures in the group that received RC muscle strengthening exercises vs TENS and mobilization. VAS 12.76 ± 1.04 vs 4.05 ± 1.32; SPADI 34.66 ± 6.69 vs 54.29 ± 12.17; PFPS 3.06 ± 0.80 vs 4.70 ± 0.81; and ROM (elevation >125 vs >110 degrees and rotations >70 vs >48 degrees).
Conclusions: Addition of a structured RC strengthening program to TENS and joint mobilization in the treatment of adhesive capsulitis resulted in improvement in pain, ROM and function.
Level of Evidence: 1b.

Introduction

Adhesive capsulitis is a condition characterized by functional restriction of both active and passive shoulder motion for which radiographs of the glenohumeral (GH) joint are unremarkable except for the possible presence of osteopenia or calcific tendonitis.[1,2] Despite extensive research, the etiology of adhesive capsulitis is not completely explained, possibly involving a nonspecific chronic inflammatory reaction of subsynovial tissue and resulting in capsular and synovial thickening affecting the function of the GH joint. Onset of adhesive capsulitis is usually gradual and idiopathic, but it may also be acute and associated with a history of minor injury to the shoulder joint.[3-6] Adhesive capsulitis is seen most commonly in patients with diabetes mellitus (27%), previous myocardial infarction (5%), immobilization (5%), stroke, and sedentary workers (4% each) with age of the subjects ranging from 25-70 years and duration of symptoms average of 3.66 +/− 2.36 months. It is also found that left shoulder is more commonly involved (54%) and 2% has bilateral involvement.[7]

Adhesive capsulitis is divided into 3 stages: the painful stage, the stiffening stage, and the thawing stage.[8,9] In the painful stage, gradual onset of shoulder pain lasts from weeks to months. Pain, which can be severe, may cause pronounced sleep disturbance.[10] The stiffening stage is characterized by progressive loss of active and passive ranges of motion (ROMs) that may last up to 1 year.[11] Most patients lose ROM in GH external rotation, abduction, and internal rotation during this stage, considered as the "capsular pattern." The final, thawing phase is characterized by the gradual recovery of ROM.[10]

Shoulder joint being the most mobile joint of the body, articular surface movements of the shoulder rely on the coordinated control of the surrounding muscles. Any impaired muscular performance may influence shoulder movements and then contribute to joint dysfunction. Therefore, the frequently observed pain-induced muscle spasm and muscle weakness around the affected shoulder may also cause pain and restricted movements in individuals with adhesive capsulitis.[10] The supraspinatus, infraspinatus, teres minor, and subscapularis muscles compose the rotator musculotendinous cuff. These muscles are considered to be part of a "cuff" because the inserting tendons of each muscle of the cuff blend with and reinforce the GH capsule. More importantly, all have action lines that significantly contribute to the dynamic stabilization of the GH joint.[9-11] Adhesive capsulitis may be related to rotator cuff tendinitis and rotator cuff repair is indicated if symptoms do not improve with extensive shoulder rehabilitation.[12]

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According to Sahrmann, impairment in the strength of rotator cuff muscles in adhesive capsulitis is commonly seen which should be identified to optimize the proper biomechanics of the shoulder in the treatment of adhesive capsulitis. Emphasis should also be given to rotator cuff strengthening in secondary adhesive capsulitis which may be due to rotator cuff weakness following any injury to the shoulder or rotator cuff tear.[13,14]

Physical therapy interventions used in patients with frozen shoulder frequently include modalities, manual techniques, and therapeutic exercise. Exercises given in the treatment of adhesive capsulitis consists of active ROM, Codman's exercise, wall walks, shoulder wheel, pulley, active and passive stretching, and rotator cuff and scapular strengthening.[1,4,6,8,15-30]

Strengthening exercises for rotator cuff and scapular stabilizers is recommended in the treatment of adhesive capsulitis.[26] Isokinetic strength of the internal and external rotators of the shoulder joint is affected in adhesive capsulitis and the need to incorporate its strengthening is emphasized.[10] Scapular stabilizer exercises were given in one study,[8] and in another study, 4 weeks of rehabilitation was given, but no details about the type of exercises given were elucidated.[28] At the time of design of this study, no other study could be retrieved that studied the effect of adding rotator cuff muscle strengthening to mobilization and pain management in the treatment of adhesive capsulitis. Hence, there was a need to study the effect of rotator cuff strengthening in patients with adhesive capsulitis and compare it with the usual care given which consists of mobilization and electrical modalities for pain management. We hypothesized that rotator cuff muscle strength training in adhesive capsulitis will help to improve the function of the shoulder joint by improving the ROM and restoring joint function. The specific aims were to find out the effects of strength training program of rotator cuff in adhesive capsulitis on pain, ROM, and functional outcome and to compare these results with the group receiving electrical modalities and mobilization only. Secondary aim was also to compare the strength of rotator cuff muscles between the 2 groups.

Method

Design

A prospective, parallel-group, randomized clinical trial was conducted, with concealed allocation, intention-to-treat analysis, and blinded outcome assessors. People with adhesive capsulitis referred for physiotherapy were recruited from the outpatient and inpatient departments of Kasturba Medical College, Hospitals, Mangalore. The method of generating random sequence was permuted block randomization and concealment was by sequentially numbered, sealed, opaque envelopes which were done by the second author. Following baseline measurement, participants were randomly allocated via block randomization into 2 groups; one group received transcutaneous electrical nerve stimulation (TENS) and mobilization, whereas the other group received strengthening of the rotator cuff muscles in addition to the treatment given to the first group. Participants were measured at baseline and after 4 weeks of intervention (week 4). Qualified assessors who were blinded to group allocation conducted the measurements at baseline and week 4.

