# CLINICAL INVESTIGATIONS

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# Shoulder Muscle Isometric Strength and Active Range of Motion in Patients With Frozen Shoulder Syndrome After Manipulation Under Anesthesia

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***Key words:*** *frozen shoulder syndrome; rehabilitation; maximal voluntary contraction; flexibility; pain.*

***Summary.*** *Background and Objective. Frozen shoulder syndrome (FSS) causes pain and restriction of movement in the shoulder. The aim was to assess changes in shoulder muscle isometric maximal voluntary contraction (MVC) force and active range of motion (AROM) in patients with frozen shoulder syndrome (FSS) after manipulation under general anesthesia (MUA).*

*Material and Methods. In total, 18 patients with FSS (9 women and 9 men) with a mean age of 53.6 years (SD, 9.7) participated in this study. MVC force of shoulder flexors, adductors, and internal and external rotators was measured by a handheld dynamometer. AROM in the same directions was measured goniometrically. The patients were screened according to the intensity of pain by day and at night. The data were collected before MUA and 1 and 6 months after MUA.*

*A significant reduction in MVC force and AROM was noted before MUA in the involved extremity as compared with the uninvolved extremity ($P<0.05$). These parameters for the involved extremity were significantly increased 1 month after MUA ($P<0.05$). However, 6 months after MUA, MVC force and AROM did not differ significantly compared with the uninvolved extremity ($P>0.05$), whereas AROM of flexion and external rotation remained significantly reduced ($P<0.05$). A significant reduction in shoulder pain by day and at night was recorded 1 and 6 months after MUA ($P<0.05$).*

*Conclusions. In the patients with FSS, the fastest improvement of MVC force and AROM occurred following the first month after MUA. However, 6 months after MUA, shoulder muscle MVC force for the involved extremity did not differ significantly as compared with the uninvolved extremity, whereas the shoulder AROM in flexion and external rotation remained lower.*

## Introduction

Frozen shoulder syndrome (FSS) usually emerges in the sixth decade of life with the peak age of 56 years, and the condition occurs slightly more often in women than men (1). In patients with FSS, pain in the shoulder starts slowly and is felt in the deltoid muscle, one cannot sleep on the affected side, and there is a slight local tenderness (2). This self-limiting disorder with stages lasting up to 1 to 3 years (3) is characterized by a limitation of both active and passive range of motion (ROM) of the glenohumeral joint that is not primarily due to an underlying condition, such as arthritis, rotator cuff tear, cervical radiculopathy, or peripheral neuropathy (4). The goal of treatment in patients with shoulder stiffness is to restore and retain ROM and function of the shoulder and decrease pain (5).

The recovery of patients with FSS after manipulation under general anesthesia (MUA) has been usually evaluated by measuring ROM (6, 7) and with different questionnaires (8–10). Numerous studies have been conducted on shoulder muscle activation and function during isometric contraction with healthy subjects (11).

Brox et al. (12) investigated the influence of pain on activation in brief maximal isometric abduction in patients with rotator tendinosis of the shoulder. They found that the mean pain rating on maximal voluntary contraction of the involved side of patients was reduced by a subacromial injection. The mean maximal voluntary contraction force improved from 163 to 184 N. Pain and force of the uninvolved side and in controls were unaltered.

Roe et al. (13) investigated a pain reduction induced by supervised exercises over several months in patients with rotator tendinosis. The results of the study demonstrated increasing maximal force and muscle activation, and that pain reduction after supervised exercises was associated with an improved isometric maximal voluntary contraction (MVC) force, but the side difference in maximal force

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generation was maintained. Muscle activity during MVC increased on both sides.

van Meeteren et al. (14) investigated the responsiveness to change of isokinetic dynamometry of the shoulder and found that the parameters of isokinetic dynamometry could provide additional information as compared with the usual outcome measures of pain and functional level.

Jürgel et al. (15) investigated patients with FSS before and 4 weeks after physiotherapy and found that the patients' maximal voluntary contraction force increased and pain decreased significantly after individualized physiotherapy.

van der Net et al. (16) investigated muscle strength in children and adolescents with mixed connective tissue diseases. They found that the strength of proximal muscles (hip flexors, shoulder abductors, and knee extensors) was significantly lower than in controls, whereas the strength of distal muscles (dorsal flexors of the foot and hand grip) showed no differences.

