ORIGINAL ARTICLE

Shoulder muscle function in frozen shoulder syndrome patients following manipulation under anesthesia: A 6-month follow-up study

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Summary
Introduction: The present study evaluates changes in shoulder muscle function in patients with frozen shoulder syndrome (FSS) following manipulation under general anesthesia (MUA).

Patients and methods: Fifteen FSS patients with mean (± SD) age of 53.6 ± 9.7 years were included in this study. Isometric endurance of the shoulder muscles was characterized by time and net impulse (NI), which were assessed with the patient holding a weight in the hand until exhaustion. Fatigability of the deltoid and trapezius muscles during isometric endurance test was assessed by electromyogram power spectrum median frequency (MF) slope per minute. Patients were also screened for daytime pain. Data were collected before MUA, and at 1 and 6 months postoperatively.

Results: Six months postoperatively, the MF slope for the trapezius and deltoid muscles of the involved and uninvolved shoulders did not differ (P > 0.05), whereas NI remained lower and endurance time was longer (P < 0.05). Shoulder pain was reduced as compared to preoperative levels (on visual analog scale) 1 and 6 months postoperatively (P < 0.05).
Introduction

Frozen shoulder syndrome (FSS) usually occurs during the sixth decade of life [1,2] and its prevalence is reported to be between 2 and 5% in the general population [3,4], with female predominance [4,5]. Pain in the shoulder comes on slowly and is felt in the deltoid. The patient cannot sleep on the affected side, and there is some local tenderness and stiffness in the shoulder [1,4,6,7]. Range of active and passive motion is restricted in upward movement and rotation, and there is muscle weakness, with atrophy of the deltoid and spinatus muscles [2,8]. FSS can greatly influence patients’ quality of life [8,9] due to disuse, for periods ranging from several months to many years [10,11].

In general, FSS outcome measurements in studies of treatment efficacy include passive and active range of motion, various questionnaires [10–12] and visual analog scales [13–15].

Performing everyday activities that involve the use of the hands requires active range of motion (aROM) in all directions, muscle strength, fatigue resistance and endurance. FSS studies usually assessed shoulder aROM and pain; however, it is also important to take account of muscle endurance and fatigability before and after treatment to assess full recovery of shoulder function.

In patients with FSS, it was noted that the high-speed external rotator strength and isometric internal rotator strength of the affected shoulder were significantly impaired [16,17] and that isometric external rotation was predictive of disability [16]; however, isokinetic dynamometry may provide additional information to the usual outcome measures of pain and functional level [18,19].

It was shown that electromyographic (EMG) activity in the upper and lower trapezius muscles under isometric activation was increased in FSS patients; trapezius muscle activity may contribute to scapular substitution movement in compensation for impaired glenohumeral motion [8,20]. Experimental comparison of endurance time across body regions found that the ankle was the most fatigue-resistant and the shoulder the most fatigable joint [21].

However, previous research in this field has concentrated on muscle activation, maximal voluntary muscle contraction, isometric strength and ROM in FSS patients before and after therapy. To the best of our knowledge, fatigability and endurance have not been the main outcome measures after manipulation under general anesthesia (MUA) or other treatments for FSS. The aim of the present study was to assess shoulder-muscle isometric endurance and fatigability and pain before and 1 and 6 months after MUA. The hypothesis was that no significant differences would emerge in isometric endurance, isometric working capacity and fatigability of the shoulder muscles between the involved and uninvolved shoulders 6 months after MUA and physiotherapy.

Patients and methods

Patients

Fifteen patients with FSS participated in this study. Mean age (± SD) was 53.6 ± 9.7 years (range, 38 to 74 years), height 167.1 ± 9.1 cm and weight 71.0 ± 11.8 kg. The study was conducted at the University of Tartu. Subjects were recruited by orthopedic surgeons in Tartu University Hospital between September 2006 and December 2008.

The inclusion criteria were: unilateral FSS, defined as greater than 50% loss of passive ROM of the shoulder joint relative to the unaffected side in one or more of the three directions of movement (i.e., abduction, flexion and external rotation) [22,23]; shoulder pain at rest; and inability to sleep on the affected side. The average interval from onset to manipulation was 8.6 months (range, 3 to 12 months). FSS stage was either 2 or 3.