Participants and therapists

Patients were included if they had 1-3 month of onset of pain and stiffness, restriction of ROM in external rotation, abduction, and flexion less than 50% in comparison to the other shoulder, pain during sleep, difficulty with grooming, dressing activities, and reaching activities— to the shoulder level, behind the back, and overhead. Exclusion criteria was osteoarthritis or signs of bony damage due to trauma on the radiographs of the affected shoulder, hypermobility and instability, neurological disorder causing muscle weakness in the shoulder, any local (inflammation or infection) or systemic (cerebrovascular accident or myocardial infarction) disease, upper limb nerve tension testing reproduces the reported symptoms and shoulder pain can be increased or decreased with altering nerve tension positions or shoulder pain is reproduced with palpatory provocation of the relevant peripheral nerve entrapment site.

The intervention was given by a postgraduate student (henceforth mentioned as therapist) under the guidance of an experienced therapist with doctorate qualification and experience of more than 15 years in musculoskeletal physiotherapy.

Intervention

All participants underwent 4 weeks of rehabilitation. It consisted of 3 sessions per week for 4 weeks (total of 12 sessions). Rehabilitation was aimed at increasing ROM, decreasing pain, and improving the functional outcome. Pendular and free ROM and stretching exercises for the shoulder were taught as home program.

The difference between the experimental group and control group was the addition of strengthening exercises to the rotator cuff to the experimental group. Both the groups received GH joint mobilizations (GH caudal glide to increase abduction, GH posterior glide to increase flexion and to increase internal rotation, and GH anterior glide to increase external rotation). To increase scapular motions of elevation, depression, protraction, retraction, and rotation, scapular mobilization was given (10-15 repetition of intensive mobilizations were given for all the techniques). The detailed methodology of mobilizations is given in Appendix 1. The electrotherapy modality used was TENS (ACU TENS-4). Two pairs of rubber electrodes were placed over the shoulder, electrode was sited over the place where the most intense pain was felt or the greatest tenderness was elicited and the tissue was separated from the electrodes with the help of conducting jell. Stimulation duration was set at 15 minutes at a frequency of 150. The intensity of the current was set at a comfortable level as determined by the subjects and it ranged from 25 to 35 mA. During stimulation subject experienced paresthesia and mild twitches, the current was turned up if the subjects accommodated to the current 5 minutes into the stimulation.

Strengthening exercises to the rotator cuff muscles were given to the experimental group. Strengthening exercises included isometric and isotonic exercise using a pragmatic approach. When the pain did not allow isotonic strengthening exercise, pendular and isometric exercises to the rotator cuff muscles were given. The "shoulder sling" exercise was used to help retrain the initial setting phase of the rotator cuff when initiating abduction. The shoulder sling exercise for a "rotator cuff set" is considered analogous to a "quad set" exercise in the lower extremity.[28] Later, as per the tolerance of the patient within pain limits, strengthening exercises were started with red Theraband and 1- to 2-kg dumbbells. About 8-12 repetitions for 3 sets were given in each session for total of 12 sessions (thrice a week). All the exercises were performed under the supervision of the treating therapist. The details of the exercises are given in Appendix 2. The intervention was monitored to ensure safety and adverse events.

Outcome measures

The primary outcomes were impairments (pain, shoulder ROM, and functional disability). Secondary outcomes were impairment (strength of the shoulder muscles). Patients rated the intensity of their worst pain, using a visual analogue scale that ranged from 0 (no pain) to 10 (worst imaginable pain). The visual analogue scale is a valid and reliable measure of pain intensity in adults with shoulder pain or adhesive capsulitis.[31] Shoulder Pain and Disability Index[32] and Patient-Specific Functional Scale (PSFS) questionnaires[33] were taken to collect data regarding functional disability due to pain and stiffness. A 12-inch goniometer was used to measure shoulder ROM, following standardized procedures.[34] Hand-held dynamometer was used to measure shoulder muscles strength.[35] Appendix 3.

All the measurements were taken twice, before and after the completion of treatment sessions, by a blinded assessor, who was a physiotherapist but was not involved in the examination or treatment of the patient. All the patients attended a 12-session treatment program (thrice a week for 4 weeks) administered by another physiotherapist. The same physiotherapist gave all the treatment sessions for all the patients.

Data analysis

The sample size of 21 in each group was calculated using 95% confidence level and 80% power. Sample size calculations were performed a priori, using an alpha of 0.05 and power of 0.80. Statistical analyses were performed using SPSS statistics, version 17. For participant characteristics, means and standard deviations for interval data were obtained for normally distributed data. Paired *t*-tests were performed for within group comparisons and unpaired *t*-test for between the group.

Results

Participant characteristics

A total of 51 subjects with adhesive capsulitis were screened. Of them, 9 were excluded. A total of 42 patients were selected and randomly allocated to 2 groups: one group got TENS and mobilization and the other group got TENS, mobilization, and rotator cuff strengthening.

The flow of participants in the study is presented in Fig. 1.

Both the groups were homogenous with respect to age, gender, and affected extremity Table 1.

Primary analysis

Pain, ROM, and function were the primary outcome measures analyzed between the 2 groups. Both the groups had similar characteristics at baseline with respect to function. VAS and shoulder flexion were significantly different between the groups Table 2.

Adherence to the treatment

Participants in both the groups performed all the exercises as prescribed. No adverse effects were noted.