However, previous research in this field has concentrated on muscle activation and isometric strength in healthy individuals, and ROM and isokinetic dynamometry in patients with FSS. To our knowledge, there are no studies to assess shoulder muscle isometric MVC force in patients with FSS who undergo MUA, which is a reliable and inexpensive method for assessing FSS patients' shoulder muscle isometric strength (17, 18). Decreased muscle strength may influence shoulder movements and then contribute to joint dysfunction.

The aim of the study was to assess shoulder muscle isometric MVC force and AROM in patients with FSS before and 1 and 6 months after MUA. We hypothesized that patients with FSS would have less isometric MVC force for the involved extremity as compared with the uninvolved extremity, whereas MUA and physiotherapy program would significantly improve these characteristics, so 6 months after MUA, the involved extremity would not differ from the uninvolved extremity in this respect.

## Materials and Methods

*Patients.* In total, 18 patients with FSS (9 women and 9 men) aged 38 to 74 years participated in this study. The mean age of the patients was 53.6 years (SD, 9.7), the height was 167.1 cm (SD, 9.1), and the body weight was 71.0 kg (SD, 11.8). The study was conducted in the Laboratory of Kinesiology and Biomechanics, University of Tartu. The subjects were recruited by orthopedic surgeons in the Traumatology and Orthopedics Clinic, Tartu University Hospital.

The subjects' inclusion criteria were as follows: unilateral FSS defined as >50% loss of passive ROM of the shoulder joint relative to the unaffected side in 1 or more 3 movement directions (i.e., abduction, flexion, or external rotation) (19), shoulder pain at rest, and inability to sleep on the affected side. The average duration from the onset of the disease to manipulation was 8.6 months with a range being 3 to 12 months. The patients had FSS of stage 2 or 3. The dominant shoulder was involved in 9 patients, and the nondominant shoulder in 9 patients, too.

The subjects' exclusion criteria were the following: previous MUA of the affected shoulder; other conditions involving the shoulder (rheumatoid arthritis, osteoarthritis, damage of the glenohumeral cartilage, Hill-Sachs lesion, osteoporosis, or malignancies in the shoulder and chest region), traumatic bone, or tendon changes in the affected shoulder; neurological deficits affecting shoulder function in activities of daily living; pain or disorders of the cervical spine, elbow, wrist, or hand; and injections with corticosteroids in the affected shoulder in the past 4 weeks. Patients with serious cardiac problems or those who had undergone a cardiac operation were also excluded.

The demographic data, including age, sex, employment status, and sports and leisure activities of the subjects were recorded at baseline. A history was taken concerning previous treatments (injections, physiotherapy, etc.) and current pain medications. Concomitant diseases and the use of medications were also registered.

The data of 3 patients (men) were not included in the analysis since 1 subject had a bone fracture of the other arm 1 month after MUA and 2 patients refused to participate in the future study. Therefore, the data of 15 subjects were used for statistical analysis. The subjects were moderately physically active, and no professional athletes were included. They had neither orthopedic or neurological limitations nor contraindications for exercise testing or training. All the patients had 7 sessions of physical therapy before MUA.

The subjects were informed about the procedures, and their written consent was obtained. The study carried the approval of the Ethics Committee of Human Studies of the University of Tartu.

*Familiarization With Tests.* The subjects were instructed, and the shoulder muscle isometric strength and active ROM (AROM) measurement procedures were demonstrated 24 to 48 hours before collecting the first data. This was followed by a practical session to familiarize the subjects with the procedures. Before testing, each subject underwent a 10-minute warm-up consisting of gymnastics and stretching exercises. Both extremities were tested; the uninvolved extremity was tested first. The data collection was performed on the morning before MUA and 1 and 6 months after MUA.

*Treatment.* A conservative treatment in the patients with FSS before MUA included pain and anti-inflammation drugs (NSAID, intra-articular injections). A physiotherapy program was based on an outpatient basis and consisted of 7 exercise therapy procedures in a gymnasium or swimming pool with the duration of 50 minutes per day including exercises for improving the limited AROM and/or massage procedures with the duration of 20 minutes per day and/or electrical therapy procedures with the duration of 5 to 10 minutes per day for relieving pain; and after that patients continued exercises at home.