The exclusion criteria were: 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 or chest region); traumatic bone or tendon conditions in the affected shoulder; neurological deficits affecting shoulder function in everyday activity; pain or disorder of the cervical spine, elbow, wrist or hand; and corticosteroid injection in the affected shoulder during the previous 4 weeks. Patients with serious cardiac problems or history of cardiac surgery were also excluded.

Demographic data, including age, sex, occupational status, and sports and leisure activities, were recorded at baseline. A history was taken concerning previous treatments and current analgesia. Concomitant diseases and medication were recorded.

The subjects were moderately physically active; however, no professional athletes were included. They had no orthopedic or neurological limitations or contraindications for exercise testing or training. All patients had about seven physical therapy sessions before MUA.

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

Familiarization with tests

The subjects were given the instructions and a demonstration of the isometric endurance test 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-min warm-up consisting of gymnastics and stretching exercises. Both shoulders were tested, with the uninjured shoulder tested first. Data collection was performed preoperatively and 1 and 6 months postoperatively.

Treatment

The manipulation was done under general intravenous barbiturate anesthesia for all patients. The technique used for manipulation was following:

- gradual flexion in the sagittal plane to the maximum possible extent, with the surgeon’s assistant immobilizing the scapula;
- passive external rotation in 0° abduction;
- external rotation in 90° abduction;
- internal rotation in 90° abduction and cross-body adduction.

Care was taken not to fracture the humerus during manipulation. External rotation forces were very carefully applied with the patient’s elbow immobilized and the wrist moved by the surgeon’s thumb and the two opposing 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 manipulation.

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

Electromyography

During the isometric endurance test, the EMG activity of the deltoid and trapezius muscles was continuously recorded using a standard MG 440 electromyograph (Medicor, Hungary). Paired bipolar surface electrodes (Ag-AgCl, 8-mm diameter, 20-mm interelectrode distance) were used. The skin under the electrode was shaved, abraded and cleaned with alcohol and a conducting gel was applied to obtain good signal transfer from the skin to the electrodes. The electrodes were placed over the middle deltoid muscle halfway between the insertion and the acromion. The electrodes over the upper trapezius muscle were placed one third laterally and 2 to 4 cm above the line between the C7 process and the acromion. The ground electrode was placed at the radial styloid process of the non-tested arm. Correct electrode placement was confirmed by appropriate EMG activity observed during a manual muscle test.

The EMG preamplifier output signals were digitized online (sampling frequency, 1 kHz) by an analog-to-digital converter installed in a PC and saved to a hard disk for further analysis. The EMG power spectrum median frequency (MF) was calculated by Fast Fourier Transform algorithms, with a 1024 data-point window (1 s) sliding over the whole recorded signal area with a 512 point shift (50% overlap). During the isometric endurance test, MF was determined and averaged over each 5-s period, and the following characteristics were calculated: initial MF (MF1) as the mean value for the first 10 s, and end-of-test MF (MF2) as the mean value for the last 10 s. Additionally, MF slope per kilogram of weight held during the endurance test was calculated by the following formula:

$$MF\, slope = \frac{(MF1 - MF2) \cdot t}{MF1 \cdot P \cdot 60} \cdot 100\, (\% \cdot \text{min/kg})$$

where $t$ is endurance time and $P$ is the weight held in the hand by the subject during the endurance test. MF slope was used for the assessment of shoulder muscle fatigability.

All measurements were rounded off, as is common in research practice, to the nearest 5° [23]. The same physiotherapist performed all assessments.

Shoulder girdle muscle endurance test

During isometric endurance testing, the subject was seated on a standard chair and the fully extended upper limb was positioned with the shoulder in 45° flexion and 45° abduction. In this position, the subject held a weight in the hand (5 kg for men, and 3 kg for women) until exhaustion. The isometric working capacity of the shoulder muscles was assessed by net impulse (NI), calculated by the following formula:

$$NI = F \cdot t \cdot (N \cdot \text{s}),$$

where $F$ is hand-held weight $\times 9.81$, and $t$ is endurance time.