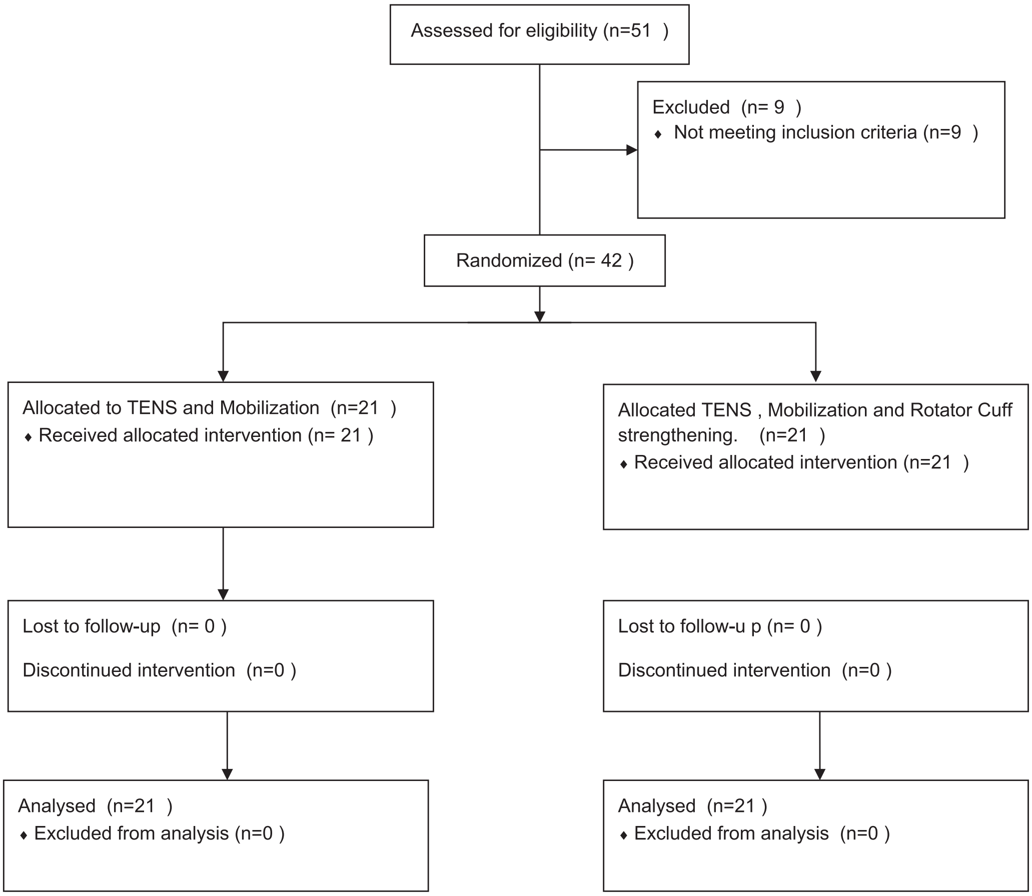

Fig. 1. Consort diagram.

Table 1
Characteristics of patients at baseline

Variables	Control (21)	Experimental (21)	*t*-value	*P* value
Age (y ± SD)	54.19 ± 8.33	56.00 ± 10.42	0.62	.54
Gender (M, F)	14, 7	10, 11		.21
Hand dominance (R, L)	21, 0	20, 1		
Affected extremity (R, L)	9, 12	10, 11		
Duration (wk)	3.83 ± 2.2	5.52 ± 3.7	1.80	.08

SD = standard deviation; M = male; F = female; R = right; L = left.

After treatment

At the end of 4 weeks (12 treatment sessions), highly significant changes were seen in the experimental group in pain, function level, and shoulder ROM except in flexion Table 3.

Secondary analysis

Strength of shoulder muscles was taken as secondary analysis. At baseline only strength of shoulder adductors muscles was significantly different between the 2 groups (Table 4). Both the groups showed highly significant difference in strength after 4 weeks of intervention ($P = .00$). When compared between the groups, the strength increased significantly in the experimental group in all the muscle groups except for the flexors Table 4.

Discussion

This study compared the effectiveness of adding rotator cuff strengthening exercises to joint mobilization and TENS in patients with adhesive capsulitis. The results showed that there was an added effect of rotator cuff strengthening in patients with adhesive capsulitis on decreasing pain, improving the ROM, and improving the functional outcome after 12 sessions of intervention (3 sessions per week for 4 weeks).

The use of TENS in addition to mobilization was suggested to be the cause for pain relief and increasing ROM. TENS alleviates pain as it blocks pain through both peripheral and central mechanisms.[36] We preferred the use of TENS over interferential therapy commonly used in our set up as there is weak evidence to support its use in the treatment of musculoskeletal conditions.[37] TENS has been commonly used in the treatment of adhesive capsulitis and has been found to be effective when used with other treatments like exercises[38] or exercise and mobilization.[39] In one study, when interferential therapy was compared with TENS, TENS was found to be more effective, but the parameters used in that study were different from ours.[40]

Table 2
Baseline values of VAS, PSFS, and SPADI and shoulder ROM (mean ± SD)

Variables	Control group (21)	Experimental group (21)	*t*-value	*P* value
VAS (cm)	6.48 ± 1.66	7.43 ± 0.81	2.36	.02*
PSFS	7.04 ± 1.11	6.76 ± 0.91	0.89	.378
SPADI	84.33 ± 19.72	87.67 ± 10.23	0.69	.38
Shoulder flexion ROM(degrees)	117.76 ± 23.79	99.38 ± 26.38	2.37	.02*
Shoulder abduction ROM (degrees)	95.38 ± 15.36	87.67 ± 23.85	1.25	.22
Shoulder internal rotation ROM(degrees)	40.48 ± 9.37	42.71 ± 8.59	8.07	.43
Shoulder external rotation ROM(degrees)	36.90 ± 15.57	41.33 ± 10.86	1.07	.30

PSFS = Patient-Specific Functional Scale; ROM = range of motion; SD = standard deviation; SPADI = Shoulder Pain and Disability Score; VAS = visual analogue scale. Shoulder ROM in degrees.
*$P < .05$ significant.