The manipulation was done under general intravenous anesthesia with barbiturate for all the patients. The technique used for the manipulation was the following: a) gradual flexion in the sagittal plane to the maximum possible extent while the surgeon's assistant fixed the scapula; b) passive external rotation performed at 0° of abduction; c) external rotation at 90° of abduction; and d) internal rotation at 90° of abduction and gross-body adduction. Care was taken not to fracture the humerus during the manipulation. External rotation forces were very carefully applied when the patient's elbow was fixed, and the wrist was moved simultaneously by the surgeon's thumb and the opposing 2 fingers. A full range of motion was always achieved. The shoulder joint was injected with 19 mL of 1% lidocaine and 1 mL of steroid in a 20-mL syringe immediately after the manipulation.

All the patients performed immediate passive exercise in the ward soon after MUA. They underwent gentle active-assisted motion with a physiotherapist after MUA. The motion was practiced in flexion, extension, abduction, adduction, and internal and external rotation. The physiotherapy continued on an outpatient basis and included supervised and therapeutic home exercise programs focused on stretching (2 times per day, 5 days per week). Further physiotherapeutic procedures included isometric strengthening exercises followed by the use of elastic bands and power simulator as soon as pain and active shoulder motion allowed. Each subject was treated by physiotherapists with at least 2-year clinical experience. The subjects had 10 physiotherapy sessions during 1 month 3 times per week and were advised to use the affected shoulder in daily activities whenever possible.

*Shoulder Muscle Isometric Strength Testing.* Shoulder muscle isometric MVC force in flexion, adduction, and external and internal rotation was measured by a handheld dynamometer (Lafayette Manual Muscle Test System, Lafayette Instrument Company, USA). In this study, during the testing of shoulder muscle MVC force, the subject was seated on a standard chair. During the assessment of shoulder flexion MVC force, the fully extended upper extremity was positioned with the shoulder flexed to 45°. The handheld dynamometer was placed medially on the distal end of the humerus approximately 5 cm superior to the elbow joint. During the assessment of shoulder adduction MVC force, the fully extended upper extremity was positioned with the shoulder abducted to 45°. The handheld dynamometer was placed medially on the distal end of the humerus approximately 5 cm superior to the elbow joint. The assessment of shoulder external and internal rotation MVC force was performed with the shoulder in a vertical position and the elbow flexed to 90°. The handheld dynamometer was placed laterally (during external rotation) and medially (during internal rotation) on the distal part of the elbow approximately 5 cm superior to the wrist. The forearm was pronated during all the strength tests. The positions were carefully supervised by the experimenter, and the subjects were encouraged to act in a desired way. The subjects were required to exert isometric MVC pushing against the dynamometer for approximately 3 seconds. Before each contraction, the subjects were instructed to push as hard as possible. The best results from 3 attempts were taken as isometric MVC force. A rest period of 1 minute was allowed between the attempts. The same physiotherapist performed all the assessments of shoulder muscle strength.

*Active Range of Motion.* AROM of the shoulder in flexion and adduction was measured by a gravitational goniometer (bubble inclinometer, Fabrication Enterprises Inc., USA) and in internal and external rotation by a gravitational goniometer (Myrin, Follo A/S, Norway). The subjects were positioned standing for all AROM tests according to the standard guidelines (20). All the measurements were rounded off to the nearest 5° as is common in the research practice (21). All the assessments were performed by the same physiotherapist.

*Pain Assessment.* The patients reported their shoulder pain level with a self-assessed, 10-point visual analogue scale (VAS) with endpoints of 0 representing no pain and 10 representing the worst possible pain) (9). The pain was reported by day and at night before MUA and 1 and 6 months after MUA.