Pain assessment

Self-assessment of shoulder pain was reported on a 10-point visual analog scale (VAS) ranging from no pain (0) to worst possible pain (10) [15].

Statistical analysis

Data were expressed as means with standard deviations (± SD). One-way analysis of variance (ANOVA) followed by the Bonferroni post-hoc comparison was used to evaluate differences between the involved and uninvolved shoulder. A paired t-test was used to evaluate differences between pre- and postoperative findings. The significance threshold was set at $P < 0.05$. 
Results

Patients showed lower preoperative NI ($P < 0.05$) during endurance testing, shorter endurance time ($P < 0.05$) (Fig. 1) and lower EMG power spectrum MF slope for the deltoid and trapezius muscles during endurance testing for the involved than for the uninvolved shoulder (Fig. 2). One and 6 months postoperatively, NI and MF slope for the deltoid and trapezius muscles of the involved shoulder during endurance testing were greater ($P < 0.05$) and endurance time was longer ($P < 0.05$) than preoperatively. Six months postoperatively, NI during endurance testing in the involved shoulder remained significantly lower ($P < 0.05$) and endurance time shorter ($P < 0.05$) than in the uninvolved shoulder (Fig. 1A,B), whereas the EMG power spectrum MF slope did not differ significantly ($P > 0.05$) between the involved and uninvolved shoulders (Fig. 2A,B).

A significant ($P < 0.05$) decrease in pain was noted at day 1 and 6 months postoperatively as compared to the preoperative level (Fig. 3).

Figure 1 Mean ($\pm$ SD) isometric working capacity (NI) of shoulder muscles during endurance testing (A) and isometric endurance test time (B) in patients with frozen shoulder syndrome (FSS) before and 1 and 6 months after manipulation under general anesthesia (MUA) ($n = 15$). *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Figure 2 Mean ($\pm$ SD) shoulder muscle median frequency (MF) slope of the deltoid (A) and trapezius (B) muscles during isometric endurance testing in patients with frozen shoulder syndrome (FSS) before and 1 and 6 months after manipulation under general anesthesia (MUA) ($n = 15$). *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Figure 3 Mean ($\pm$ SD) pain evaluated by visual analogue scale (VAS) in patients with frozen shoulder syndrome (FSS) before and 1 and 6 months after manipulation under general anesthesia (MUA) ($n = 15$). ***$P < 0.001$. 
Discussion

The most important finding of the present study was that shoulder muscle endurance time remained shorter and isometric muscle working capacity remained lower 6 months after MUA for the involved as compared to the uninvolved shoulder.

The isometric working capacity (NI) of the involved shoulder muscles during endurance testing was significantly lower (65%) than for the uninvolved shoulder before MUA, and increased after MUA at 1 and 6 months postoperatively (43% and 22% respectively as compared to preoperative level); however, the values for the involved shoulder remained significantly lower (32%) than for the uninvolved shoulder 6 months after MUA. As a previous study by our team demonstrated, in the FSS patients who received a 4-week individualized physiotherapy program, the NI of the involved shoulder muscles during endurance testing increased by 27% compared to pre- and post-rehabilitation levels; however, these patients did not require MUA [24].

DePalma [2] affirmed that FSS is a clinical entity induced by muscular inactivity of the shoulder in individuals over 40 years of age. Bicipital tendosynovitis is the most common etiologic factor for inactivity. Pain is the outstanding clinical feature in FSS.

Maintenance of normal bone, dense fibrous tissue and muscle structure requires a minimal level of repetitive loading; activity below this level causes atrophy and decreases tissue organization and strength. Within weeks of a reduction in the frequency or intensity of activity, myofiber and myofibril volumes and oxidative capacity are reduced, causing decreases in muscle mass and strength [25]. In the present study, patients had had FSS symptoms for 3 to 12 months before MUA. They had severe pain in arm movement and limited shoulder joint aROM. Thus working capacity was lower in the involved than in the uninvolved shoulder.