Table 3
VAS, PSFS, and SPADI between the groups

Variables	Control group (21)	Experimental group (21)	*t*-value	*P* value
VAS (cm)	4.05 ± 1.32	2.76 ± 1.04	3.50	<.001**
PFPS	4.70 ± 0.81	3.06 ± 0.80	6.55	<.001**
SPADI	54.29 ± 12.17	34.667 ± 6.69	6.49	<.001**
Shoulder flexion ROM	137.05 ± 21.697	144.10 ± 19.120	1.12	.271
Shoulder abduction ROM	110.14 ± 15.736	127.86 ± 15.190	3.71	<.001**
Shoulder internal rotation ROM	52.19 ± 11.784	70.62 ± 7.909	5.96	.001**
Shoulder external rotation ROM	48.62 ± 15.442	74.67 ± 9.302	6.62	.001**

PSFS = Patient-Specific Functional Scale; ROM = range of motion; SPADI = Shoulder Pain and Disability Score; VAS = visual analogue scale.
**$P < .05$, very highly significant.

Mobilization techniques are frequently used in shoulder joints with adhesive capsulitis. Various combinations of end-range mobilization, midrange mobilization, and mobilization with movement, “high-grade” or “low-grade” Maitland joint mobilization techniques have been used in patients with adhesive capsulitis and have been found to improve ROM and self-reported levels of function.[15-18,41] The improvement in both the groups could be due to the combined effect of pain management and joint mobilization.

However, when both the groups were compared, there was improvement in the group that received rotator cuff strengthening exercise as compared with the group that received only TENS and mobilization. This can be explained by the added effect of rotator cuff muscles strengthening program. For the GH joint to be stable and functional within its range and maintain normal dynamic and stable stabilizing mechanism, the rotator cuff muscles which are considered to be part of a “cuff” because the inserting tendons of each muscle of the cuff blend with and reinforce the GH capsule, must generate sufficient force throughout the entire range to maintain the normal stability.[42-44] More than its stabilizing effect it may be that muscle contraction helped promote additional gliding at tissue interfaces not achieved with stretching alone. Mobilization with exercise has been found to be effective in the treatment of rotator cuff disease, but no conclusion could be drawn for adhesive capsulitis.[23] A number of exercises are recommended for adhesive capsulitis.[45] Strengthening exercises for rotator cuff are recommended in the treatment of adhesive capsulitis.[26] In one study, rotator cuff strengthening exercise was given to one group but the improvement cannot be attributed to rotator cuff strengthening as it was given along with stretching exercises and more than one electrotherapeutic modality when compared with the other group that received only one modality and mobilization.[46] Rotator cuff exercises were not found to be more effective when used with electrotherapeutic modalities or without,[47] and no added benefit was found when used with manual therapy when compared with joint distension in adhesive capsulitis.[48]

The reduction in pain and for function was statistically and clinically significant in both the groups (referred minimum clinically important difference [MCID] value for VAS = 1.4cm[49] and referred MCID value for SPADI = 18 points[50]). However, clinically significant increase in the joint ROM was seen in the group that received rotator cuff strengthening and not the group that received only TENS and mobilization (referred MCID value for shoulder flexion is 9, abduction 18 and external rotation 12),[51] all were achieved in the strengthening group, whereas it was achieved only for flexion in the TENS and mobilization group. Hence, adding rotator cuff strengthening is clinically significant in the treatment of adhesive capsulitis which is characterized by loss of motion of abduction and external rotation.

Table 4
Strength of shoulder muscles at baseline/after 4 weeks (mean value in lb)

Strength of shoulder muscles	Control group (21)	Experimental group (21)	*t*-value	*P* value
Flexors	9.95 ± 1.80/12.14 ± 1.65	8.86 ± 1.93 /12.57 ± 1.89	1.90/0.78	.07/.438
Extensors	11.38 ± 1.83/13.05 ± 1.80	11.52 ± 2.50/15.10 ± 2.34	0.21/3.17	.83/.003**
Abductors	8.67 ± 1.43/10.71 ± 1.35	7.76 ± 1.70/11.71 ± 1.82	1.87/2.02	.07/.05*
Adductors	10.76 ± 1.51/12.10 ± 1.38	12.05 ± 2.22/15.57 ± 2.27	2.19/6.00	.034*/.001*
Internal rotators	7.24 ± 1.48/9.14 ± 1.49	7.48 ± 1.40/11.67 ± 1.65	0.54/5.19	.6/.001**
External rotators	6.71 ± 1.10/8.64 ± 1.4	7.00 ± 1.41/11.71 ± 1.7	0.73/6.3	.47/.001**

*$P < .05$ significant; **$P < .05$, very highly significant.

Finally, the increase in the strength of the rotator cuff muscles after the treatment sessions in the group that received strengthening exercises could be attributed to the specificity of strengthening of the rotator cuff muscle strengthening.

Limitations

Strengthening of scapular stabilizer should also be introduced as soon as adequate ROM is obtained in patient with adhesive capsulitis as scapular stabilizers help to maintain the scapulohumeral rhythm that is found to be distorted in adhesive capsulitis. However, in this study, scapular strengthening was not given. Further studies can be done that include scapular strengthening as well. Bearing in mind the long-lasting nature of the disease and the fact that patients can easily become unmotivated, a continuous follow-up is mandatory that was lacking in this study. Further studies should be done for a longer follow-up.