*Statistical Analysis.* The data are presented as arithmetical means and standard deviations (SD). A 1-way analysis of variance (ANOVA) followed by the Bonferroni post hoc comparisons was used to evaluate differences between the involved and uninvolved extremities. A paired $t$ test was used to evaluate differences between pre- and postoperative characteristics. A level of $P<0.05$ was selected to indicate statistical significance. The main differences in the measures of the present study (shoulder AROM and MVC force in external and internal rotation) between the involved and uninvolved extremities were tested for statistical significance ($\alpha=0.05$). Statistical power analysis demonstrated that 15 participants were sufficient to detect a significant difference in shoulder AROM ($\beta=0.96$ and $\beta=0.99$) and MVC ($\beta=0.99$ and $\beta=0.97$) force in external and internal rotation between the involved and uninvolved extremities before MUA.

**Results**

*Changes in Shoulder Muscle Isometric Strength.* Before MUA, the patients with FSS showed a significant reduction in MVC force in shoulder flexion, adduction, and external and internal rotation for the involved extremity as compared with the uninvolved extremity ($P<0.05$) (Fig. 1). However, 1 and 6 months after MUA, MVC force in shoulder flexion, adduction, and external and internal rotation increased for the involved extremity in the patients with FSS as compared with the level before MUA ($P<0.05$) (Fig. 1 A–D). On the other hand, 6 months after MUA, MVC force in shoulder flexion, adduction, and external and internal rotation did not differ significantly for the involved extremity in the patients with FSS as compared with the uninvolved extremity ($P>0.05$).

*Changes in the Shoulder Active Range of Motion and Pain.* Before MUA, the patients with FSS demonstrated a reduction in the shoulder AROM in flexion, adduction, and internal and external rotation for the involved extremity as compared with the uninvolved extremity ($P<0.05$) (Fig. 2). However, 1 and 6 months after MUA, the shoulder

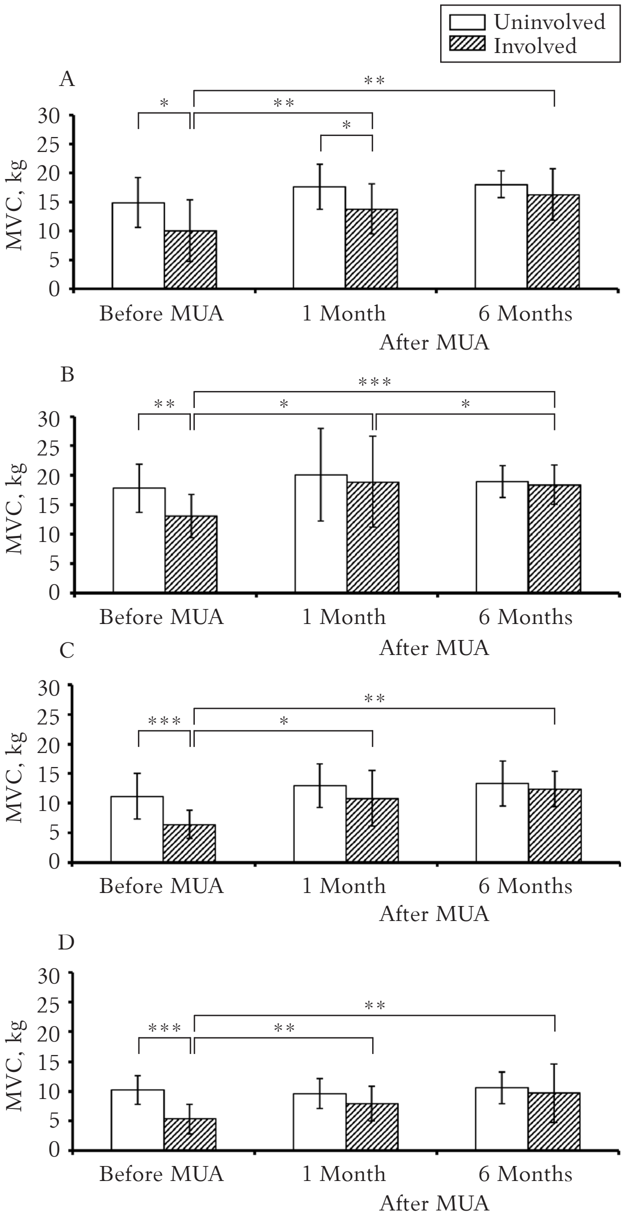


*Fig. 1.* Isometric maximal voluntary contraction (MVC) force of shoulder muscles in flexion (A), adduction (B), and internal (C) and external rotation (D) in the patients with frozen shoulder syndrome before and 1 and 6 months after manipulation under general anesthesia (MUA) (n=15)