Before MUA, endurance time for the involved shoulder was 67% shorter than for the uninvolved shoulder; 1 month after MUA, it had increased by 45% over the preoperative level, and by 60% at 6 months; 1 month after MUA, however, six patients were not able to hold the weight on the involved side, and three were still not able at 6 months. Endurance time for the involved shoulder remained significantly shorter 6 months after MUA then for the uninvolved shoulder. Brox et al. [26] found that the mean time to exhaustion was 103 s for the involved shoulder and 160 s for the uninvolved shoulder in women and 159 s and 289 s respectively in men. Increased pain, emotional distress and disability were associated with this decrease in endurance time. In patients with rotator tendosynosis of the shoulder, the time to exhaustion of the involved shoulder was 149 s versus 204 s for the uninvolved side [27]. Motor function can be impaired in musculoskeletal pathology [28]. Due to central inhibitory mechanisms, maximum voluntary contraction force, endurance time [29,30] and motor unit firing rate are reduced [31], with change in muscle activation strategy during isometric [30,32] and dynamic motor tasks [29,30]. Muscle pain or disability may constitute a direct inhibiting factor for muscle function, and above all also causes reduced activity levels or prolonged inactivity, thereby reducing muscle mass and endurance [33]. In patients with chronic pain and severe disuse syndrome, pain decreased significantly after a clinical phase ranging from 3 to 6 weeks, although arm endurance time did not improve after treatment [34].

We examined the EMG power spectrum MF slope over time per kilogram weight held in the hand during the isometric endurance test, with MF slope recordings from the deltoid and trapezius muscles. Trapezius and middle deltoid muscle MF slope before MUA was significantly lower in the involved shoulder (82% and 75%, respectively) than in the uninvolved shoulder; it increased significantly (59% and 58%, respectively) 1 month and 6 months after MUA (30% and 32%, respectively), with no significant difference between shoulders 1 and 6 months after MUA.

In our previous study, EMG power spectrum MF slope of the deltoid muscle increased by 29% after rehabilitation, whereas the MF slope of the trapezius muscle for both the involved and uninvolved shoulder did not differ significantly from pre- to post-rehabilitation [24]. Roe et al. [35] showed that after treatment, the surface EMG (absolute value of average rectified EMG during maximal voluntary contraction) for the deltoid and trapezius muscles of the involved side increased significantly in patients with rotator tendosynosis, whereas fatigue and recovery were unaltered by the exercise regimen. Lin et al. [16] found that FSS patients could produce maximal muscle strength in lower speed movement, but with impaired ability to maintain that force output. In order to sustain force output, muscular endurance is required. During isometric contraction, muscle pain causes a decreased production of force, shorter endurance time and decreased activation of the painful muscles, but also affects the activity of other non-painful synergic muscles [32]. The activity of chronically painful trapezius muscles increased, due to a reduction in pain-related inhibition, leading to increased strength [36]. Importantly, muscle strength improved over the entire torque-velocity range, which documents a general increase in functional strength. It is very important to ensure improvement in aROM by strength exercises in all directions of motion for FSS patients.

The fastest decrease in pain occurred in the first month after MUA: from 6.1 to 0.8 points (86%). This decrease continued, and 6 months after MUA the pain score was 0.6 points. Patients reported that pain was worst in the first week after MUA; in this period, 10 patients took painkillers. Twelve of the 15 patients reported no daytime pain 6 months after MUA. Several studies [15,37,38] showed the same pattern of decreasing pain in FSS patients.

The present study has limitations, because only a small number of patients with FSS were investigated.

In conclusion, the present study demonstrated that patients with FSS had reduced shoulder muscle isometric working capacity during submaximal contraction, shorter endurance time and lower fatigue-resistance in the involved trapezius and deltoid muscles before MUA as compared to the uninvolved side. The fastest improvement in shoulder function occurred 1 month after MUA; pain decreased significantly. However, isometric endurance remained shorter and isometric working capacity was reduced as compared with the uninvolved shoulder 6 months after MUA. Physiotherapists should pay more attention to improving shoulder region muscle endurance and fatigability. To maintain lasting functional benefit, exercises probably need to be continued...
for life. Further research should assess the fatigability and isometric endurance recovery of shoulder muscles after MUA in FSS patients for a longer period than 6 months.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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