Conclusion

There was not only statistically significant changes in pain, function, and ROM but also clinically significant increase in the ROM of the shoulder joint in the group that received strengthening of rotator cuff muscles in addition to TENS and mobilization of the shoulder joint in patients with adhesive capsulitis.

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Appendix 1. Joint mobilization techniques

GH caudal glide

Indication: To increase abduction.

Patient position: Supine, with arm in resting position; support the forearm between your trunk and elbow.

Placement: Place one hand in the patient's axilla to provide the grade 1 distraction. The web space of therapist hand was placed just distal to the acromion process.

Mobilizing force: With the superiorly placed hand, glide the humerus in an inferior direction.

GH posterior glide

Indications: To increase flexion and to increase internal rotation.

Patient position: Supine, with the arm in resting position.

Therapist position and hand placement: Stand between the patient's trunk and arm. Support the arm against your trunk, grasping the distal humerus with your lateral hand. This position provides grade 1 distraction to the joint. Place the lateral border of your top hand just distal to the anterior margin of the joint, with your fingers pointing superiorly. This hand gives the mobilizing force.

Mobilizing force: Glide the humeral head posteriorly by moving the entire arm. The position of the patients' arm changes as the flexion range increases, and the posterior glide can be given by the therapist.

GH anterior glide

Indications: To increase extension and to increase external rotation.

Patient position: Prone, with arm in resting position over the edge of the treatment table, supported on your thigh. Stabilize the acromion with padding.

Therapist position and hand placement: Stand facing the top of the table with the leg closer to the table in a forward stride position. Support the patient's arm against your thigh with your outside hand; the positioned on your thigh provides a grade 1 distraction. Place the ulnar border of your other hand just distal to the posterior angle of the acromion process, with your fingers pointing superiorly; this hand gives the mobilizing force.

Mobilizing force: Glide the humeral head in an anterior and slightly medial direction. Bend both knees so the entire arm moves anteriorly.

Scapulothoracic articulation

Indications: To increase scapular motions of elevation, depression, protraction, retraction, and rotation.

Patient position: If there is little mobility, begin prone, and progress to side-lying, with the patient facing you. The patient's arm is draped over your inferior arm and allowed to hang so that muscles are relaxed.

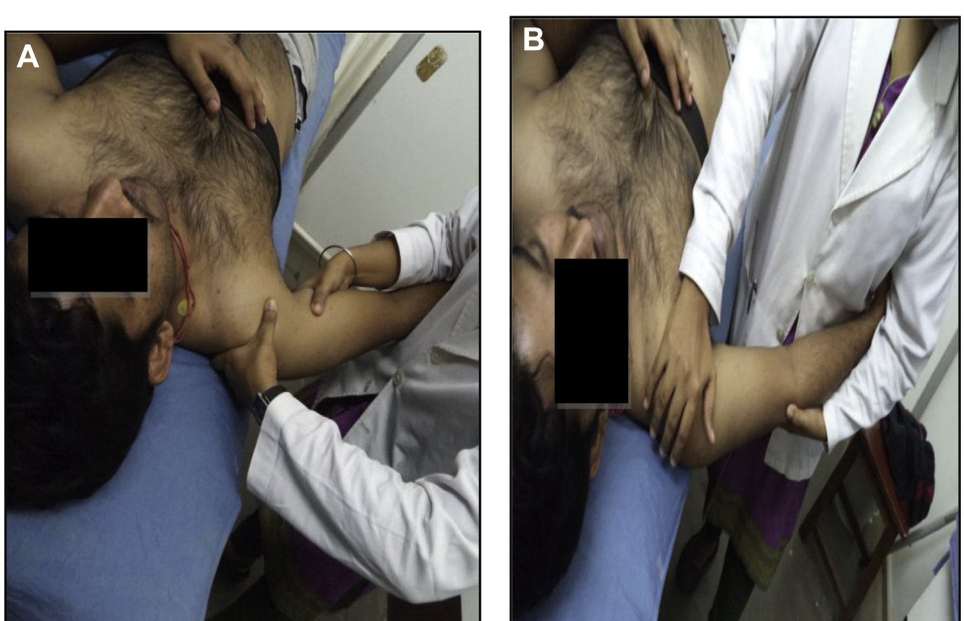

Fig. 1. Glenohumeral joint mobilization: caudal glide (**A**), posterior glide progression (**B**), one hand (**C**), or a belt (**D**) is used to exert a grade 1 distraction force. Distraction for external rotation progression (**E**), anterior glide in resting position (**F**), scapulothoracic mobilization (**G**).

Fig. 1. (*continued*).

Hand placement: Your superior hand is placed across the acromion process to control the direction of motion. The fingers of your inferior hand scoop under the medial border and inferior angle of the scapula.

Mobilizing force: The scapula is moved in the desired direction by lifting from the inferior angle or by pushing on the acromion process.

Appendix 2

Pendulum exercise

Repetitions: 2 sets of 10; 3 days per week.

Main muscles worked: deltoids, supraspinatus, infraspinatus, subscapularis.

Fig. 1. Pendulum exercises. Abduction (**A** and **B**), flexion and circumduction (**C** and **D**).

Fig. 2. Shoulder sling exercise for abduction.

Step-by-step directions:

- Lean forward and place one hand on a counter or table for support. Let your other arm hang freely at your side.
- Gently swing your arm forward and back. Repeat the exercise moving your arm side to-side and repeat again in a circular motion.
- Repeat the entire sequence with the other arm.

Isometric exercises of rotator cuff

External rotation

The infraspinatus and teres minor assist in external rotation of the arm and lie on the outer edge of the scapula. Stand next to a door or wall with your arm at your side and your elbow bent to 90 degrees. Press the outside of your forearm into the wall but do not actually move your arm or body. Hold for 5 seconds and relax. Perform 3 sets of 8 to 10 isometric external rotations.