Values are means and error bars indicate standard deviation. $^*P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

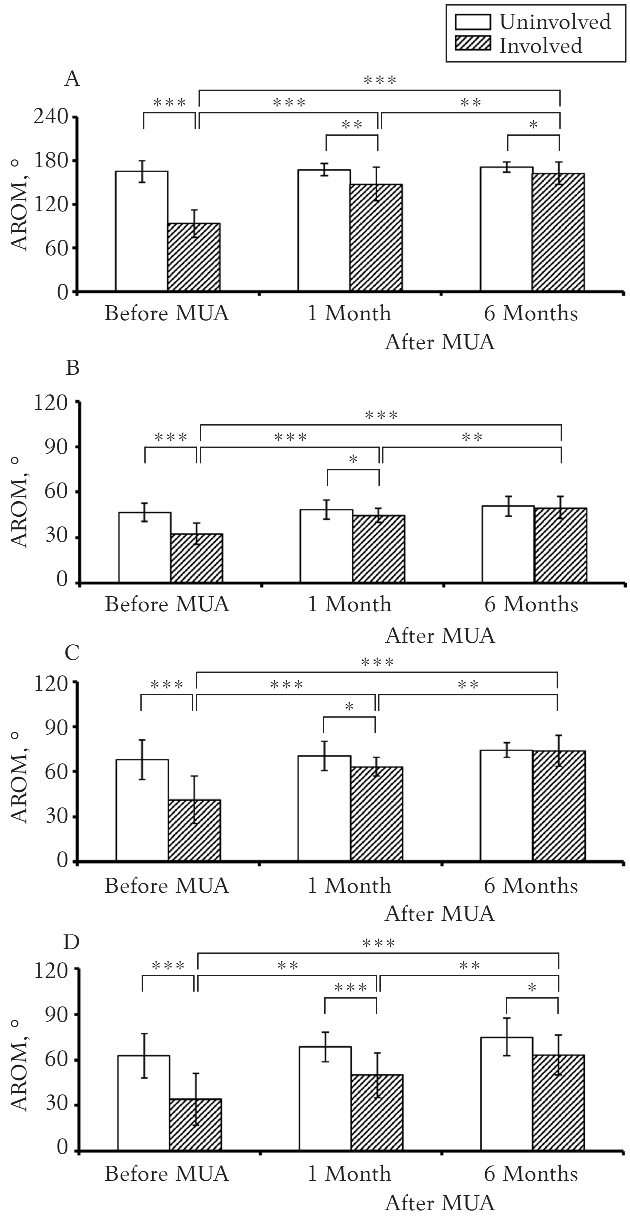


*Fig. 2.* Active range of motion (AROM) in shoulder flexion (A), adduction (B), and internal (C) and external rotation (D) in the patients with frozen shoulder syndrome before and 1 and 6 months after manipulation under general anesthesia (MUA) (n=15)

Values are means and error bars indicate standard deviation. $^*P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

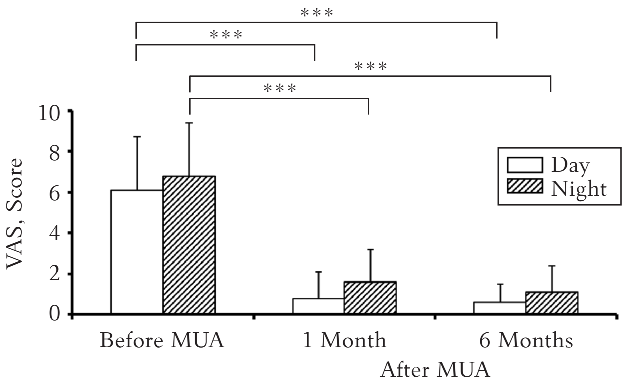


*Fig. 3.* Pain by day and night evaluated by a visual analogue scale (VAS) in the patients with frozen shoulder syndrome before and 1 and 6 months after manipulation under general anesthesia (MUA) (n=15)

Values are means and error bars indicate standard deviation. ***$P$<0.001.