Internal rotation

The supraspinatus and subscapularis work together to help internally rotate the shoulder. To work these muscles, stand next to a door or wall with your arm at your side and your elbow bent to 90 degrees. Place your palm on the door or wall and press inward to contract the subscapularis and supraspinatus. Keep your elbow at your side and do not actually move your arm. Press in and hold for 5 seconds before relaxing. Perform 3 sets of 8-10 isometric internal rotations.

Abduction

The "shoulder sling" exercise can be used to help retrain the initial setting phase of the rotator cuff when initiating abduction. The Shoulder Sling exercise for a "rotator cuff set" is considered analogous to a "quad set" exercise in the lower extremity. The elastic band creates an "upward and inward" vector of resistance that the patient must push against in a "down and out" vector. This movement simulates the initiation of abduction as well as the depression and stabilization functions of the rotator cuff, which occur before and during abduction. "Shoulder Sling" exercise designed to facilitate "setting" of the rotator cuff. Place an elastic loop under the elbow and around the neck and opposite shoulder. Simultaneously depress your shoulder and initiate abduction.

Dynamic muscle strengthening of rotator cuff—eccentric exercises

Three times per week, 8-12 repetitions for 3 sets, using Therabands.

Shoulder external rotation (infraspinatus and teres minor)

Position the arm at the patient's side or in various positions of abduction, scaption, or flexion. Flex the elbow to 90 degrees and apply the resistive force through the hand at right angles to the forearm. Be sure that the patient rotates the humerus and does not extend the elbow.

Patient position and procedure: Sitting or standing, using elastic resistance (Theraband) in front of the body at elbow level. Instruct the patient to grasp the elastic material and rotate his or her arm outward.

Shoulder internal rotation (subscapularis)

Position the arm at the patient's side or in various position of flexion, scaption, or abduction. The elbow is flexed to 90 degrees and the resistive force is held in the hand.

Patient position and procedure: Sitting or standing using an elastic material (Theraband) with the line of force out to the side and at the level of elbow. Have the patient pull across the front of the trunk into internal rotation.

Shoulder abduction and scaption (deltoid and supraspinatus)

Since it is commonly accepted that most functional activities occur with the humerus 30-45 degrees forward to the frontal plane where the arc of motion is more in line with the glenoid fossa of the scapula (this motion is called scaption), the abduction exercises were given in this plane.

Dynamic muscle strengthening of RC concentrically

Three sets 10-12 repetition with 1-2kg weight (dumbells). (**A**) Lie on opposite side and place a small towel roll under the upper arm. Keep elbow bent to 90° and lift hand up away from the floor. (**B**) Lie on your back with knees bent. Keep elbow at your side & bent to 90°. Lower hand out to the side and bring back across the stomach. (**C**) Lie on opposite side. Turn thumb toward leg, bring arm forward 30°, keep elbow straight and left arm from body about 45°. (**D**) and (**E**) Point thumb toward floor,

Fig. 3. Theraband exercises for RC strengthening. ER (**A** and **B**) and IR (**C** and **D**). RC = rotator Cuff; IR = internal rotation; ER = external rotation.

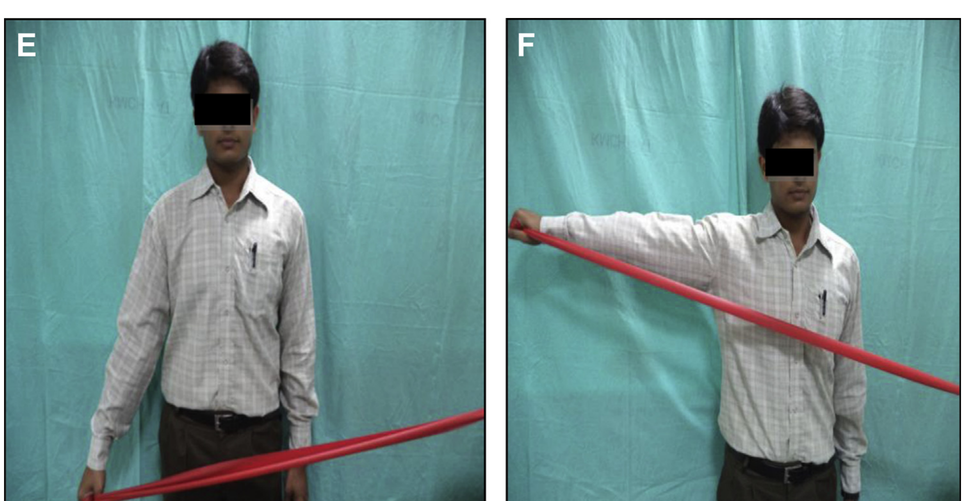

Fig. 4. Theraband exercises for RC strengthening. Abduction (**E** and **F**).