AROM in flexion, adduction, and internal and external rotation increased for the involved extremity in the patients with FSS as compared with the level before MUA ($P$<0.05) (Fig. 2 A–D). Nevertheless, 6 months after MUA, the shoulder AROM in flexion and external rotation of the involved extremity in the patients remained significantly lower as compared with the uninvolved extremity ($P$<0.05), whereas the shoulder AROM in internal rotation and adduction did not differ significantly as compared with the uninvolved extremity ($P$>0.05).

In the patients with FSS, a significant decrease in pain by day and at night was noted 1 and 6 months after MUA as compared with the level before MUA ($P$<0.05) (Fig. 3).

## Discussion

This study assessed changes in shoulder muscle isometric strength and shoulder AROM in the patients with FSS before MUA and 1 and 6 months after it. The most important finding of this study was that the fastest recovery of shoulder muscle MVC force and AROM proceeded following the first month after MUA. However, the recovery of AROM in flexion and external rotation need more attention and exercising for more than 1 month.

Our results indicated that before MUA in the patients with FSS, shoulder muscle isometric MVC force for the involved extremity was lower by 33% in shoulder flexion, by 26% in adduction, by 43% in internal rotation, and by 48% in external rotation as compared with the uninvolved extremity. However, 1 month after MUA, shoulder muscle isometric MVC force for the involved extremity in the patients with FSS increased by 27% in the flexion, by 31% in the adduction, by 33% in the external rotation, and by 49% in the internal rotation as compared with the level before MUA. On the other hand, 6 months after MUA, shoulder muscle isometric MVC force improved for the involved extremity in the patients with FSS; however, this was a nonsignificant difference as compared with the uninvolved extremity.

In our previous study, the shoulder function in the patients with FSS was measured before and 4 weeks after the conservative treatment (15). It emerged that the shoulder muscle isometric MVC force for the involved extremity in flexion, adduction, internal rotation, and external rotation increased by 18%, 17%, 19%, and 15%, respectively, after a 4-week treatment. Andrews et al. (22) composed the normative values for isometric muscle force with a handheld dynamometer for asymptomatic adults. In the 50–59-year-old group, the mean values of lateral and medial rotation in the dominant hand were 10.3 and 10.4 kg for women and 15.9 and 19.7 kg for men, respectively.

In our study of the patients with FSS, the isometric MVC force of shoulder muscles for the uninvolved extremity was similar; however, the isometric MVC force for the involved extremity was significantly lower 6 months after MUA.

Bohannon (23) measured shoulder muscle isometric MVC force in patients with neurological diagnoses and found that the mean force in adduction, internal rotation, and external rotation was 8.6, 8.2, and 9.7 kg, respectively. This indicates that shoulder muscle isometric MVC force decreased in different disease conditions. It is important to begin with strength exercises as soon as possible for patients with FSS after MUA. Cadogan et al. (18) demonstrated that the resisted muscle test for peak isometric muscle force during resisted abduction (affected side) with a manual muscle tester showed high levels of reliability. Hirschmann et al. (24) found a high retest reliability for the strength measurements in all evaluated positions (shoulder abduction at 30°, 60°, and 90°). We believe that the assessment of shoulder muscle MVC force in patients with FSS is important because in successful activities of daily living, near-normal ROM and muscle strength is needed.

Wong and Tan (25) noted that in patients with FSS, mild disuse atrophy of the deltoid and supraspinatus muscles in longstanding cases was usually observed. DePalma (26) noted that all shoulder motions were guarded, and painful atrophy of the deltoid and spinatti muscles was discernible. Before MUA, patients' movements are limited and painful, and muscles are inactive. This condition is ideal for developing muscle atrophy. Immediately after MUA, patients should begin with physiotherapy, launching a decrease in pain and a slow improvement in AROM and muscles strength, depending on how much the patient is exercising. Othman and Tailor (8) noted that an aggressive postoperative physiotherapy regime was essential immediately after MUA in patients with FSS. It has been demonstrated that experimentally induced muscle pain decreases a motor unit firing rate during submaximal isometric contractions in humans (27). Muscle pain influences motor control via numerous reflex and central mechanisms (28). This can explain why in the patients with FSS shoulder muscle isometric MVC force before MUA and 1 month after MUA was lower as compared with the uninvolved extremity. When pain decreased, the patients with FSS were able to produce more force in shoulder muscles and could increasingly use the involved extremity in everyday activities.

Roe et al. (13) explained that in patients with rotator tendinosis, the increase in muscle activation could be caused by a combination of the training effect on the muscles and increased motor drive.

We assessed pain in the patients with FSS by day and at night on a 10-point VAS scale. Before MUA, the mean pain index was 6.1 points by day and 6.8 at night. However, 1 and 6 months after MUA, the pain decreased significantly by day and at night as compared with the level before MUA, i.e., 0.8 and 1.6 points 1 month after MUA and 0.6 and 1.1 points 6 months after MUA, respectively. The patients said that before MUA, pain had disturbed their everyday life, especially activities requiring overhead movement with the involved hand, and sleeping at night.

DePalma (26) identified that at all times during the course of the disease, pain was the most significant clinical manifestation. In our study, a few days after MUA, patients used analgesics, and 1 week after MUA, pain began to decrease. Diwan et al. (6) showed that the preoperative pain according to the VAS, ranging from severe to very severe, decreased 1 week postoperatively to mild-to-moderate; this reduction of pain was maintained at 12 weeks, continued to reduce to mild at 6 months, and remained on this level at 2 years. Kivimäki et al. (9) investigated patients with FSS who were allocated to the manipulation under anesthesia group or home exercise group. The pain before therapy was 6.6 points in the manipulation group and 6.4 points in the exercise group. The outcomes were measured during follow-up examinations at 6 weeks and 3, 6, and 12 months after manipulation. Pain in the manipulation group was 4.9, 3.9, 2.0, and 1.5 points respectively.

Roubal and Placzek (28) found that translational manipulation after failed arthroscopic capsular release for recalcitrant adhesive capsulitis showed changes in pain as follows: initial evaluation, a score of 7; 1 day after postarthroscopic release, a score of 6; posttranslational manipulation, a score of 2; and 2-year follow-up, a score of 1.

In our study, AROM in the patients with FSS for the involved extremity in flexion, adduction, and internal and external rotation was by 30%–46% lower before MUA as compared with the uninvolved extremity. However, 1 month after MUA, AROM increased in all the movements by 27%–37%; however, flexion and external rotation remained significantly lower 6 months after MUA as compared with the uninvolved extremity. Baums et al. (29) and Wang et al. (3) demonstrated similar pain and ROM recovery after arthroscopic release and MUA in patients with FSS in flexion and internal and external rotation.

The limitation of AROM in internal and external rotation is specific for patients with FSS (7, 9). DePalma (26) identified that frozen shoulder developed only when muscular inactivity initiated in shoulder joints of individuals aged more than 40 years or in that period of life when degenerative alterations in the musculotendinous cuff, synovialis, and biceps tendons were evident both macroscopically and microscopically. Mengiadi et al. (30) found that thickening of the coracohumeral ligament and the joint capsule in the rotator cuff interval, as well as the subcoracoid triangle sign, was a characteristic MR arthrographic finding in frozen shoulder. Contracture of the rotator cuff interval is prevalent in patients with FSS (5).

Kivimäki et al. (9) found that AROM in external rotation was 38° 6 weeks after MUA, 48° 3 months after MUA, 59° 6 months after MUA, and 65° 12 months after MUA. Farrell et al. (7) followed up patients with FSS for a mean duration of 15 years (range 8.1 to 20.6 years) and found that the AROM in the external rotation improved from 23° to 67°.

## Conclusions

The patients with frozen shoulder syndrome had a reduced isometric strength for shoulder flexors, adductors, and external and internal rotators, active range of movement in the same directions, and pain before manipulation under general anesthesia in the involved extremity as compared with the uninvolved extremity. The fastest improvement in the shoulder function proceeded following the first month after MUA and physiotherapy sessions. The shoulder muscle AROM in flexion and external rotation for the involved extremity was reduced as compared with the uninvolved extremity 6 months after MUA. The use of a handheld dynamometer in the assessment of patients with frozen shoulder syndrome provided additional information on the functional level outcome measures.

Further research is needed for the assessment of shoulder muscle strength and fatigability in patients with FSS.

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## Statement of Conflict of Interest

The authors state no conflict of interest.

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