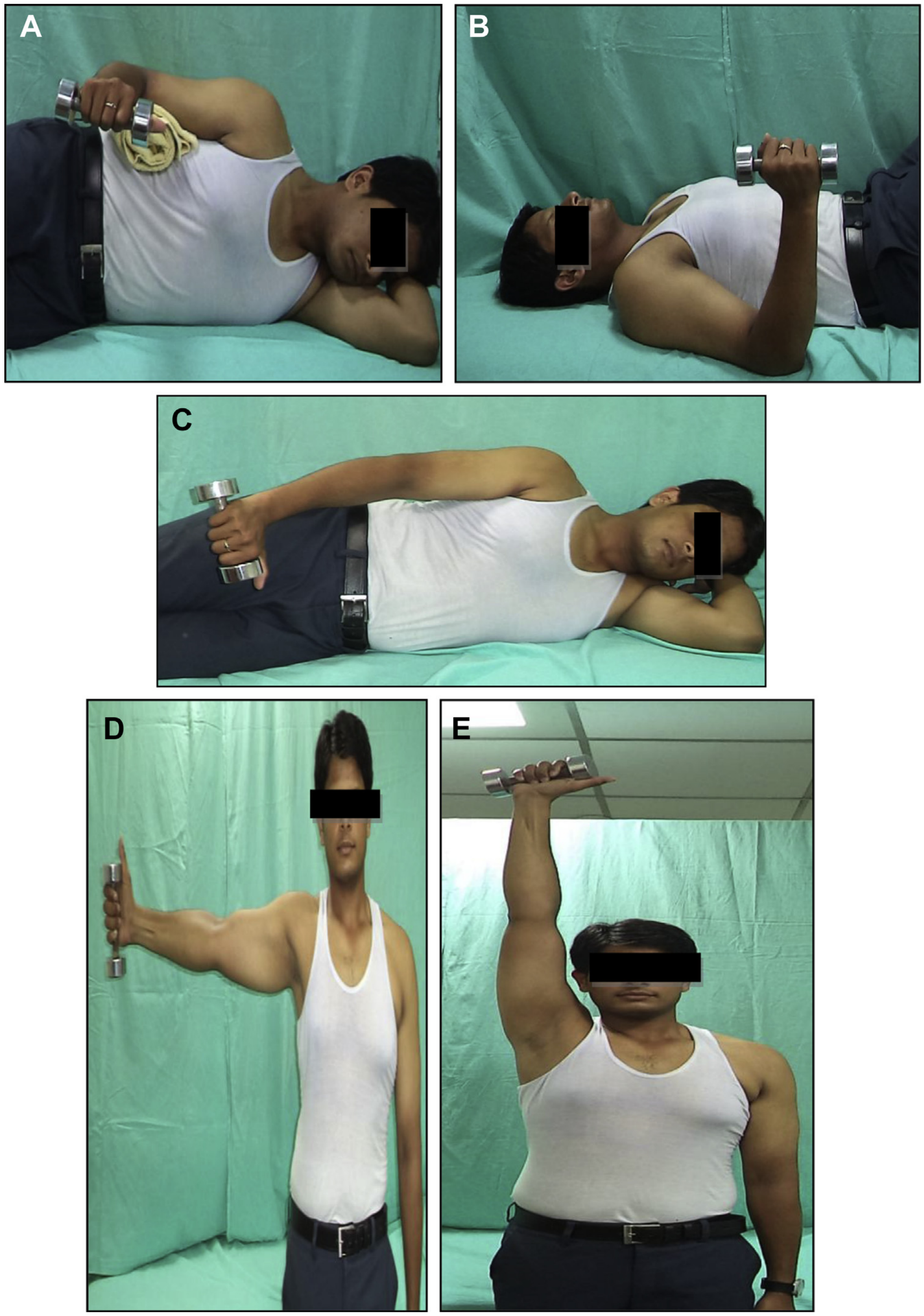

Fig. 5. RC strengthening by dumbells. External rotation (**A**), internal rotation (**B**), supraspinatus (sidelying) (**C**), abduction (90°) (**D**), abduction (>90°) (**E**).

bring arm forward 30° from the side of the body then lift arm upward about 45°.

Appendix 3. Muscle testing with handheld dynamometer

Isometric muscle force of the shoulder flexors, extensors, abductors and adductors, internal and external rotators was measured using handheld dynamometer.

Instruction:

1. During the strength testing, the subject was seated on a standard chair.
2. The position was carefully supervised by the therapist, and the subjects were verbally encouraged to perform the exercise.
3. The subjects were asked to exert maximal voluntary isometric force production during pushing against the dynamometer for approximately 3 seconds.
4. Before each contraction, the subjects were instructed to “push as strongly as possible.”
5. The best result out of the 3 attempts was taken as isometric muscle force.

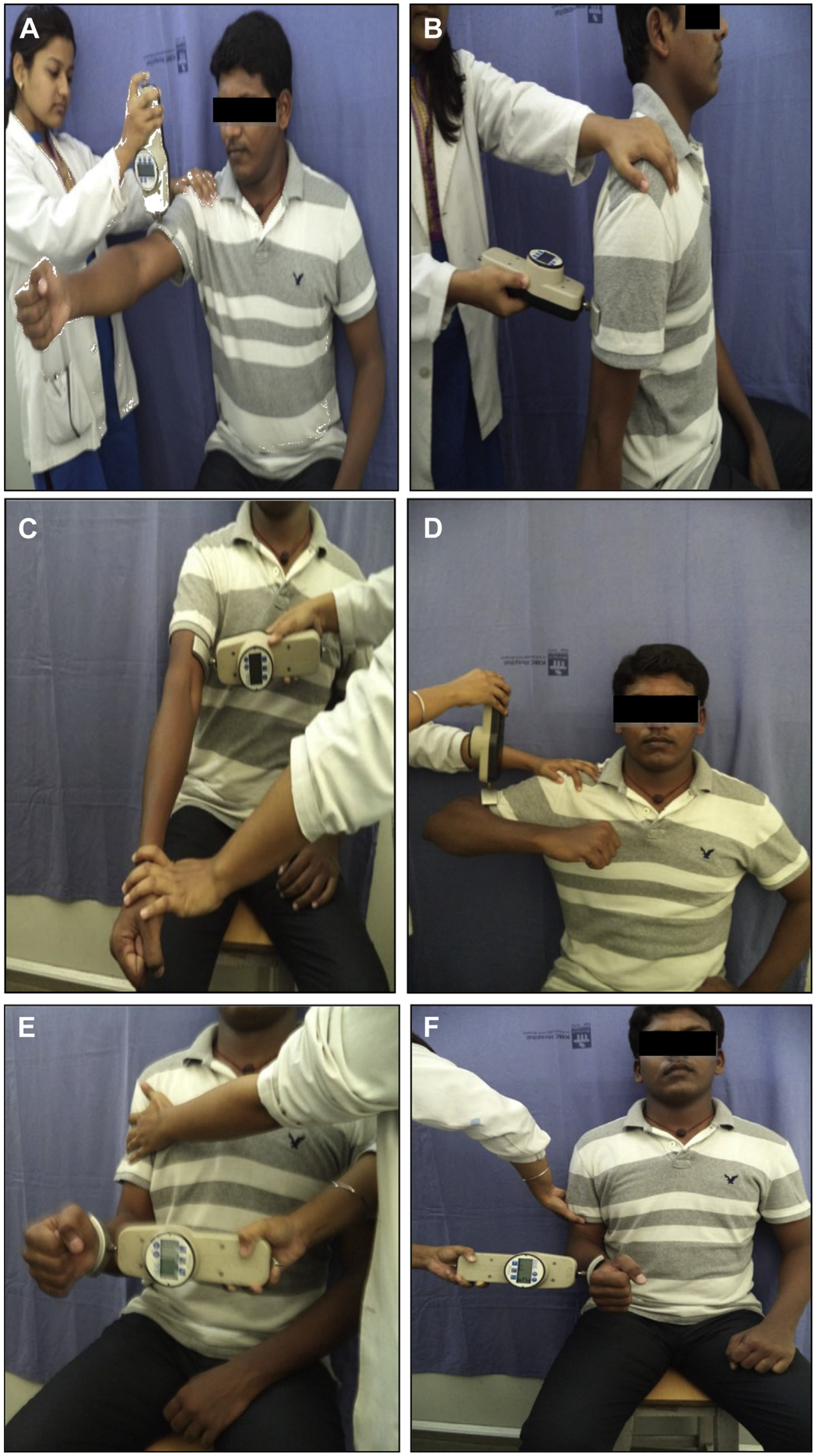

Fig. 1. Measurement of shoulder muscles strength by handheld dynamometer. Flexion (**A**), extension (**B**), adduction (**C**), abduction (**D**), internal rotation (**E**), external rotation (**F**).

6. A rest period of 1 minute was allowed between attempts.
7. All shoulder muscle strength assessments were performed by a single physiotherapist.

Shoulder flexion

Procedure and patient position: During shoulder flexion strength assessment, the upper extremity was positioned with the shoulder flexed to 90°. Handheld dynamometer was placed on the distal end of the humerus approximately 5 cm superior to elbow joint.

Shoulder extension

Procedure and patient position: During shoulder extension strength assessment, the upper extremity was positioned by the side of the body in neutral rotation. Handheld dynamometer was placed posteriorly on the distal end of the humerus approximately 5 cm superior to elbow joint.

Shoulder adduction

Procedure and patient position: During shoulder adduction strength testing, the upper extremity was positioned to approximately 80° of flexion. Handheld dynamometer was placed medially on the distal end of the humerus approximately 5 cm superior to elbow joint.

Shoulder abduction

Procedure and patient position: During shoulder abduction strength testing, the raised upper extremity was positioned with the shoulder abducted to approximately 80° and the elbow fully flexed.

Handheld dynamometer was placed laterally on the distal end of the humerus approximately 5 cm superior to elbow joint.

Shoulder internal and shoulder external rotation

Procedure and patient position: Shoulder external and internal rotation strength assessment was performed with the shoulder in the vertical position, and the elbow flexed to 90°. Handheld dynamometer was placed medially and laterally on the distal part of the forearm approximately 5 cm superior to the wrist during shoulder internal and external rotation testing, respectively.

Range of motion measurements by goniometer

Shoulder flexion

Measurement tool: Universal goniometer.

Testing position: Supine with hips and knees bent and lumbar spine flat. Arm is at the side with the palm in and the thumb up.

Stabilization: Body weight should stabilize scapula but manual stabilization may be required to prevent excessive scapular rising and tipping posteriorly.

Goniometer axis: Lateral aspect of the center of the humeral head approximately 1″ below the acromion process.

Stationary arm: Parallel to midaxillary line of the trunk.

Moving arm: Parallel to longitudinal axis of the humerus pointing toward the lateral epicondyle.

Movement: Shoulder flexion.

Shoulder abduction

Measurement tool: Universal goniometer.

Testing position: Supine with the hips and knees bent. Arm is in the anatomical position with the shoulder externally rotated.

Stabilization: Stabilize the thorax.

Goniometer axis: Anterior aspect of the shoulder just inferior and lateral to the coracoid process.

Stationary arm: Parallel to midaxillary line of the trunk.

Moving arm: Anterior aspect of the upper arm parallel to longitudinal axis of the humerus.

Movement: Shoulder elevation in scapular or frontal plane.

Shoulder internal/external rotation

Measurement tool: Universal goniometer.

Testing position: Supine with the shoulder and elbow abducted 90°. The forearm is midway between pronation/supination with the entire humerus is supported by the table.

Stabilization: Stabilize the distal humerus through the full ROM and stabilize the thorax/scapula at the end ROM.

Goniometer axis: The olecranon process of the ulna projecting through the humeral shaft toward the humeral head.

Stationary arm: Parallel to the supporting surface or perpendicular to the floor.

Moving arm: Parallel to the longitudinal axis of the ulna pointing toward the styloid process.

Movement: Internal and external rotation.